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Message from Assistant Editor In Chief

Let me first of all take this opportunity to wish all our readers a very happy, peaceful and prosperous year ahead and wish a Happy New Year.

This is the first issue of the Second Volume of International Journal of Engineering Research and General Science. A total of 9 research papers are published and I sincerely hope that each one of these provides some significant stimulation to a reasonable segment of our community of readers.

In this issue, we have focused mainly on the technology with the recent research that can have a great impact in our society through conceptual ideas implementation approach. As such, we encourage submission of more recent and relevant ideas and research papers from our readers too, which will be published in the upcoming issues.

Author's response for this issue was really inspiring for us. We received many papers in this issue from different parts of the world as Nepal, India, Pakistan, Bangladesh, France, Algeria, Congo, China, Japan etc than previous one but our technical team and editor members accepted very less number of research papers for the publication. We have provided editors feedback for every rejected as well as accepted paper so that authors can work out in the weakness more and we shall accept the paper in near future. We apologize for the inconvenient caused for rejected Authors but I hope our editor feedback helps you discover more horizons for your research work.

I would like to take this opportunity to thank each and every writer for their contribution and would like to thank entire International Journal of Engineering Research and General Science (IJERGS) technical team and editor members for their hard work for the development of research in the world through IJERGS.

Last, but not the least my special thanks and gratitude needs to go to all our fellow friends and supporters. Your help is greatly appreciated. I hope our reader will find our papers educational and entertaining as well. Our team have done good job however, this issue may possibly have some drawbacks, and therefore, constructive suggestions for further improvement shall be warmly welcomed.

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Development of Heat Exchangers for Water Pasteurization in Improved Cooking

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ABSTRACT - — In Nepal, drinking unsafe water is attributed for the mortality of 13,000 children. The prevalence of this cause of morbidity and mortality in many poor rural regions has created a need for water quality intervention. These days various household drinking water treatment options are currently available in Nepal. Almost 85% of Nepalese population use cooking stove and more than 70% of the heat energy is wasted through chimney of cooking stove. Three different heat exchangers with different efficiencies were designed for Water Pasteurization by utilizing waste heat of flue gas.

Locally available hollow aluminum pipe (internal diameter 8 mm, length 3.65 m) was coiled into a spiral ovular helix of 12 cm in diameter. Two different heat exchangers with coiled unit placed inside and outside of the chimney were designed. Similarly a jacket type heat exchanger with 0.5m height was also designed for Water Pasteurization.

With 6 hours of average cooking period per day, total water output from three different prototypes was found in the rage of 24 to 28 liters/per day. Water quality test for treated samples from three different prototypes was done and the *E. coli* test result was less than 5 CFU/100ml and thus treated water was safe to drink.

Keywords— Heat exchangers, Pasteurization, Improved cooking stove, *E. coli*, Thermal efficiency, Water boiling test, Carbon trade, Biomass, Flue gas, Distillation, Heat transfer.

Introduction

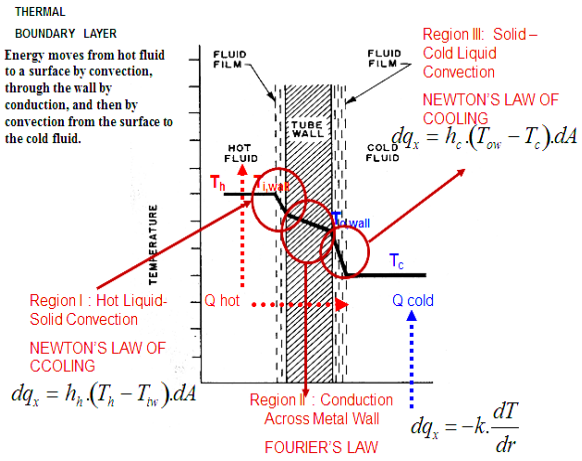
Solid biomass fuels such as wood, dung and agriculture residue are used by more than 85% of the Nepali population for daily cooking and heating activities (CBS, 2007). Two major characteristics of energy systems in Nepal are excessive dependence on biomass energy and very low efficiency in its use. Similarly, many household water treatment systems (HWTs) are currently available in Nepal to treat unsafe water. Many household water systems such as solar disinfection (SODIS), Boiling, Chlorination and filtration has been developed and promoted by different NGOs and GOs like Environment and Public Health Organization (ENPHO).

Indoor air pollution and unsafe water are two major environmental risk factors in the developing countries (Corvalán and Üstün, 2006). Globally, 1.8 million people, mostly children, die from waterborne diarrheal disease annually (ITDG, 2004; Smith etal.,2004; WHO 2007a, 2007b). In Nepal, drinking unsafe water is attributed to the mortality of 13,000 children (DWSS and UNICEF, 2006; WHO, 2007; UNICEF, 2005). The occurrence of these major causes of mortality in many poor rural regions of Nepal has created a need for water quality interventions. Thus there is a need to develop an integrated technology that eliminates risk factors at the rural level.

Heat exchangers can be installed in the chimney for water pasteurization in improved cooking stoves making it safe to drink and utilization of heat from the waste flue gas increases the overall efficiency of the stove system. This technology uses pasteurization method for water purification, where water should be maintained at certain temperature for certain period of time in the system. In order to do so, retention time of water in the system plays a critical role for purification. Alike pasteurization, distillation is also a process of water purification. Distillation involves boiling the water and then condensing the steam into a clean container. Water purification, such as distillation, is especially important in regions where water resources or tap water is not suitable for ingestion without boiling or chemical treatment. Use of this distilled water for drinking can contribute a lot in reducing death rate due to water borne disease.

Heat exchangers are devices that facilitate the exchange of heat between two fluids that are at different temperatures while keeping them from mixing with other. Heat transfer in a heat exchanger usually involves convection in each fluid and conduction through the wall separating the two fluids. During the analysis of heat exchangers, it is convenient to work with an overall heat transfer coefficient

U that accounts for the contribution of all these effects on heat transfer. The rate of heat transfer between the two fluids at a location in a heat exchanger depends on the magnitude of the temperature difference at that location, which varies along the heat exchanger. In the analysis of heat exchangers, it is usually convenient to work with the *logarithmic mean temperature difference LMTD,* which is an equivalent mean temperature difference between the two fluids for the entire heat exchanger.



Principle of Heat Exchanger (parallel flow)

Methodology

The range of method includes both primary and secondary analyses, with activities ranging from direct field investigation to elaborate desk works. The methods along with the detail procedures followed are described below.

Literature review

It is essential for the development of theoretical foundation as well as to gain current knowledge on related topic including substantive findings. Also, some required secondary data can be extracted through literature review.

Experimental activity

The experiment was performed to measure the mass flow rate of flue gas as well as average temperature of the flue gas in chimney. To design the heat exchanger we need to find the design parameters. The major design parameters are temperature profile of the chimney, flow rate of the water to be obtained, mass flow rate of the flue gas, thermo physical properties of water, flue gas and materials.

In order to find out these design parameters some primary lab testing were carried out and the thermo physical properties were determined from different literature. After some primary lab testing, the temperature profile of the chimney was known by using thermocouples. To determine the mass flow rate we used excel sheet based software and determined the velocity of flue gas in the chimney. After determining the velocity of the flue gas, discharge and hence mass flow rate of flue gas using continuity equation was determined.

$$Q_D = V.A$$

Then, total heat transfer rate of chimney section was calculated.

$$q_s = \dot{m}.\dot{C}_{p.}dt$$

Design of heat exchangers

The design of heat exchangers was done by writing a program in MS-Excel. Heat exchanger was designed using concept of parallel flow heat exchanger. Different assumptions were made before designing the heat exchanger which is mentioned below:

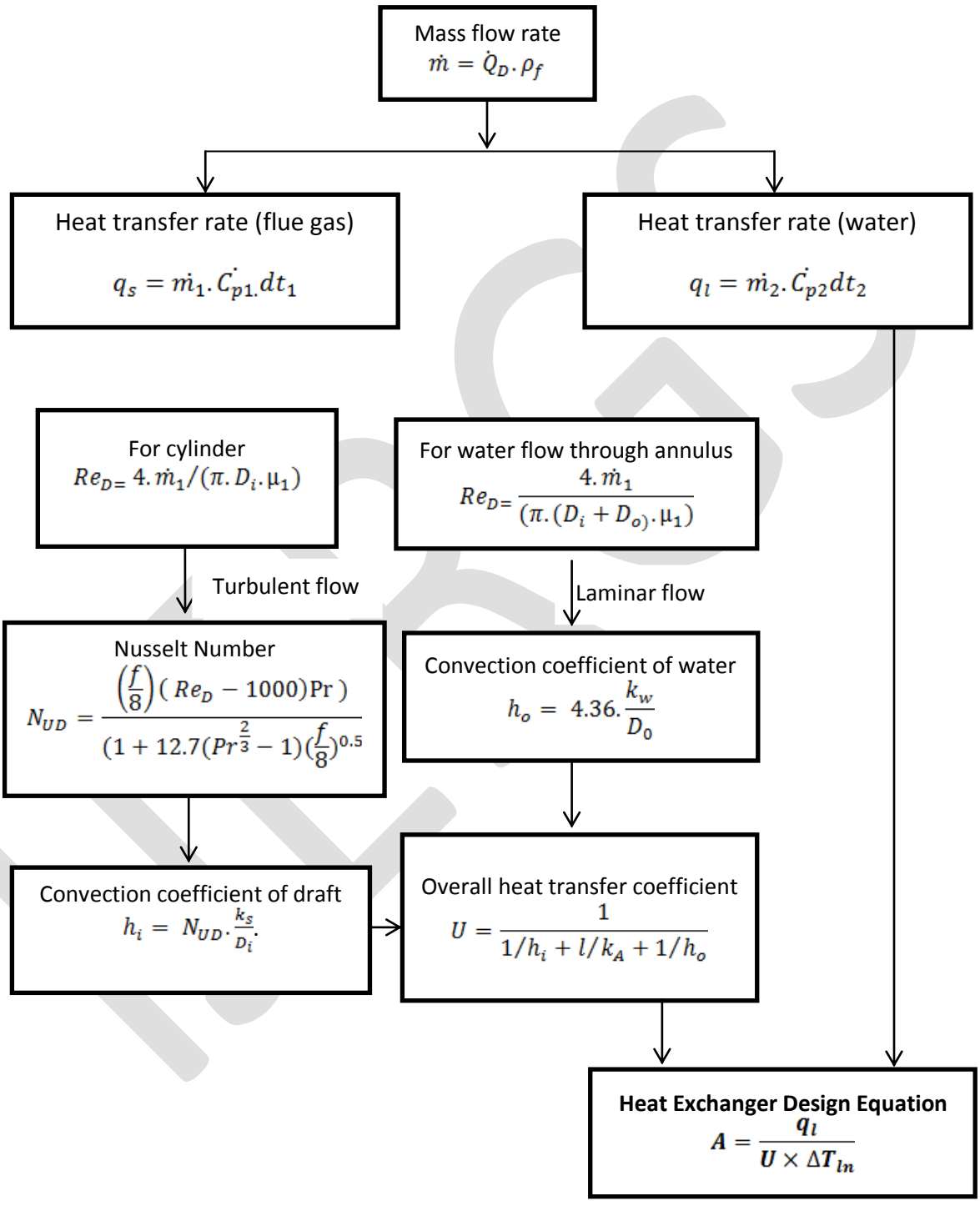
i. Negligible heat loss to surroundings.

ii. Negligible kinetic and potential energy changes.

iii. Constant Properties

iv. Negligible fouling factors.

v. Fully developed conditions for the water and flue gas.



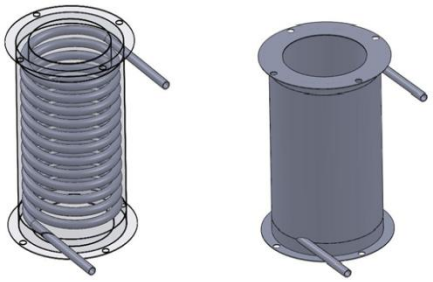
Schematic Representation of Methods Applied for designing Heat Exchangers

Fabrication of heat exchangers

F**irst mode**l of heat exchanger i.e. aluminum coil inbuilt inside the chimney was made by coiling the aluminum coil in the inner wall of the chimney. The total length of the aluminum coil that was calculated to obtain the predefined quantity of distilled water i.e. 3 l/hr was found to be 3.8 m i.e. 11 no of turns but extra 2 no of turns was added for factor of safety and uncertainties. But the length of the aluminum coil that is normally available in the market was only 3.65 m i.e. 9.7 no of turns. The inlet hole was made at the bottom of the chimney where the temperature is very high about 600 °C. The outlet hole was made at a location where the chimney temperature was about 400 °C.

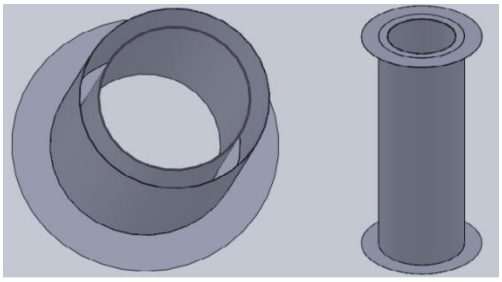
Fabricating first Prototype (Aluminum Coil Inside)

Second model of heat exchanger i.e. aluminum coil winded outside the chimney system was fabricated to overcome the problem of tar deposition in the first model. Length of aluminum coil calculated was 3.65m. Both the concentric cylinders were made up of cast iron of 1mm thickness. The aluminum coil was then winded on the outer surface of the inner cylinder. . Concentric cylinders were bonded together on both the ends with cylindrical cast iron metal sheet, welded finely along the perimeter of the cylinder to avoid the leakage of flue gas two holes were made in the system one for the inlet and the other for the outlet pipe for the water flow. This inbuilt system has to be placed in the chimney system to be fitted with nut and bolts



Second prototype (Coil and Jacket combination)

Third model of heat exchanger i.e. sealed concentric cylinders was made of Galvanized Iron sheet because they avoid the problem of rusting. The height of the heat exchanger was 0.5 m, with gap between the concentric cylinders to be maintained at 15 mm on both the sides. Since, the water is contained in between the cylinders the system should be free from rusting to maintain the quality of water for drinking purpose. Two concentric cylinders were attached together properly by sheet bending and pressing technique as arc welding on GI sheet was not possible. To ensure the leakage problem, M-Seal and Silicon Gel were used all around the joints. Two holes for inlet and outlet water similar to that of the previous system was also made using hand drill



Third Prototype (Jacket type)

Testing of heat exchangers

Before starting the test, both qualitative and quantitative information about the stove, fuel and the test conditions was recorded. These include:

a) Air temperature,

b) Average dimensions of wood (length x width x height)

c) Wood moisture content (%-wet basis)

d) Dry weight of standard pots

e) Local boiling point of water was determined by using the same digital thermometer and sensor that was used in the testing.

These parameters were recorded in the WBT data sheet along with the weight of the fuel wood that was used. Once these parameters had been measured and recorded and the fuel was prepared, the test was started.Three different models of heat exchangers were tested independently. Bucket was filled with 20 L of water and placed in a place maintaining the height for water pressure. Blocker was used so as to maintain the water flow rate entering the system. Then, stove was run in normal condition. Ten minutes after running the stove, the outflow of water from the bucket was started. The amount of distilled water collected in ten minutes was noted. The condensation of the steam was done by bending the outlet pipe. But, complete condensation was not found to occur. Condensation of steam was carried out by introducing the stem directly into beaker containing 3 liters of water. Gradual temperature increase in water was also noted. The temperature rise of the raw water was noted in different time. Once the water reached Pasteurization temperature, steam was introduced in the container containing 3 liters of water for another ten minutes. Then, sample was taken for *Escherichia coli* (E.coli) test. Final amount of water condensed in the beaker was noted.

Result and discussion

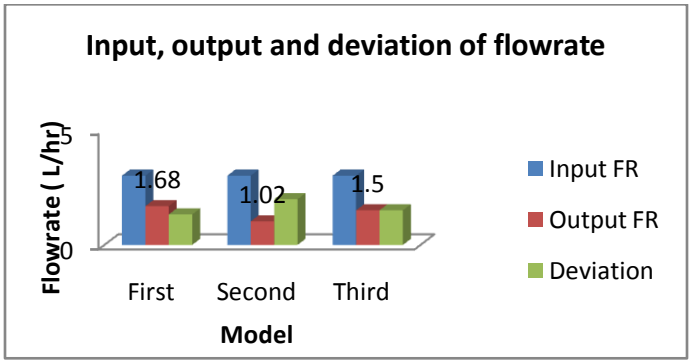
The effectiveness of three different models of heat exchanger was different from one another. The effectiveness of heat exchanger is based on the amount of heat transferred from the hot fluid to the cold fluid. During our project we conducted numbers of tests. Results based on those experiments are discussed below.

First model of heat exchanger had the maximum ability of heat transfer from the flue gas to the water. With 9 no of turns of aluminum coil, the amount of distilled water collected in the beaker was found to be 280 ml in 10 minutes. This implies the flow rate to be 1.68 L/hr. This model of heat exchanger being more efficient than other models in terms of heat transfer was failed in long run use because of the tar deposition. The flue gas in the chimney contains tar, which is a complex organic compound gets deposited in the aluminum coil. The tar behaves as an insulating material and reduces the amount of heat transferred to the aluminum coil hence reducing the efficiency of the coil and ultimately the heat exchanger system. Another big problem of this model is cleaning of the system. To overcome this problem other two models of heat exchanger were proposed.

The **second model** of heat exchanger had lesser efficiency than that of the first model. That was because the heat from the flue gas is not directly transferred to the aluminum coil rather it is first transferred to the cast iron cylinder and then to the aluminum coil. This system overcomes the tar deposition problem on the aluminum coil which helps in increasing the life time of the system. Thus, on the long run use this system is efficient and the temperature resistivity of cast iron is also more than that of the aluminum which increases the proximity of the system. However, the fabrication of this heat exchanger is more difficult and time consuming than the previous

one. This is also more expensive than the previous one as the cost of the cast iron is also included along with the aluminum coil. Total amount of distilled water collected was 1.02 L/hr

The **third module** of heat exchanger was efficient in terms of heat transfer but was very difficult to fabricate. Joints were sealed by bending and pressing technique which is very difficult to perform and time consuming. The joints were not completely leak proof and M-seal was used to counter it. But due high temperature about 600 ºC the life of M-seal is shortened and after few hours, the system was suffered from the leakage problem. The amount of distilled water collected was found to be 1.5 L/hr.



Output flow rates of the system.

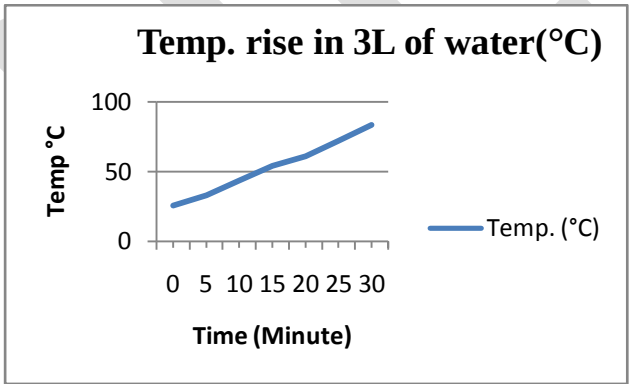
Water collected through Pasteurization

Distilled water was collected by condensing the vapor directly into container containing 3 liters of water.

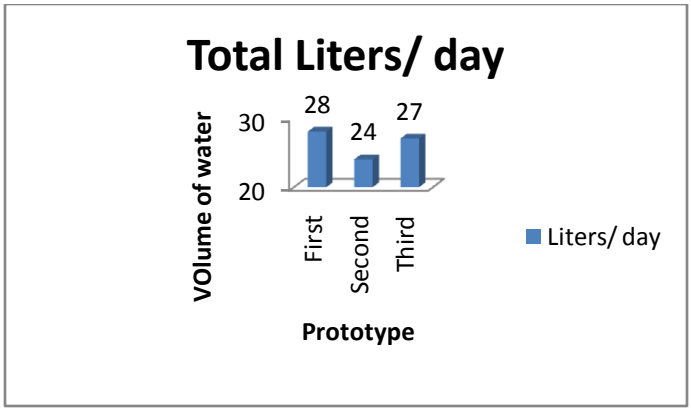
Heat exchangers	Initial volume of water (L)	Final Volume of water (L)	Amt. of Distilled water (L)	Total vol. of water pasteurized. (L)
First Model	3	4.68	1.68	4.68
Second Model	3	4.02	1.02	4.02
Third Model	3	4.5	1.5	4.5

Final amount of water pasteurized in one hour.

The steam was condensed in a beaker containing 3 liter of raw water of temperature 25.3°C. During condensation, steam was introduced directly into the raw water and gradually the temperature of the water which was at 25.3°C started to rise and reached 83.7 °C in 30 minutes. Further maintaining the water for ten minutes, the water can be expected to get pasteurized. As we know the water at 80 °C when heated for ten minutes gets pasteurized.



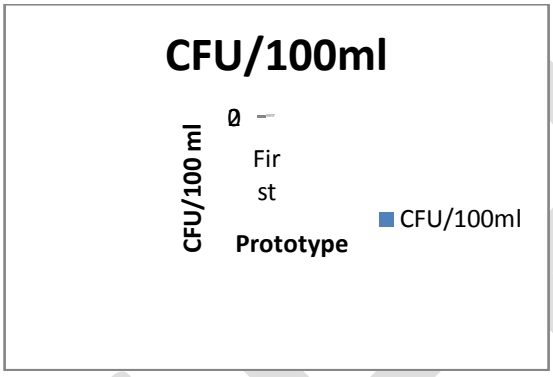
Temperature rise in 3 liters of water



Volume of water pasteurized per day

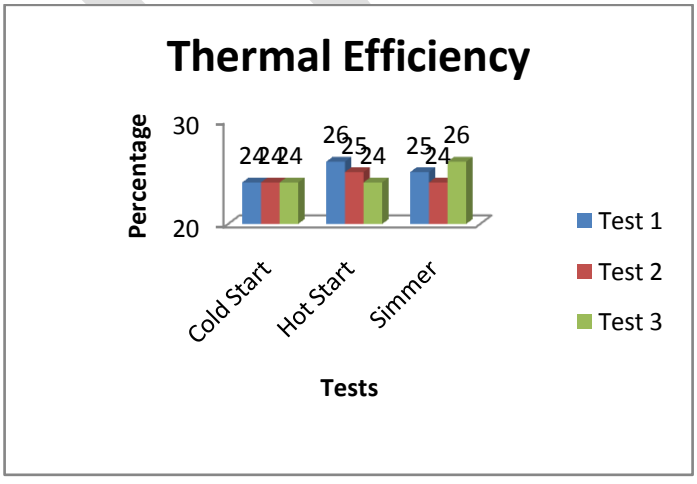
Considering the stove to be used in an average of 6 hr/day, the total amount of pasteurized water including the distilled water collected per day was found to be 28 L/day, 24 L/day and 27 L/day for first, second and third model respectively. For a normal family in Nepal this quantity of drinking water is sufficient for a day.

E. coli testing



Three samples of three different prototypes were taken for lab test. The colony counting for the raw water was TMTC (too many to count). Colony counting for treated was within the WHO guideline for Drinking Water, which is less than 5 CFU per 100ml. This result shows that the treated water is safe to drink.

Thermal Efficiency:



Results from WBT

This result shows that the overall efficiency of the system (ICS) is not disturbed by embedding heat exchangers in chimney but it definitely increases the overall efficiency of the system. However, overall efficiency calculation was not done.

Cost and Energy saved by implementing the system:

Heat Exchanger	Vol. of Pas. Water (ltr/hr)	Daily production (ltr/day)	Fuel wood saved (tons/year)	Total cost saved per year. (Nrs)	Amount of carbon reduction (Ton/yr.)	Amount earned by carbon trade (USD/yr)
First Module	4.68	28	10.074	60444	4.28	128.4
Second Module	4.02	24	8.803	52818	3.68	110.4
Third Module	4.5	27	9.855	59130	4.12	123.6

Total amount of cost and fuel wood saved by Heat exchangers and amount earned by carbon trade

The heat energy contained in flue gas is wasted to the atmosphere. Heat Exchangers use the waste heat and helps in producing Pasteurized Water which can be used for drinking purpose. This means we had saved the significant quantity of firewood that would have been needed to generate drinking water. It is estimated that 1 kilogram of wood is needed to boil 1 liter of water and make it drinkable (WHO, Water sanitation health). The local firewood cost in Dhulikhel is Nrs. 6/kg.1kg fuel Wood generates 418 gm carbon equivalent of carbon emission in ICS (Bajracharya, 2010). Nordhaus has suggested, based on the social cost of carbon emissions, that an optimal price of carbon is around $30(US) per ton carbon equivalent of carbon emission and will need to increase with inflation(Nordhaus, carbon credit).

CONCLUSION

All the heat exchangers were able to recover the wasted heat to some extent. The wasted heat was recovered by pasteurizing the water which is finally used for drinking purpose. The blending of the heat exchanger to the chimney system didn't decrease the overall efficiency of the Stove. Thus we can say that by blending the heat exchanger with the chimney system will certainly increase the overall efficiency of the stove system but further research should be carried out. The collected pasteurized water was safe for drinking meeting the WHO standards. Installing the heat exchanger helps to reduce the quantity and cost of firewood that would have been needed to generate drinking water resulting to carbon emission reduction and carbon trading. The installation of heat exchanger in the chimney system is very easy and simple which can be installed in any stove either traditional or improved cooking stove having chimney system.

Finally, we would like to conclude that by installing these heat exchangers in the chimney system helps to generate pure drinking water economically recovering the wasted heat from the chimney and reducing the carbon emission.

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Evaluation of Schistosoma mansoni cercaricidal activity of Solamargine a steroid glycoalkaloid from Solanum syzybrilifolium

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ABSTRACT - The cercaricidal activity of a mixed solamargine (1) and β-solamarine (2) solution were directly tested against *Schistosoma mansoni* cercariae and a time-concentration relationship was observed; the concentrations needed to kill all cercariae (LC_{100}) within 10 min of exposure were 0.01 mg/mL. Mixed solamargine (1) and β-solamarine (2) solution have a high level of cercaricidal activity against free swimming cercariae and it seems to be ecologically safe, since it is known to have very low toxicity to fish. The possible use of such sublethal concentrations in schistosomiasis transmission sites as an oriented promising technique to control this parasite and to minimize or prevent water pollution with pesticides.

Introduction

Schistosomiasis, a disease of various mammals including man, is caused by blood flukes of the genus *Schistosoma* (Brown, 1980). It is still a major helminth infection in the world at the beginning of the 21st century and an important public health problem in many tropical and bubtropical countries. Schistosomiasis is one of the major communicable diseases and it is second after the malaria in socio-economic and health importance in the developing countries (Bergquist and Colley, 1998; Larhsini *et al.*, 2010). It is endemic in 74 countries in the world (WHO, 1985), affects 200 million people, expose 800 million to the risk of the infection (Gryseels, 1991; Capron and Capron, 2002; Bilia *et al.*, 2000).

Controlling of the snail intermediate hosts of this disease by molluscicides (synthetic and/or of natural origin) is still one of the most promising means (WHO, 2009; Bagalwa *et al.*, 2010; Mahmoud *et al.*, 2011; Adewumi *et al.*, 2013). There are different kinds of schistosomiasis, but in all cases, the life cycle involves in the aquatic snails. The parasite multiplies into hundreds of cercariae in the snail and that can penetrate the intact human skin who is exposed to infected waters after leaving the snails (Marston and Hostettman, 1993). Chemotherapy is a general strategy for schistosomiasis control; but another more interesting strategy is to interrupt the disease vital cycle by snail's or cercariae's elimination.

For the control of snail-borne diseases, several synthetic compounds were developed such as copper sulfate, sodium pentachlorophenate, sulphonated hydrocarbons, tributylin fluoride. Only niclosamide (marketed as Bayluscide; Andrews *et al*, 1983) is widely used in control programs (Perrett and Whitfield, 1996). On the other hand, there is probability that some resistance to niclosamide can be induced under extreme conditions of genetic selection of the snails (Sulivan *et al*, 1984). Therefore, the potential use of plants for the biological control of the intermediate hosts of human schistosomiasis and other snail - transmitted parasitic infections has received a considerable attention (Medina and Woudbury, 1979; Kloos and McCullough, 1985; and Kloos *et al.*, 1985

and Perrett and Whitfield, 1996). The use of plants with molluscicidal properties is simple, inexpensive, and appropriate for the local control of the snail vector (Marston and Hostettman, 1993).

The phytochemical investigation of *Solanum szybrilifolium* (Solanaceae), species plants known to synthesize steroidal alkaloids and spirostane derivatives and some of which has shown the molluscicidal activity of plant (Wanyonyi *et al.*, 2003). But its cercaricidal activity is not known until now. In our study, the methanolic extract of the fruit of *Solanum szybrilifolium* was fractionated and the biological activity of one fraction (B) was tested against cercaria produced by snails infested by *Schistosoma mansoni*. Two known compounds, solamargine (1), a chacotriose solasodine, and β-solamarine (2), a chacotriose tomatidenol, isolated from the active fraction B were reported for the first time in *Solanum szybrilifolium* (Bagalwa *et al.*, 2010). This fraction B has been presented as potential molluscicide in the future snail control programs with a careful monitoring on the environmental damaging effects, especially when indigenous populations use this plant for fishing during the dry season (Bagalwa *et al.*, 2010).
In the present work, we describe the cercaricidal activity of the fraction B isolated in *Solanum szybrilifolium* collected in East part of the Democratic Republic of Congo. The result of such study may provide cheap, locally produced, biodegradable and effective control agents against schistosomiasis in rural areas of developing countries where this disease is endemic.

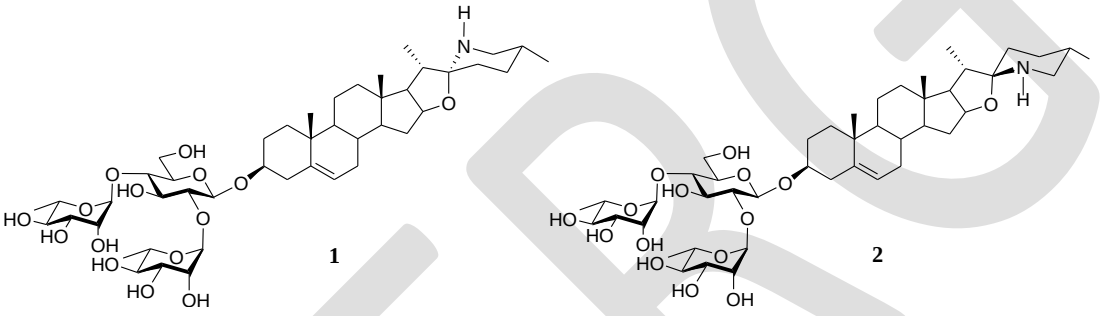

Figure 1. Structure of solamargine (1) and β-solamarine (2)

Material and Methods

Cercariae obtain

Schistosoma mansoni cercariae were obtain from snail *Biomphalaria pfeifferi* collected in the streams located at Lwiro (Kalengo and Birunga) using plankton net and kept in the laboratory of Malacology of the Centre de Recherche en Sciences Naturelles (Bagalwa and Baluku, 1998). In fact, snails were put in container with deionised water and exposed to artificial light for 3 h and the cercariae that released from snails in this period were concentrated by their phototropism on the top of a container made black on the base. The cercariae that were collected from the container by graduated wells (0.3 mL) and had the same emergence age (Helmy *et al.*, 2007; Medina *et al.*, 2009).

Extraction and isolation of the steroidal alkaloids Saponin

The dried and powdered fruit (300 g) was extracted with 96% methanol. The MeOH extract was concentrated and precipitated with acetone. Then, the crude saponin precipitate was dialyzed to give a saponin rich extract (2.69 g). This extract (2.5 g) was fractionated by VLC on reversed phase C_{18} (MeOH–H_2O, 60:40, 70:30, 80:20 and 100:0, each 300 ml) to give fraction A (1.52 g), B (680 mg), C (277 mg) and D (58 mg), respectively. Fraction A was repurified by RP-18 VLC (MeOH–H_2O, 40:60, 60:40, 80:20 and 100:0, each

200 ml) to give fraction A1 (1.08 g), A2 (64 mg), A3 (116 mg) and A4 (212 mg). A part of fraction B (100 mg) was chromatographed on silicagel CC (4 g) eluted with a gradient of $CHCl_3$–MeOH–H_2O (70:30:1 to 70:30:2) to give 1 (20 mg). A part of fraction C (70 mg) was purified by silicagel CC using a gradient of $CHCl_3$–MeOH (9:1 to 7:3) followed by preparative TLC on silicagel with $CHCl_3$–MeOH–H_2O (70:30:5) as eluant, to give solamargine (1) (13 mg) and β-solamarine (2) (5.8 mg).

Preparation of dilution and Cercaricidal activity

A series of concentrations of mixed solamargine solution was prepared on basis of weight/volume using deionised water. Therefore, 0.6 mg of mixed solamargine was dissolved in 10 mL of deionised water. Six concentrations were made by dilution with deionised water (0.06; 0.03; 0.01; 0.001; 0.0001 and 0.00001 mg/mL). A standard was made with 0.1 mg of digitonine in 100 mL of distilled water (0.0001 mg/mL) (Bagalwa *et al.*, 2010). Approximately 20-30 freshly emitted cercariae were placed in each well and three wells for each concentration were tested (using different gradual concentrations) and it is the same for the positive (digitonine) and negative (distilled water) control. During the exposure period, the cercariae were observed under a binocular loupe after 10, 20, 30, 40, 50 and 60 minutes. The observation was made on the cercarial movement and mortality recorded at successive intervals of time. 50 ml of deionised water containing 20-30 fresh cercariae were used as negative control (Ritchie *et al.*, 1974; Medina *et al.*, 2009) and another group of cercariae was exposed to digitonin as a positive control. Results were expressed in percentage in terms of destruction of the cercariae. The effectiveness of the tested isolated extract on *Schistosoma mansoni* cercariae was determined (Litchfield et Wilcoxon, 1949). The collected data was computerized to give LC_{00}, LC_{50}, and LC_{100} values determined by probit analysis.

Results

Compound **1** and **2** (Figure 1) at the concentration going from 0.01 mg/mL to 0.06 mg/mL, presents a high activity against *Schistosoma mansoni* cercariae, killing the totality of the cercariae (100 %) in 10 minutes (Table 1).

Table 1. Cercaricidal activity of mixed solamargine (1) and β-solamarine (2) solution isolated from *Solanum syzybrilifolium* according to the time of exposure

Extrait	Concentration tested (mg/mL)	Mortality rate (%) of cercariae after exposure period (minute)					
		10	20	30	40	50	60
Solarmagine and β-solamarine	0.06*	100	100	100	100	100	100
	0.03	100	100	100	100	100	100
	0.01	100	100	100	100	100	100
	0.001**	19±13	31±5	50±0	61±5	61±5	86±5
	0.0001	0	0	0	11±5	11±5	14±5
Control deionised water		0	0	0	0	0	0

Control digitonin	0.001	100	100	100	100	100	100
	0.0001	0	0	0	0	0	0

Legend: * Lethal concentration of fish (LC_{100})
** No effect to fish (LC_{00})

The mortality rate of cercariae varied with time and concentration of the solamargine rate. From concentration 0.06 mg/mL to 0.01 mg/mL the mortality rate is 100 % equivalent to the concentration of 0.001 for the digitonin. At the concentration of 0.001 mg/mL the mortality rate increased with the time of exposure as shown in figure 2.

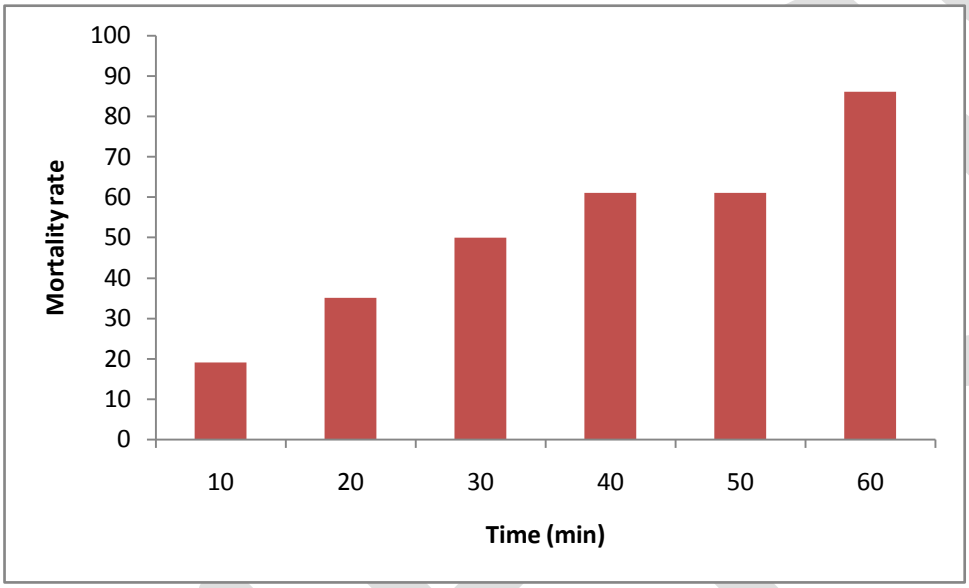

Figure 2. Mortality rate (%) of cercariae at the concentration of 0.001 mg/mL of solamargine (1) and β-solamarine (2) extract from *Solanum syzybrilifolium* according to the time of exposure (min)

The LC_{00}, LC_{50} and LC_{100} of the cercaricidal activity at different time of exposure is presented in table 2.

Table 2. Cercaricidal activity (mg/mL) at different time of exposure

Lethal Concentration	Concentration (mg/mL) after exposure period (minute)					
	10	20	30	40	50	60
LC_{00}	0.01	0.01	0.01	0.01	0.01	0.01
LC_{50}	0.0047	0.0048	0.0037	0.0033	0.0031	0.0025

LC_{100}	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

The LC_{50} of the solamargine decreased with the time of exposure. But the LC_{100} and LC_{00} doest not varied in time.

The relationship between the mortality rate and the time of exposure is present in the figure 2.

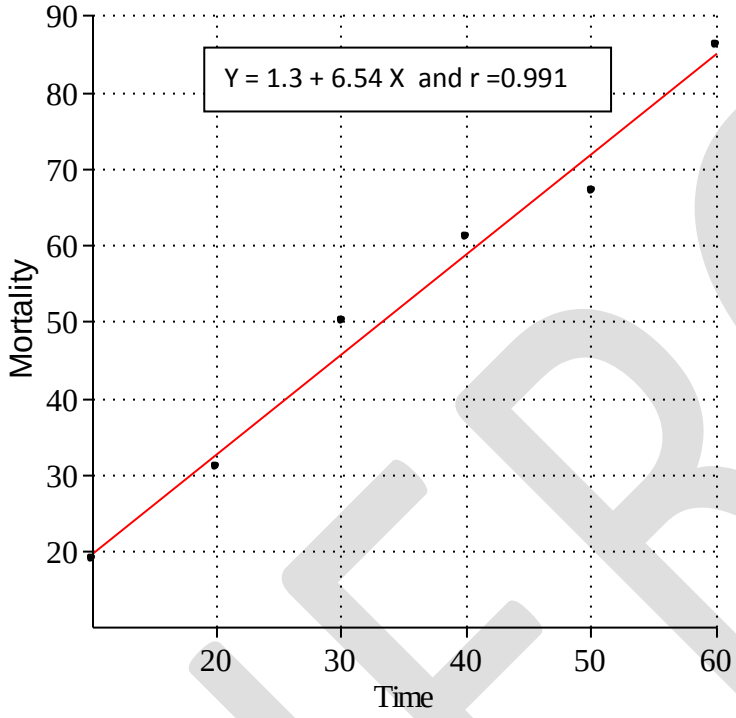

Figure 2. Correlation relationship between the mortality rate (%) and the exposure time (minute) of cercariae again extract at 0.001 mg/L.

This figure shows a positive correlation between mortality rate and the time of exposure of cercariae at the concentration of 0.001 mg/mL.

Discussion

Biomphalaria pfeifferi, known as intermediate host of *Schistosoma mansoni* is widely distributed in tropical region. *Biomphalaria pfeifferi* larvae lethality assay is considered to be the most useful for the preliminary assessment of general activity, and the toxicity bioassays have show correlation with some cytotoxic and pesticide activities (Harborne and Dey, 1991; Shoeb *et al.*, 2007; Subhan *et al.*, 2008). In this work, the bioassays were performed to evaluate the toxicity of Solamargine extract in *Solanum szybrilifolium* against *Schistosoma mansoni* cercariae in vitro. All *Solanum szybrilifolium* extracts and the isolated compound, solarmagine, exhibited high

molluscicidal activity and low lethality against non-target species (fish and macroinvertebrate) (Bagalwa *et al.*, 2010). The lethal concentration of solamargine (1) and β-solamarine (2) solution again fish with 100 % of lethality was 0.06 mg/L (100 %) in laboratory conditions. At this concentration this concentration the mortality of cercariae was also 100 %. Using the extract concentrations that kill 100 % of fish, total death of *Schistosoma mansoni* cercariae was recorded. 50 % death of cercariae was remarked after 1/2 hour of exposure to concentrations of 0.001 mg/mL. Moreover, cercariae exposed to extract concentrations 0.01 mg/mL were completely killed after 10 minutes. This lethal concentration (0.01 mg/mL) is better than the lethality of the extracts of *Croton floribundus* (0.4 mg/mL) observed in laboratory experiment (Medina *et al.*, 2009; Kamel *et al.*, 2010) and for *Calendula micrantha* witch killed 100 % of cercariae by 100 ppm dry powder within 2 and 24 h of exposure (El-Emam *et al.*, 1986). The same result was observed when cercarial are tested against *Furcraea selloa marginata* and *Bacillus thuringiensis kurstaki* (Osman *et al.*, 2011). The high activity of the mixed solamargine (1) and β-solamarine (2) solution are due to the possible synergism within the two compounds and between different glycoalkaloid types under natural conditions as proved by others authors (Wanyonyi *et al.*, 2002; Roddick *et al.*, 2001; Al Chami *et al.*, 2003; Ikeda *et al.*, 2003). For extracts of the Arabian or Somali gum *Commiphora molmol* (family: Burseraceae), Masoud *et al.*, (2000) found that the oleo - resin extract showed a more pronounced cercaricidal potency than the oil. Total death of cercariae was remarked after 1/4 h of exposure to 10.5 and 2.5 ppm. This concentration is high than the concentration of solamargine obtains in this study. At the concentration of 0.001 mg/mL the mortality rate increased with the time of exposure (Figure 2). The LC_{50} of the cercaricidal activity decreases with the time of exposure (Table 2).

The relationship between the mortality rate and the time of exposure (Figure 2) shown a positive linear correlation ($Y = 1.3 + 6.54 X$ and $r = 0.991$). Ahmed and Ramzy, (1997) observed that the cercaricidal properties of water extract of the leaves of *Solanum nigrum* were directly tested against *Schistosoma haematobium*, *Schistosoma mansoni* and *Fasciola gigantica* cercariae and a time-concentration relationship was observed; the concentrations needed to kill all cercariae (LC_{100}) within 10 min of exposure were 0.01 mg/mL for *Schistosoma mansoni* cerariae and 0,001 mg/mL for digitonin.

Mixed solamargine (1) and β-solamarine (2) solution have a high level of cercaricidal activity against free swimming cercariae. Any cercaria which is not killed by the application may be so attenuated that it becomes either unable to infect humans or fail to mature and cause significant pathology in those who they do infect as observed in others works (Hilal *et al.*, 1989; Perrett *et al.*, 1994; Ahmed and Ramzy, 1997). On the other land, it seems to be ecologically safe, since it is known to have very low toxicity to fish (Bagalwa *et al.*, 2010). Saponins affect surface tension due to their froth-forming ability. The haemolytic activity of saponins is attributed to their formation of complexes with cholesterol in red blood cell membranes, which causes a collapse of the cell and the release of haemglobin (Hostettmann and Marston, 1987; Adewumi *et al.*, 2013). The molluscicidal activities of saponins have been shown to vary with the position of the glycoside chain (mono and bidesmosidic differences), nature of the sugar chains, the sequence of the sugars, the interglycosidic linkages and the substitution patterns of the aglycone (Hostettmann and Marston, 1987). Than saponins seems to hold the greater promise for the control of snail vectors schistosomiasis and cercariae.

Conclusion

It is concluded that cercarial sublethal concentrations from molluscicides (synthetic or of plant origin) that may be present in water bodies during schistosomiasis control operations, could be of great value for attenuation of cercarial infectivity to the final host. This study throws light, also, upon the possible use of such sublethal concentrations in schistosomiasis transmission sites as an oriented promising technique to control this parasite and to minimize or prevent water pollution with pesticides.

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Probabilistic Seismic hazard Analysis of Kathmandu City, Nepal

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ABSTRACT -Kathmandu is classified as a highly earthquake prone city of Nepal. The center of Kathmandu City is located in the vicinity of ten independent seismic source zones which in reality are active faults. This creates uncertainties in the size, location and the rate of recurrence of earthquakes. Probabilistic seismic hazard analysis provides a framework in which these uncertainties can be identified, quantified and combined in a rational manner to provide a more complete picture of the seismic hazard. This study presents a PSHA of the center of Kathmandu city using the attenuation relationship given by Cornell et al (1979) in order to determine various levels of earthquake-caused ground motion that will be exceeded in a given future time period.

KEYWORDS -seismic source zone; active faults; recurrence of earthquakes; seismic hazard; attenuation relationship; earthquake-caused ground motion

1. INTRODUCTION

Kathmandu city has been subjected to frequent earthquakes of moderate intensities and about once in a century to disastrous earthquake of higher magnitude. Earthquake was first recorded in Nepal on June 7, 1255 AD when one third of the total population in Kathmandu were killed by a 7.7 Richter scale.

Magnitude-Frequency Data on Earthquakes in Nepal and the Surrounding Region (1911AD-1991AD)

	Earthquakes of magnitudes in Richter scale				
	5 to 6	6 to 7	7 to 7.5	7.5 to 8	>8
No. of events	41	17	10	2	1
Recurrence interval in years	2	5	8	40	81

Table 1: Earthquakes in Nepal (1911 to 1991)

Recent earthquakes near Kathmandu city are shown in figure1

Figure 1: Recent earthquakes near Kathmandu

- *Gangtok, Sikkim, India. October 3, 2013. Magnitude 5.3*
- *Banepa, Nepal. August 30, 2013. Magnitude 5.0*
- *Tulsipur, Nepal. June 28, 2013. Magnitude 5.0*
- *Tulsipur, Nepal. August 23, 2012. Magnitude 5.0*
- *Kishanganj, West Bengal, India. March 27, 2012. Magnitude 5.0*
- *Kathmandu, Nepal. November 12, 2011. Magnitude 4.2*
- *Gangtok, Sikkim, India. September 14, 2011. Magnitude 6.9*
- *Darjiling, West Bengal, India. June 3, 2011. Magnitude 5.0*
- *Kathmandu, Nepal. December 29, 2010. Magnitude 5.2*
- *Khandbari, Nepal. February 26, 2010. Magnitude 5.5*

The most destructive earthquake came on Jan 16, 1934 AD; the Great Nepal Bihar Earthquake of magnitude 8.4 that resulted in damage intensity of IX-X MMI in many parts of Kathmandu valley.

The seismic vulnerability of Nepal and particularly Kathmandu valley is clearly justified, however study of the seismic hazard potential of the valley has not been performed systematically. The seismic hazard potential of a site is identified by conducting probabilistic seismic hazard analysis and constructing hazard curves. Hazard curve is a graphical representation of seismic intensity parameter such as peak ground acceleration and its annual probability of exceedence. It requires the identification of seismic source zones affecting the site, rate of recurrence of earthquake at each source, distance from each source to the site, probability density function of magnitude and systematic synthesizing of these to obtain the probability of exceedence of certain peak ground acceleration at the site due to all sources in its vicinity.

2. NUMERICAL STUDY

The seismic hazard curve does not vary significantly across the length and breadth of the city due to its small size thus making it cogent to consider only the center of the city. The ten independent seismic source zones, near the center of Kathmandu, which in reality are active faults are characterized in table2.

Source Zone	EQ Sources (Faults)	Fault name	Fault type	Assumed $M_{S,max}$	Assumed $M_{w,max}$	a	b	Source to site distance (km)
1	HFF-1.10	Narayani River	R/RL	6.7	6.5	4.17	1	83
2	HFF-1.15	Dhalkebar	R	7.2	6.8	3.38	1	84
3	MBT-2.3	ArungKh.	R,N down	7.5	7.0	4.24	1	140
4	MBT-2.4	Narayani	R	7.0	6.7	4.17	1	78
5	MBT-2.5	Hetauda	R	7.3	6.9	4.17	1	38
6	MCT-3.3	GosaiKunda	R	7.5	7.0	4.17	1	21
7	HFF-1.13	Amlekhgunj	R	7.0	6.7	4.17	1	47
8	LH-4.10	Sunkoshi-RoshiKh.	Rt-lat-st-sl	6.7	6.5	4.17	1	68
9	MBT-2.6	Udaipur-Sunkoshi	Rev.norm	8.0	7.3	4.23	1	104
10	LH-4.7	Saptakoshi-Deomai	R	7.6	7.1	4.24	1	185

Table 2: Characteristics of seismic sources and source-to-site distance

2.1 Mean annual occurrence rate

The threshold magnitude is taken as 4.5 since smaller magnitude earthquakes are not believed to be capable of damaging structures and are thus unnecessary to consider for seismic hazard analysis. The mean annual occurrence rate of earthquake (υ) of magnitude larger than the threshold magnitude (m_o=4.5) calculated for each source using Guttenberg-Ritcher recurrence law is divided by 16.

$$\upsilon_i = \frac{10^{a-bm_0}}{16} \quad \text{(i = 1,2,3... 10 for 10 sources)}$$

where, a = overall occurrence rate of earthquake for each source
b = relative ratio of small and large magnitudes for each source

The mean annual occurrence rate of earthquake greater than magnitude 4.5 at each source is tabulated in Table3.

Source	
1	**0.02923**
2	**0.00474**
3	**0.03435**
4	**0.02923**
5	**0.02923**
6	**0.02923**
7	**0.02923**
8	**0.02923**
9	**0.03356**
10	**0.00947**

10X1

Table 3: Mean annual occurrence rate of 10 sources

2.2 Probability density function of magnitude

Each source is capable of producing earthquakes with a variety of magnitudes with an upper bound of maximum moment magnitude ($M_{w,max}$) and a common lower bound of the threshold magnitude (m_o = 4.5). The total range of earthquake magnitudes is divided into 6 equal intervals for all sources.

m_l-m_u	4.5 - 5.0	5.0 - 5.5	5.5 - 6.0	6.0 - 6.5	6.5 - 7.0	7.0 - 7.5
Mean(m)	4.75	5.25	5.75	6.25	6.75	7.25

Table 4: Discretization of earthquake magnitudes

Each interval is discretely represented by its mean value. If the value of maximum moment magnitude of any source lies within any particular interval, the interval will have an upper bound value equal to the same maximum moment magnitude. The distribution of the earthquakes of various magnitude is assumed to follow Bounded Guttenberg-Ritcher model.

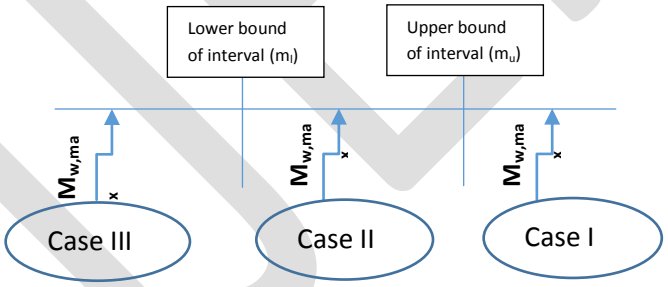

Figure 2: Position of $M_{w,max}$ in a particular interval

Case I :$M_{w,max} > m_u$

$P(M = m) = P(m_l < m < m_u) = \frac{2.303 * b * e^{-2.303 b (m - m_0)}}{1 - e^{-2.303 b (M_{w,max} - m_0)}} * (m_u - m_l)$

Case II :$M_{w,max} < m_u$ and $M_{w,max} > m_l$

$P\left(M = \frac{m_l + M_{w,max}}{2}\right) = P(m_l < m < M_{w,max}) = \frac{2.303 * b * e^{-2.303 b (\frac{m_l + M_{w,max}}{2} - m_0)}}{1 - e^{-2.303 b (M_{w,max} - m_0)}} * (M_{w,max} - m_l)$

Case III :$M_{w,max} < m_l$

$P(M) = 0$

The probability density function of magnitude for all the 10 sources are tabulated in table5 and plotted in figure3

	Magnitude						
Source	4.75	5.25	5.75	6.25	6.75	7.25	
1	**0.65400**	**0.20677**	**0.06537**	**0.02067**	**0.00000**	**0.00000**	
2	**0.65073**	**0.20574**	**0.06505**	**0.02056**	**0.00491**	**0.00000**	
3	**0.64952**	**0.20535**	**0.06493**	**0.02053**	**0.00649**	**0.00000**	
4	**0.65158**	**0.20600**	**0.06513**	**0.02059**	**0.00368**	**0.00000**	
5	**0.65005**	**0.20552**	**0.06498**	**0.02054**	**0.00583**	**0.00000**	
6	**0.64952**	**0.20535**	**0.06493**	**0.02053**	**0.00649**	**0.00000**	
7	**0.65158**	**0.20600**	**0.06513**	**0.02059**	**0.00368**	**0.00000**	
8	**0.65400**	**0.20677**	**0.06537**	**0.02067**	**0.00000**	**0.00000**	
9	**0.64850**	**0.20503**	**0.06482**	**0.02049**	**0.00648**	**0.00155**	
10	**0.64910**	**0.20522**	**0.06488**	**0.02051**	**0.00649**	**0.00065**	10X6

Table 5: Probability Density Function of magnitude P(M)

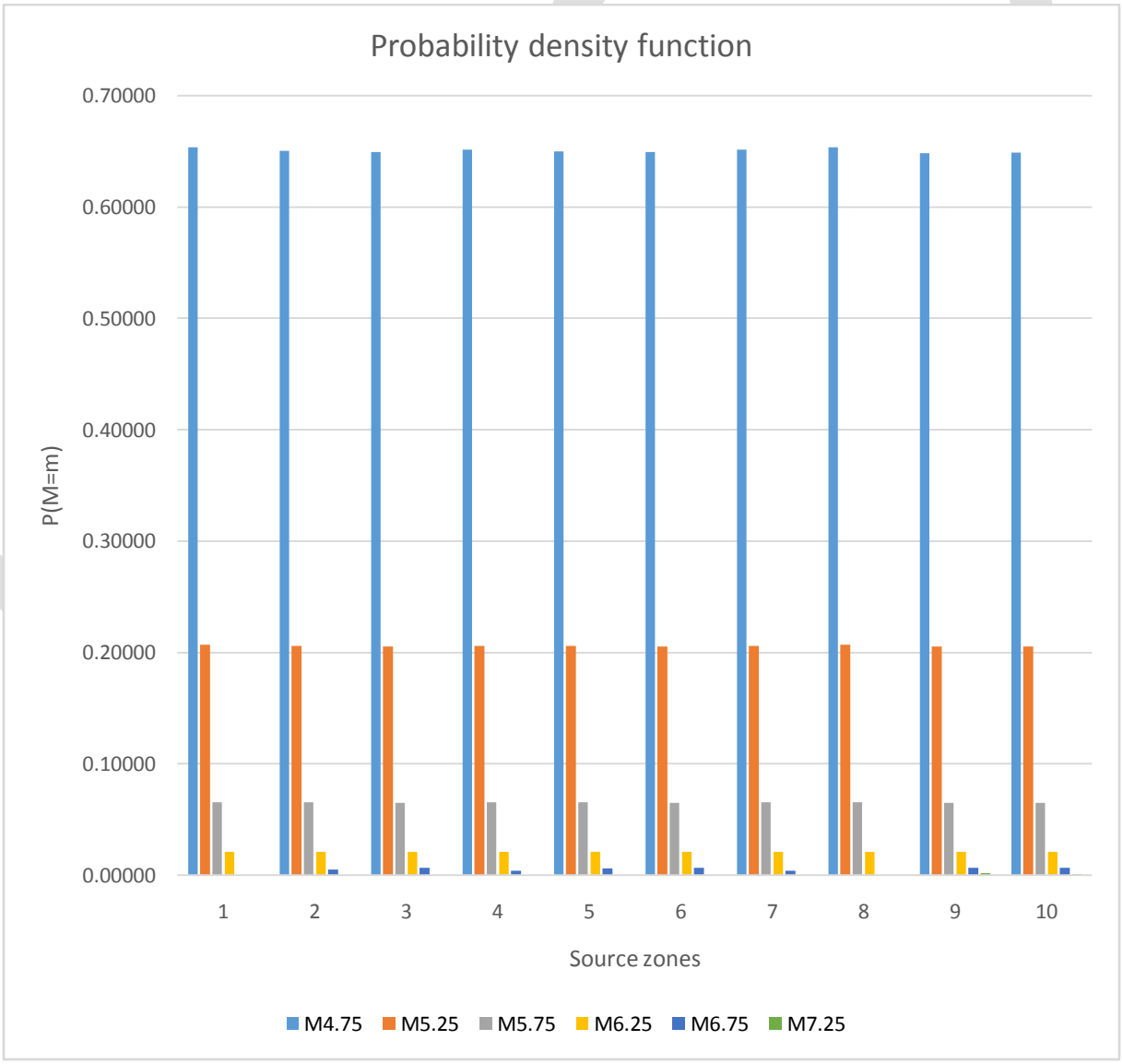

Figure 3: Probability density function of magnitude

2.3 Probability of exceeding certain Peak Ground Acceleration Level provided a fixed magnitude of earthquake

The attenuation relationship used for the Probabilistic Seismic Hazard Analysis is the one proposed by Cornell et al. (1979) for the mean of natural logarithm of Peak ground acceleration.

$$\ln PGA = 6.74 + 0.859\ M - 1.80 \ln (R+25)$$

where, PGA is in gal and $\sigma = \sigma_{\ln PGA} = 0.57$

The natural log of PGA is normally distributed, so the conditional probability of exceeding any PGA level (PGA*) is,

$$P\ (PGA>PGA^* \mid M=m, R=r) = 1 - \phi\left(\frac{\ln PGA^* - \ln PGA}{\sigma}\right)$$

where, $\phi(\ )$ is the standard normal cumulative distribution function

A total of 60 PGA levels starting from 0.01g m/s^2 (9.81 gals) to 0.6g m/s^2 (588.6 gals), i.e., ln(PGA*) have been considered in this hazard analysis.

All the source zones are point sources, so each source to site distance R is known to be r, consequently the probability of R = r is 1 and the probability of R ≠ r is 0.

$$P(R = r) = 1 \text{ and } P(R \neq r) = 0$$

2.4 Probability of exceeding certain Peak Ground Acceleration Level

Since all continuous distributions for M and R have been discretized, so the total probability of exceeding certain PGA level is given by,

$$\lambda(\text{PGA} > PGA^*) = \sum_{i=1}^{n_s} \upsilon\,(M_i > m_0) \sum_{\text{j}=1}^{n_m} \sum_{k=1}^{n_R} P(PGA > PGA^* \,|m_j, r_k) P(M_i = m_j) P(R_i = r_k)$$

where, the range of possible M_i and R_i has been discretized to n_m and n_R intervals respectively. In this analysis, $n_s = 10$ sources, $n_m = 6$ and $n_R = 1$

$$\lambda(\text{PGA} > PGA^*) = \sum_{i=1}^{10} \upsilon\,(M_i > m_0) \sum_{\text{j}=1}^{6} P(PGA > PGA^* \,|m_j, r) P(M_i = m_j)$$

The total probability of exceeding certain PGA level is tabulated in table6.

PGA* (times g)	λ(PGA>PGA*) All sources
0.01	**0.16788**
0.02	**0.10220**
0.03	**0.06760**
0.04	**0.04727**
0.05	**0.03427**
0.06	**0.02551**
0.07	**0.01940**
0.08	**0.01501**
0.09	**0.01179**
0.1	**0.00939**
0.11	**0.00757**
0.12	**0.00617**
0.13	**0.00508**
0.14	**0.00422**
0.15	**0.00354**
0.16	**0.00299**
0.17	**0.00254**
0.18	**0.00218**
0.19	**0.00187**
0.2	**0.00162**
0.21	**0.00141**
0.22	**0.00123**
0.23	**0.00108**
0.24	**0.00096**
0.25	**0.00085**
0.26	**0.00075**
0.27	**0.00067**
0.28	**0.00060**
0.29	**0.00054**
0.3	**0.00048**
0.31	**0.00043**
0.32	**0.00039**
0.33	**0.00035**
0.34	**0.00032**
0.35	**0.00029**
0.36	**0.00027**
0.37	**0.00024**
0.38	**0.00022**
0.39	**0.00020**
0.4	**0.00019**
0.41	**0.00017**
0.42	**0.00016**
0.43	**0.00014**
0.44	**0.00013**
0.45	**0.00012**
0.46	**0.00011**
0.47	**0.00011**
0.48	**0.00010**
0.49	**0.00009**
0.5	**0.00008**
0.51	**0.00008**
0.52	**0.00007**
0.53	**0.00007**
0.54	**0.00006**
0.55	**0.00006**
0.56	**0.00005**
0.57	**0.00005**
0.58	**0.00005**
0.59	**0.00004**
0.6	**0.00004**

60X1

Table6: $\lambda(PGA > PGA^*)$ for cumulative effect of all 10 sources

2.5 Poisson's model

The temporal occurrence of earthquake is described by using Poisson's model since the events of earthquake occurrence are assumed to be independent of each other in time and space. The rate of exceeding a certain PGA level atleast once in a period of 't' years is given by,

$$P(N \geq 1) = 1 - e^{-\lambda t}$$

The rate or probability of exceeding a range of PGA levels atleast once in 1 year, 50 years and 100 years is tabulated in table7.

		1-exp(-λt) *All sources & t = 1yr*	**1-exp(-λt)** *All sources & t = 50yrs*	**1-exp(-λt)** *All sources & t = 100yrs*
PGA* (times g)	0.01	**0.15454**	**0.99977**	**1.00000**
	0.02	**0.09715**	**0.99396**	**0.99996**
	0.03	**0.06537**	**0.96596**	**0.99884**
	0.04	**0.04617**	**0.90591**	**0.99115**
	0.05	**0.03369**	**0.81980**	**0.96753**
	0.06	**0.02519**	**0.72077**	**0.92203**
	0.07	**0.01921**	**0.62086**	**0.85625**
	0.08	**0.01490**	**0.52783**	**0.77705**
	0.09	**0.01172**	**0.44545**	**0.69248**
	0.1	**0.00935**	**0.37475**	**0.60906**
	0.11	**0.00754**	**0.31519**	**0.53104**
	0.12	**0.00615**	**0.26556**	**0.46060**
	0.13	**0.00507**	**0.22443**	**0.39849**
	0.14	**0.00422**	**0.19039**	**0.34454**
	0.15	**0.00353**	**0.16221**	**0.29811**
	0.16	**0.00298**	**0.13883**	**0.25838**
	0.17	**0.00254**	**0.11936**	**0.22447**
	0.18	**0.00217**	**0.10308**	**0.19554**
	0.19	**0.00187**	**0.08942**	**0.17085**
	0.2	**0.00162**	**0.07791**	**0.14974**
	0.21	**0.00141**	**0.06815**	**0.13165**
	0.22	**0.00123**	**0.05985**	**0.11611**
	0.23	**0.00108**	**0.05275**	**0.10271**
	0.24	**0.00096**	**0.04666**	**0.09114**
	0.25	**0.00085**	**0.04140**	**0.08109**
	0.26	**0.00075**	**0.03686**	**0.07236**
	0.27	**0.00067**	**0.03291**	**0.06474**
	0.28	**0.00060**	**0.02946**	**0.05806**
	0.29	**0.00054**	**0.02645**	**0.05220**
	0.3	**0.00048**	**0.02380**	**0.04704**
	0.31	**0.00043**	**0.02147**	**0.04248**
	0.32	**0.00039**	**0.01941**	**0.03845**
	0.33	**0.00035**	**0.01759**	**0.03486**
	0.34	**0.00032**	**0.01597**	**0.03168**
	0.35	**0.00029**	**0.01452**	**0.02883**
	0.36	**0.00027**	**0.01323**	**0.02628**

	0.37	**0.00024**	**0.01207**	**0.02400**
	0.38	**0.00022**	**0.01104**	**0.02196**
	0.39	**0.00020**	**0.01011**	**0.02011**
	0.4	**0.00019**	**0.00927**	**0.01845**
	0.41	**0.00017**	**0.00851**	**0.01695**
	0.42	**0.00016**	**0.00782**	**0.01559**
	0.43	**0.00014**	**0.00720**	**0.01435**
	0.44	**0.00013**	**0.00664**	**0.01324**
	0.45	**0.00012**	**0.00613**	**0.01222**
	0.46	**0.00011**	**0.00566**	**0.01129**
	0.47	**0.00010**	**0.00524**	**0.01045**
	0.48	**0.00010**	**0.00485**	**0.00967**
	0.49	**0.00009**	**0.00449**	**0.00897**
	0.5	**0.00008**	**0.00417**	**0.00832**
	0.51	**0.00008**	**0.00387**	**0.00773**
	0.52	**0.00007**	**0.00360**	**0.00718**
	0.53	**0.00007**	**0.00335**	**0.00668**
	0.54	**0.00006**	**0.00312**	**0.00622**
	0.55	**0.00006**	**0.00290**	**0.00580**
	0.56	**0.00005**	**0.00271**	**0.00541**
	0.57	**0.00005**	**0.00253**	**0.00504**
	0.58	**0.00005**	**0.00236**	**0.00471**
	0.59	**0.00004**	**0.00220**	**0.00440**
	0.6	**0.00004**	**0.00206**	**0.00412**

Table 7: Rate of exceeding given PGA level atleast once in 't' years

2.6 Seismic Hazard Curve

Seismic hazard curve gives a strong basis for analyzing the seismic hazard potential at a site. The seismic hazard curve presented in figure4 gives the probability of exceedence of certain PGA level (from 0.01g to 0.6g where g = 9.81m/s^2) at the centre of Kathmandu city in 1 year, 50 years and 100 years.

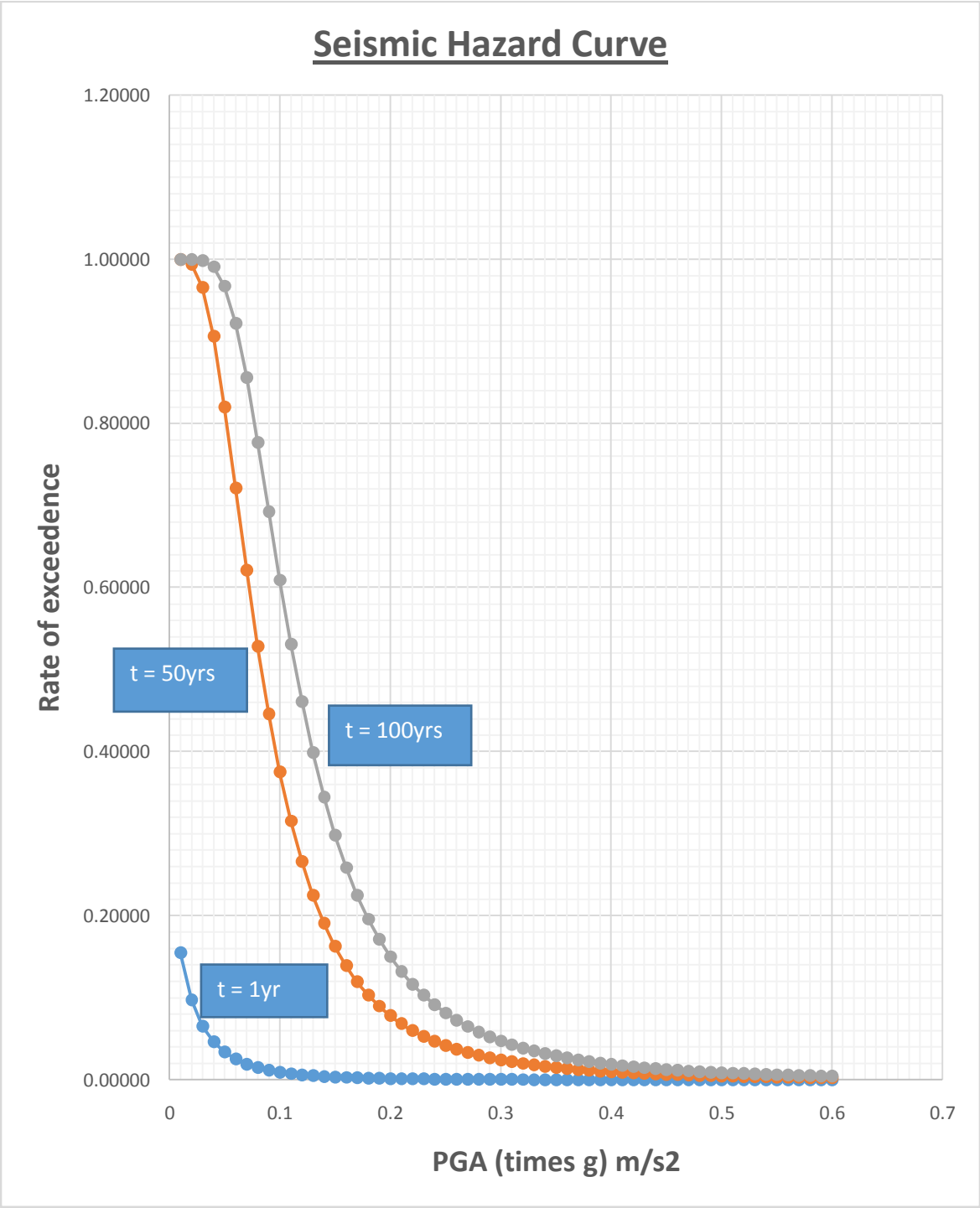

Figure 4: Seismic Hazard Curve

3. CONCLUSION

The probability density function for magnitude lends credible support to the frequent occurrence of moderate earthquakes and occasional occurrence of disastrous earthquakes. Earthquake source zone 9 (MBT-2.6) and 10 (LH-4.7) are more dangerous than the other sources as these two could induce magnitude above 7.0 which is disruptive. If a magnitude of around 7.5 occurs at Kathmandu, it can be inferred that source zones 9 and/or 10 have become dominant. Out of the two, source 9 is particularly threatening because it has greater mean annual occurrence rate of earthquake exceeding the threshold than source 10.

Similarly, the probabilistic seismic hazard analysis yields unsurprisingly high value of peak ground acceleration that is likely to occur any time in future at Kathmandu city. It is evident from the seismic hazard curve that there is a 2% rate of exceeding PGA of 0.31g in 50 years which is comparable to MMI scale of VIII and a 10% rate of exceeding PGA of 0.18g in 50 years comparable to MMI scale of VII. The PGA level of 0.5g to 0.55g is often compared with MMI scale IX (Violent earthquake) which was the case in 1934 AD (1990 BS) earthquake in Nepal. The probability of such an earthquake in Kathmandu once in a century is around 0.007 or 0.7%; so the apprehension for a "Big One" in Kathmandu is pertinent.

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Markovian approach for analysis and prediction of monthly precipitation field in the department of Sinfra (Central-west of Côte d'Ivoire)

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Abstract- Regional rainfall trends in Ivory Coast, due to climate change, show a general decrease in rainfall over the entire country. This is likely to disrupt plans streams thereby reducing the availability of surface water resources. The objective therefore assigned to this work is to analyze the precipitation field while incorporating the effect of climate change. For field analysis of precipitation, the approach follows a markovian approach, which is a stochastic approach widely used to analyze and simulate the spatio-temporal evolution of a system from transition probabilities. The study was conducted on a time series of rainfall data (1966-2000) and showed that monthly precipitation echoes are well described by a Hidden Markov Model (HMM). The arkovian approach followed in this work has helped develop a model to analyze and forecast precipitation field in the department that of Sinfra that reflects reality with accuracy about 83 %.

Keywords- remote sensing, geographic information system, hidden Markov model, water resource, precipitation field, monthly rain, forecasting

INTRODUCTION

Several models are used to analyze precipitation data which represent one of the meteorological phenomena the most difficult to analyze because of their high spatio-temporal variability [2]. However the most widely used technique is the one based on the models of Markov ([11], (12), (15), (20)). In this study for modeling the monthly field of precipitation, the model used is a Hidden Markov Model (HMM) because this model has the advantage of well formalize the transitions from one season to another and associate with each monthly contribution a hidden indicator variable which specifies the current season and explicitly describes the seasonal variation of the process generator of observations. The transition from one season to another follows a markovian process. This work will be discussed in two main areas, the first detail the main steps of the design of an unobservable Markov model. . The last axis will indicate the types of exploitation of the Hidden Markov Model through the analysis and forecasting of monthly precipitation field of the department of Sinfra.

State of art

Several stochastic models ([8], [9], (19), (26), (29)) are used to simulate the precipitation field, from observed data from stations or meteorological radars (16). These models include those that are based on the geostatistical methods (24), the disaggregation methods ([14], [25]), the disaggregation methods using Markov models (4)), the probabilistic methods ([10], [12]).

Choice of the model and justification

Prediction models of weather phenomena can be classified into two broad categories: the deterministic models and stochastic models:

- Deterministic models

It is to establish a system of equations (for most from fluid mechanics), for which the settings to the initial moment are determined by the meteorological observations. This type of model is dedicated to climate prediction. It must be reset frequently with actual observations, available, and the calculations must be able to do so in a manner close to the real time (10). The deterministic models represent general laws observed in nature by calculating and transposing into the future the average case of the observed phenomena.

- Statistical models and probabilistic

Unlike deterministic models, stochastic models account for the variability of phenomena using probability. It is here to create a system whose behaviors are of the same type as the real system. For all that, they must not coincide exactly in time, but in convergence. The emphasis is here to make a digital model whose overall characteristics are going to tend on average to those of the real system. This type of model is rather dedicated to the simulation. The one used in this case tools developed from probabilistic mathematics, to assess risks to achieve such temperature or if it rains (10).

The Hidden Markov Models are part of this last category (22), the probabilistic models. As well after having learned the actual

behavior on a set of learning that is the type of modeling that has been chosen for this study. Among the vast field of probabilistic mathematics, tools developed from Hidden Markov Models are spreading of growing way in the modeling involving the temporal phenomena. These are doubly probabilistic models who have the advantage of serve especially to deal with problems with incomplete or uncertain information (12). This type of model of Markov is used in this work to model the field of monthly precipitation, actual process, from time series of rainfall from 1966 to 2000 with a view to make forecasts.
According to the principle of the model of the Hidden Markov Model, rain is regarded as a noisy signal as well before the analysis of the field of precipitation the signal is restored which leads to the denoising data from rain. These models therefore reflect better the echoes of precipitation by integrating the effects of climate change as regards the climate data.

1 LOCATION OF THE AREA OF STUDY

The department of Sinfra, is located in the Central West of Ivory Coast and is part of the administrative region of the Marahoue. The departmental territory includes four (4) sub- prefectures: Sinfra, Bazré, Kouetinfla and Kononfla. The department of Sinfra extends over 1600 km^2 and is bounded to the North by the department of Bouaflé, on the south by the departments of Oumé and Gagnoa, on the east by the department of Yamoussoukro and to the west by the departments of Daloa and Issia . The department of Sinfra is located between longitudes 5.38°W and 6.15°W and latitudes 6.48°N and 6.82°N and is at the intersection of square degrees of Gagnoa and Daloa (figure 1):

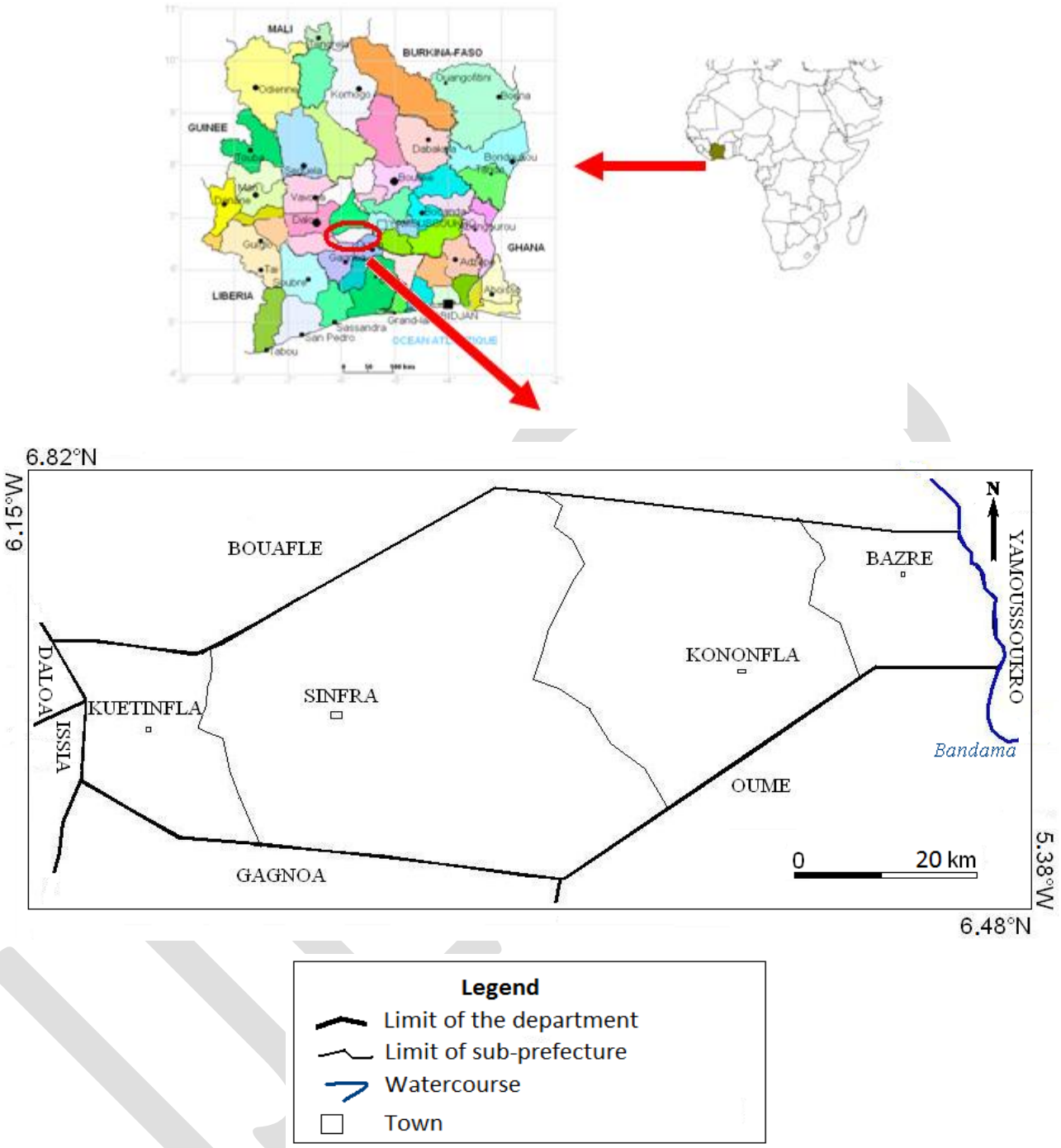

Figure 1. Location of the study area

A satellite image of the study area is given by the figure 2 below:

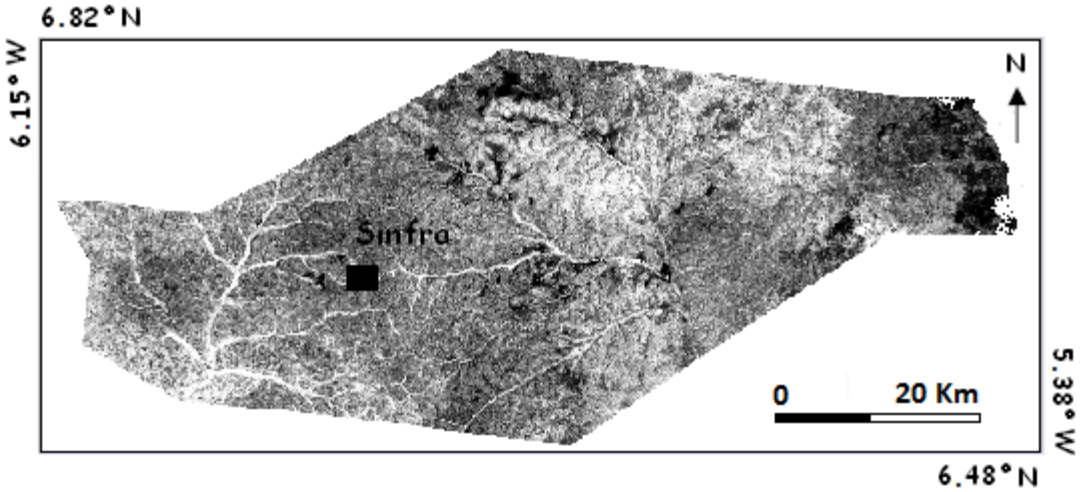

Figure 2. Image of the study area extracted from the band 4 of the satellite images Landsat ETM+ 2003

2. MATERIAL AND METHOD

To carry out this study, several types of data are necessary. The analysis of these data has necessitated the use of several software depending on the type of processing required.

2.1 MATERIAL

Several types of data were needed for the realization of this research work. The processing of Landsat TM satellite images from1986 and ETM+ from 2003 of the scene 197-055, respectively registered on 16 January and on 20 January, has enabled us to extract the study area. The topographic maps of square degrees of Daloa and Gagnoa 1/ 200 000 as scale from the Center of Cartography and Remote Sensing (CTC) have served to the extraction of the hydrographic network .Time series of daily, monthly and yearly amount of rainfall from 1966 to 2000 of the department of Sinfra and 26 rainfall stations surrounding it, from the Operating Company and Airport Development, Aeronautical and Meteorological (SODEXAM) have provided the necessary information to the analysis and prediction of the field of monthly precipitation. Given the character of multisource data, several types of treatment have been required which involves the use of several software.

The extraction of the hydrographic network has been carried out with the software Mapinfo Professional 7.5 as well as the extraction of information contained in the topographic maps. Idrisi Andes (15) was used for the processing of satellite images and the extraction of the study area. For markovian modeling the software Matlab 7 was necessary.

.

2.2 METHOD

The modeling of tmonthly precipitation field of the department of Sinfra is performed according to the principle of a Hidden Markov Model which is a doubly markovian probabilistic approach.

2.2.1 MODELING OF MONTHLY PRECIPITATION FIELD USING A HIDDEN MARKOV MODEL

- **DEFINITION**

A Hidden Markov Model is a process doubly stochastic, one component is a non-observable Markov chain. This process can be observed through another set of processes which produces a suite of observations. More simply, it is a model that describes the states of a markovian process using the transition probabilities and the probabilities of observation by states. It is a

Markovian model in which each state corresponds to an event not directly observable and thus applied to certain problems with hidden states. The case where the observation is a probabilistic function of the state is included in the principle of Markov to give a Markov model not observable but can be observed through a set of stochastic process that produces a set of observable symbols (13).

To define a hidden Markov chain, several considerations are made such as:
-All the past of the rainy phenomenon is summarized in its state at the last moment when it is known, in its previous state [20]:
-this is a discrete process, homogeneous in time, with finite state space.
Thus defined the Hidden Markov Model consists of following elements: a transition matrix A, a matrix of emission B and the initial conditions Π.

- **PRINCIPLE OF HIDDEN MARKOV MODEL (HMM)**

According to (3)), the HMM's are characterized by the following parameters:
1) The number N of states of the model.
The set S of individual states of the model: $S = \{S_1, S_2, S_3, \dots, Sn\}$ (1)
and the state at time t qt, qt Є S.
2) The number M of symbols to separate observations when the observation Ot as the physical output of the system is represented discrete outputs. The set of symbols of observations:

$$Ot = vk,\ vk \in V = \{v1,v2,v3,\ \dots vm\} \quad (2)$$

can be generated following multiple paths in a HMM
3) The distribution A of transitions probabilities of the states:

$$A = \{aij\} \quad (3)$$

Or

$$A_{IJ} = P[qt+1 = sj/qt = if],\ 1 < i,j \leq N \quad (4)$$

And

$$\sum_{j=1}^{N} aij = 1, 1 \leq i \leq N \quad (5)$$

4) The probability distribution B of observations in each state j:

$$B = \{bj(Ot)\},\ j = 1,2,3,\ \dots, N \quad (7)$$

In the case where the observations are continuous outputs, we have:

$$\int_{-\infty}^{+\infty} b_j(x)dx = 1, 1 \leq j \leq N \quad (8)$$

And in the case where the observations are as discrete outputs we have:

$$BJ\ (Ot = vk) = P[Ot = vk/qt = sj],\ 1 < j < N,\ 1 < k < M \quad (9)$$

With

$$\sum_{k=1}^{M} b_j(O_t = v_k) = 1, 1 \leq j \leq N \quad (10)$$

And in this case B is called the matrix of probabilities of symbols of observations.
5) The probability distribution of initial states. Π :

$$\Pi = \{\pi_i\} \quad (11)$$

Or

$$\pi_i = P[q_1 = s_i], 1 \leq i \leq N \quad (12)$$

$$\sum_{i=1}^{N} \pi_i = 1 \quad (13)$$

We can conclude that the complete specification of an HMM requires: (12)

- Two parameters (N and M for a discrete HMM);
- Definition of the vectors of observations;

• The distributions of probabilities A, B and Π.

We denote by:

$$\Lambda = (A,B,\Pi) \quad (14)$$

A model completely specified.

Given the appropriate values of N, M, A, B and Π, the HMM can be used as a generator of sequence of observations:

$$O = O_1O_2O_3 .... O_T \quad (15)$$

with

$$Ot = vk , vk \in V, 1 < k < M \quad (16)$$

In the case where the observation is represented as discrete outputs.

T is the number of observations in the sequence.

The design of a HMM requires several steps.

- **DIFFERENT DESIGN STEPS OF A HMM**

The design of a HMM necessarily requires the following stages:

- Evaluation of the model;

-Estimation of the sequence of hidden states;

-Learning and;

-Validation

1) STEP 1: EVALUATION OF THE MODEL

Given a sequence of observations $O = O_1O_2O_3 .... O_T$ and a model $\lambda = (A,B,\Pi)$, how can we calculate effectively the probability $P(O/\lambda)$ that the sequence of observation O is produced by λ? In practice, it is to evaluate the model in order to choose among several that which generates the better this sequence of observation O. Several techniques are used to solve this problem: the method of direct assessment, the procedure "Forward Backward" and the algorithm of Viterbi ([3], [12]).

2) STEP 2: ESTIMATION OF THE SEQUENCES OF HIDDEN STATES

This step is essentially the analysis step of the model **.**Given a sequence of observations $O = O_1O_2O_3 .... O_T$ and a model $\lambda = (A,B,\Pi)$, how can we choose a sequence of states $Q = Q_1,Q_2,Q_3 \ldots Q_T$ according to an adequate criterion? It is often interesting, given a HMM λ and a sequence of observations $O = O_1O_2O_3 .... O_T$ to determine the sequence of states $Q = Q_1,Q_2,Q_3 \ldots Q_T$ the more likely having been able to generate O. It is to determine all of the sequences of states having been able to generate O, and then to calculate their probabilities in order to determine the most probable. This method is particularly expensive in computation time because, in the general case, there are N^T possible paths. It was therefore recourse to an algorithm of dynamic programming through a lattice associated with the HMM: the algorithm of Viterbi ([3], (12), (13)).

3) STEP 3: LEARNING

How can we adjust the model $\lambda = (A, B, \Pi)$, to maximize $P(O/\lambda)$?

The objective of this step of the design of a model of the HMM is the estimation of model parameters.

The parameters of a HMM are generally not given in advance, they must be estimated from data. A long sequence of observations $O = O_1O_2O_3 .... O_T$, called learning data which is supposed to be representative of the type of data that the HMM can produce is considered at the beginning of the process. In addition the structure of the HMM (the number of states and the possible transitions between states) is fixed. The objective is to determine the parameters which make it the best account of the result of observations O or, in other words, to determine the parameters which, among the set of possible parameters, attribute to O the best probability ([3], (12), (13)).

4) VALIDATION

The validation of the model will consist of a comparison between the observed values and simulated hidden states. This process leads to the calculation of correlation coefficient R which reflects the performance of the model. This coefficient measures the ability of the model to give the sequence of hidden states knowing the sequence of observations.

The different levels of the design of the HMM are grouped in the organization chart below (fig.3):

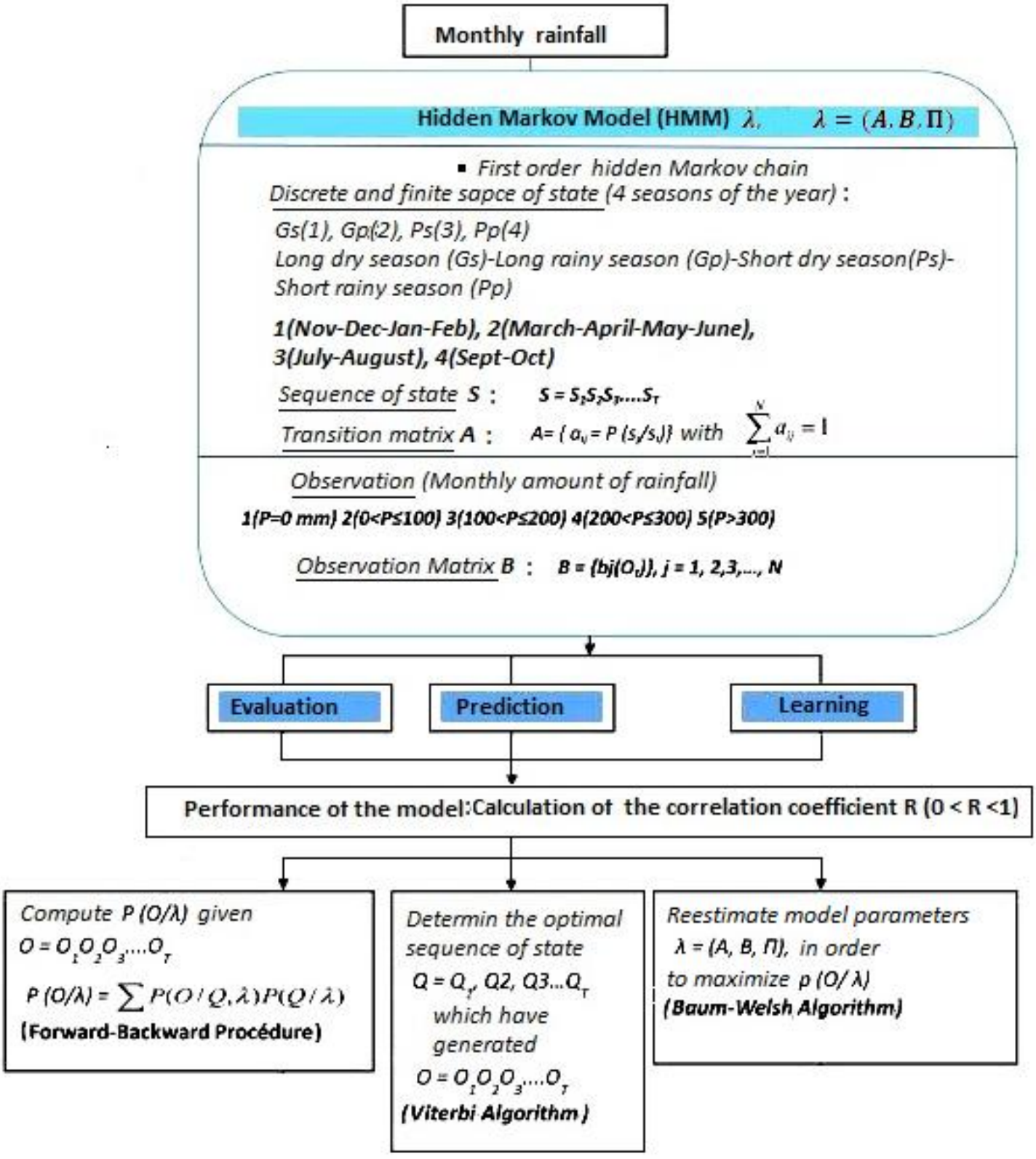

Figure 3. Flowchart of the design of a HMM for monthly precipitations [3]

After the design and validation, the use of the HMM for the analysis and forecasting of monthly field of precipitations will be done through its three modules: Learning, Evaluation and prediction.

- **EXPLOITATION OF THE MODEL**

The exploitation of the HMM is done through its three modules:

-The learning module which has been used to estimate the model parameters through the use of the algorithm of Baum-Welch),

-The analysis module which is used to determine the state in which the system was or will be for a given sequence of observations and also to make a forecast using the algorithm of Viterbi and,

-The evaluation module that allows to achieve the recognition of sequences and the estimated probabilities of occurrence of a given sequence of observations, using the principle of likelihood. This module allows to calculate the probability with which a sequence of given observation would be produced by the model.

Once constituted the model can then be used to analyze the field of precipitation in order to forecast following the flowchart below (fig.4):

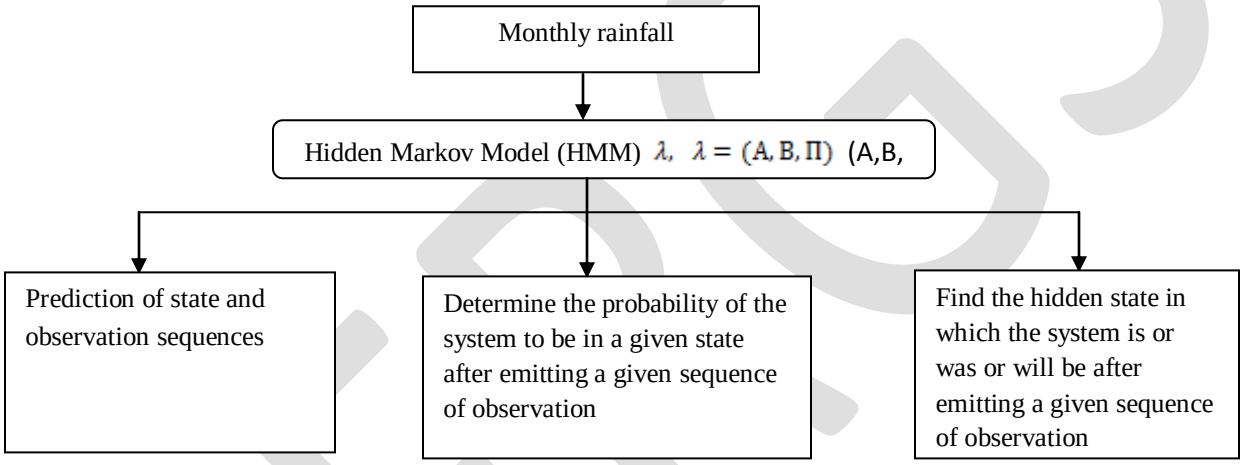

Figure 4. Diagram of operating the HMM [12]

3- RESULTS AND DISCUSSION

In this part of the work the main results are presented and discussed.

3-1 ANALYSIS OF THE PERIOD OF STUDY

The graphs of the gap in the average number of annual rainy days on figure 5 and the rainfall index on figure 6 reveal three major phases of the study period ([6], [7]):

- **First phase: the wet phase,** it is less long and extends over 6 years, from 1966 to 1971. This period is characterized by annual rainfall with a surplus.
- **Second phase: the normal phase,** it is longer and lasted 18 years, from 1971 to 1988. It is characterized by an alternation of years with low deficit and low surplus.
- **Third phase:** it lasted 11 years, from 19888 to 2000. This period is characterized by alternating dry and humid periods causing sudden and intense rain (fig. 5 and 6). Thus, an analysis of the period of study revealed a decrease in the number of rainy days during recent years, marked by a return of rainfall since 1994.

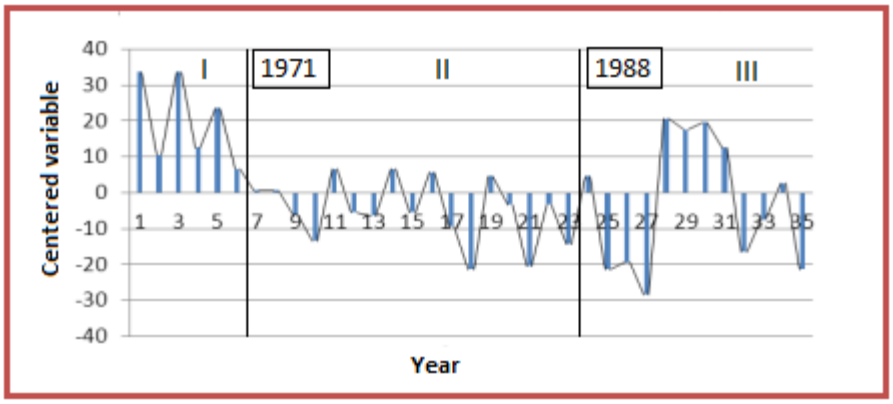

Figure 5. Graph of deviations from yearly average of the number of rainy days

Dividing the study period into three major periods I (1966 to 1971), II (1971 to 1988) and III (1988 to 2000) is confirmed by the graph of Nicholson rainfall index presented by the figure 6:

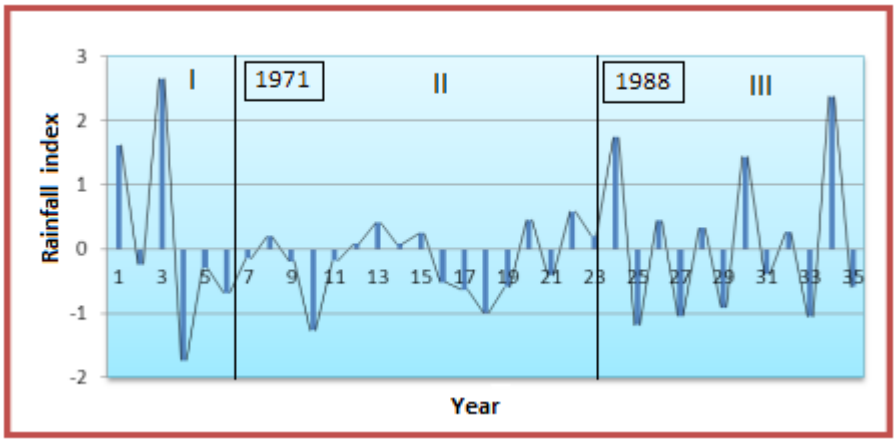

Figure 6. Nicholson Rainfall Index from 1966 to 2000

3.2 RESULT OF THE MODELING OF MONTHLY PRECIPITATION FIELD BY A HIDDEN MARKOV MODEL

The results concern the parameters and the operation of the model.

3.2.1 MODEL PARAMETERS

- **STATES OF THE SYSTEM**

The analysis of the graph of deviations from monthly average of the number of rainy days of figure 7 and the Nicholson rainfall index for monthly precipitation field of figure 8 has allowed us to identify 4 states for the HMM which has been used to model the monthly field of precipitation.

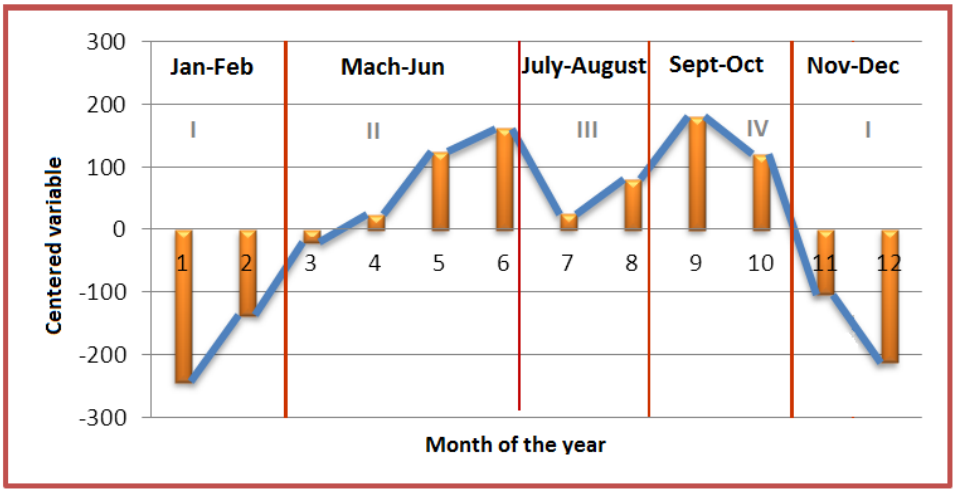

Figure 7. Graph of deviations from monthly average of the number of rainy days. in the department of Sinfra

This splitting of the year into four major periods is confirmed by the Nicholson rainfall index of monthly field of precipitation of figure 8:

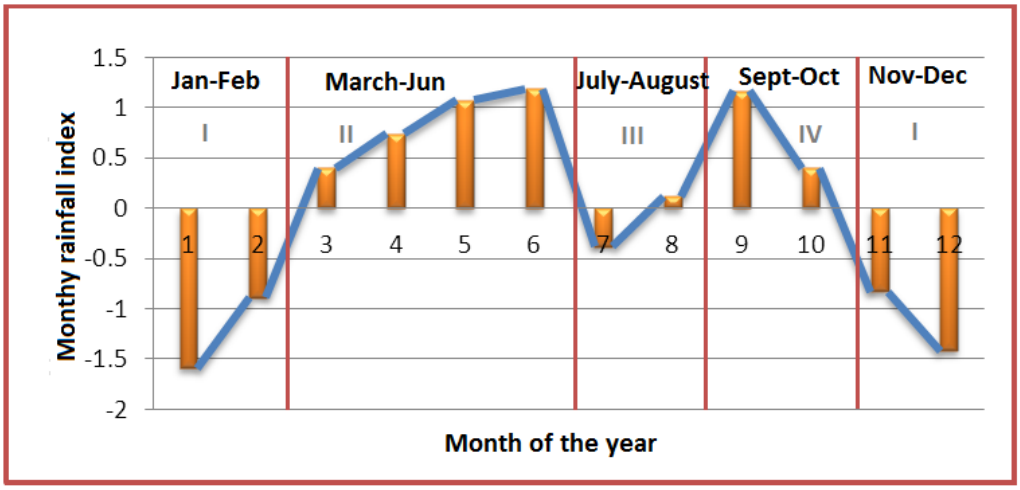

Figure 8. Monthly rainfall index from 1966 to 2000

According to these graphs (Figures 7 and 8) the set of states is constituted by the 4 seasons of the year, as follows:
- **the first State** corresponds to the long dry season, November and December of the previous year and the first 2 months of the following year, January and February Gs (1),

- **The second state** is formed by March, April, May and June indicating the long rainy season Gp (2),

-**The third state indicates** the short dry season, which include July and August Ps (3) and;

-Finally **the fourth state** which corresponds to the months of September and October Pp (4), it is the short rainy season.

- **Initialization Vector**

This vector is formed by the initial probabilities: Π= {0.25; 0.167; 0.25; 0.333} which indicate the initial conditions of the system. This vector initializes the model.

- **OBSERVATIONS**

The observations are represented by the total amount of monthly rainfall. The values below have been chosen after analysis of the distribution of amount of rainfall in the months during the entire period of study (1966-2000):

-Observation 1, it includes the null values of rainfall amount,

-Observation 2, it concerns the amount of rainfall less than 100 mm,

- **Observation 3**, it is formed by the amount of rainfall between 100 mm and 200 mm,

-**Observation 4**, it contains the amount of rainfall between 200 mm and 300 mm and,

-**Observation 5** which indicates the amount of rainfall higher than 300 mm.

3.2.2 ESTIMATION OF PARAMÈTERS (Learning)

Let us consider the following sequence of observations: 1 3 2 1 1 2 2 1 3 3 1 2 and the sequence of states following: 1 2 2 4 1 2 3 4 3 2 3 2. The use of the algorithm of Baum-Welch gives us an estimation of the transition matrix A_f and the matrix of observation B_f after 100 iterations for a tolerance of 10^{-4} (13).

- **TRANSITION MATRIX**

This matrix defines the different transitions of monthly rainy phenomenon from 1966 to 2000. It is the matrix of probability of transition A(ij), it contains the probability of transition of each state to another and also contains the residence time of the process in each state (12). A (ij) is a square matrix NxN, A=P(ij) :

$$Af=\begin{bmatrix} 0,25 & 0,333 & 0,167 & 0,25 \\ 0,25 & 0,25 & 0,5 & 0 \\ 0,222 & 0,555 & 0,222 & 0 \\ 0 & 0,333 & 0,333 & 0,333 \end{bmatrix}$$

- **EMISSION MATRIX**

It includes the probabilities of emission of observations from each state (12). The matrix of emission B is an NxM matrix:

$$Bf=\begin{bmatrix} 0,25 & 0,75 & 0 & 0 & 0 \\ 0 & 0,222 & 0,222 & 0,444 & 0 \\ 0 & 0,2 & 0,2 & 0,6 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{bmatrix}$$

The markovian model designed need a validation before any use.

3.2.2 VALIDATION OF THE MODEL

It is to measure performance and the fidelity of the model. After the learning phase, the performance of the model is evaluated through a rigorous approach which is to use the model to generate the path corresponding to a given observation chosen randomly using the algorithm of Viterbi. Then, the actual path corresponding to this same observation is determined using the rules previously defined (13).

The Sequence of states observed (actual): 1 2 2 4 1 2 3 4 3 2 3 2 and the calculated Sequence: 2 3 2 4 1 2 3 4 3 2 3 2

The two results are compared in order to calculate the error committed by the model.

For the model designed in this work, the error rate calculated is 17 %. Thus the calculation of the correlation coefficient R gives a value of 83 per cent R =0.83. The model reflects the reality at 83% as shown in the figure 9:

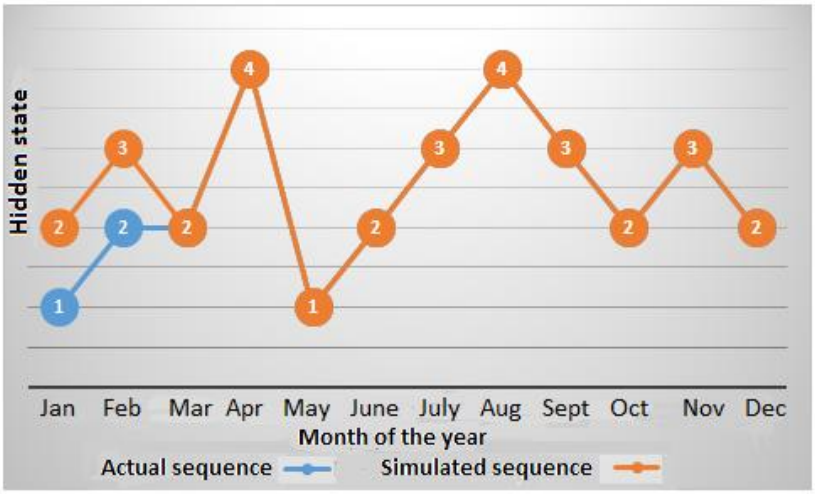

Figure 9. Comparisons of sequences of real hidden and simulated states by the model

3.2.3 EXPLOITATION OF THE MODEL

The model will be exploited through its three modules such as learning, assessment and prediction.

- **ANALYSIS OF THE PERIOD OF STUDY BY THE NON-OBSERVABLE MARKOV MODEL AND PREDICTION OF PRECIPITATION FIELD**

The parameters obtained after the learning phase of the model can be used to analyze the monthly field of precipitation.

1) Learning: The values of the probabilities of transition from one state of the system to another provide several information. In this study a long period has a duration of four months and a short period, a duration of two months.

The null values of probability of transitions A_{41}, A_{24}, A_{34} of the transition matrix A(ij) indicate that in a year and in the study area, it is very unlikely:

- To move from a short period of rain, approximately two months to a long dry period, approximately four months,

- That a short period of rain follows a long period of rain,

- That a short dry period follows a long period of rain.

It is rather likely, according to the probability values for transition a_{23} and a_{32} respectively 0.5 and 0.52:

-Only a short dry period follows a long period of rain, and

-That a long period of rain succeeds a short dry period.

The null values of probability of the matrix of emission B(ij) reveal the following information , in the same year and always in the area studied:

- It is more likely during the long dry season to have total amount of monthly rainfall less than or equal to 100 mm, according to the value of probability b_{12} equal to 0.75 and very unlikely, that the total amount of monthly rainfall may be higher than 100 mm according to the null values of probability b_{13}, b_{14}, b_{15},
- During the long period of rain the total amount of monthly rainfall does not exceed 300 mm, according to the values of probability b_{22}, b_{23} and b_{24},
- From September to October, it is possible to have the total amount of monthly rainfall between 200 mm and 300 mm, according to the probability b_{34} equal to 0.6

- During the short rainy period it is certain that the total amount of monthly rainfall is between 100 mm and 200 mm, information given by the value b_{43} equal to 1.

- **DETERMINATION OF THE LENGTH OR DRY AND WET SEQUENCES**

The length of dry and humid sequences is obtained from the following formula of the mathematical Expectancy of dry and wet durations [28]:

$$E(X_n) = \frac{1}{(1-a_{ii})}$$

Using the probabilities a_{ii} of the transition matrix A_{IJ}.

$$E(X_{11}) = \frac{1}{(1-a_{11})} = 1.33$$

It is not certain to have two extended dry consecutive period.

$$E(X_{22}) = \frac{1}{(1-a_{22})} = 1.33$$

It is not sure to have two long consecutive periods of rain in the department of Sinfra.

$$E(X_{33}) = \frac{1}{(1-a_{33})} = 1.28$$

A short dry period cannot be followed by another.

$$E(X_{44}) = \frac{1}{(1-a_{44})} = 1.5$$

By contrast, it is possible that two short periods of rain succeed.

The analysis of the field of monthly precipitation through this first phase of the operation of the model shows a general decline of the amount of rainfall and the rainy events. The disturbance of the regimes of watercourses and rainfall regimes, caused by climate variability including the aggressiveness of the fact of climate change causes the occurrence of rain more and more sudden and intense. It is also clear from this first phase that the length of the dry sequence can reach four months and that of the humid sequence cannot also not exceed four months.

2) EVALUATION: for this step, it will be to say if a given sequence of observations can be generated by the model designed in other term this is to calculate the probability with which the model designed can produce the event considered. The evaluation showed that the model was able to recognize the sequences that it has generated. The model is also capable to give the probability with which an event can occur.

3) FORECASTS: This phase corresponds to the operation of the predictive power of the HMM. It is to plan for the event the more likely at a future date, through the analysis function of the model. For example, for the year 2015 for the following sequence of observations: 1 3 2 1 1 2 2 1 3 3 1 2, through the algorithm of Viterbi, the sequence of states in which the system will be is: 2 3 2 4 1 2 3 4 3 2 3 2 which constitute the event the more likely for this sequence of observation (9) as shown in the figure 10:

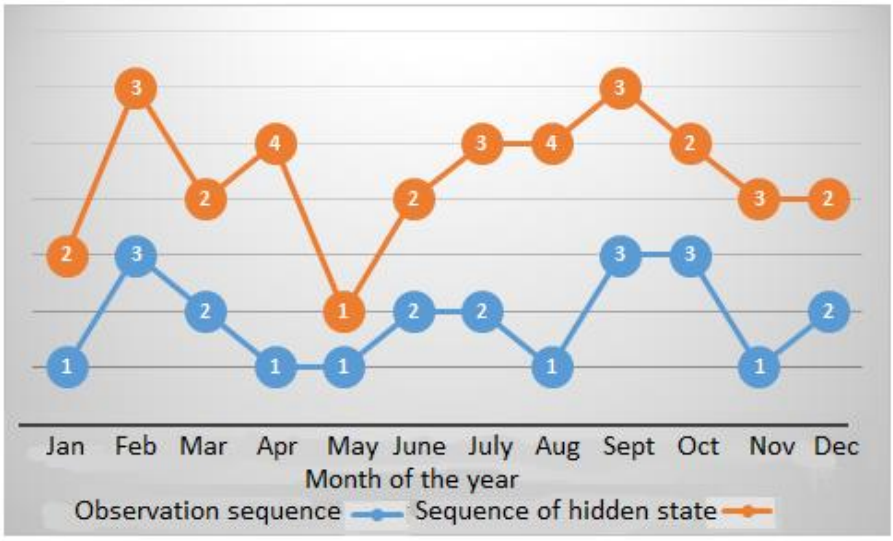

Figure 10. Forecasting of the sequence of hidden states for a sequence of observation in 2015

The sequence of observation can also be predicted that is to say, the total quantities of rainfall for each coming month of the years.

The stochastic model of precipitation thus formed is capable to generate several synthetic series of precipitation having the same statistical and physical properties as the historical data.

3.3 DISCUSSION

The work of [1] and [20] have served to highlight the dynamic nature of the rainfall across two states (rainy, dry). In addition to the dynamic aspect, the work of (20) put the emphasis on the asymptotic behavior of precipitation by increasing the memory effect of the observable Markov models. The work of [12] analyze the time in a day by using the observable Markov models and also show that the seasons of the year are correctly described by a Hidden Markov Model. The relationship between the different seasons of the year and the time in a day was modeled using a HMM with a good precision (12).

In our work, the relationship between the different seasons of the year and the amount of rainfall highlights 4 states (the seasons of the year) and 5 observations (the classes of amount of monthly rainfall in a month). The high number of observation, 5 against 3 as in [12] gives to our analysis an aspect more detailed. Our model has the advantage of providing the total amount of monthly rainfall while specifying the corresponding period of the year. The model can give the amount of rainfall of the months of the coming years. It can therefore be used for the reconstitution of rainfall data base. The use of this type of model in hydrology is advantageous because it proceeded to denoising data before any modeling while integrating the effect of climate variability, thereby improving the results.

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CONCLUSION

The echoes of precipitation are well described by the Hidden Markov Model, which are stochastic models doubly stochastic. The structure of the monthly field of precipitation is well described by a HMM with 4 states and 5 observations that models the structures of the dry and wet sequences of the monthly field of precipitation with an accuracy of 83 %. Thus the modeling of actual phenomena by a HMM is effective and reflects the reality .This study shows an alternating of of wet and dry sequence longer which characterize a general trend in the decline in rainfall in the department of Sinfra. This analysis also reveals a tendency to rupture leading to sudden and intense rain.

The Markov models allow, in effect, to better assess the influence of the past on the behavior of the rainy phenomenon and to give a better description of the precipitation. The influence of the past on the behavior of the rainy phenomenon is taken into account by this type of

template to give a better description of precipitation The Hidden Markov Models have the advantage of taking into account the effect of memory and are very used to simulate the time evolution of a system from the transition probabilities.

The rainfall is highly variable in time and space, the use of non-homogeneous Markov model in which the transition probabilities vary in time, would improve the results. Rainfall data collected by a meteorological radar can be used in order to have a continuous coverage and follow the fields of precipitation of fine spatio-temporal scales.

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Regularized Constant Modulus Algorithm: An improvement on Convergence rate and Steady-State Statistics for blind adaptive eqalization

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Abstract— This paper addresses the problems of poor convergence and high value of mean square error, embedded with various blind adaptive equalization techniques in mobile communication and proposes an improved design providing enhancement in performance and ease of operation. The effectiveness of proposed approach is evaluated against different algorithms and simulations prove that design facilitate in reducing convergence time and low MSE. Proposed algorithm also ensures that equalizer does not converge to any wrong solutions under time varying and noisy conditions.

Keywords— CMA, MMA, LMS, RLS, PSK, QAM, MSE

INTRODUCTION

Digital filters of fixed frequency response are widely used in mobile communication to attenuate noise and other unwanted signals. However filtering is done by adaptive digital filters in situation for which noise containing frequencies erratically place over the signal bandwidth. The coefficients of adaptive filter are updated at each transaction in assistance of a training signal with the target of minimizing the MSE between reference sequence and the solution of adaptive filter thus converges the filter to a global minimum. Adaptive algorithms like RLS, LMS, etc then updates the equalizer filter coefficients accordingly. But the power expense and utilization of bandwidth by this overhead sequence need to be avoided in ever growing mobile communication by means of substitution by smart equalizers, which use the statistical properties of signal to find the instantaneous error. Performance function of these equalizers is defined by a weight vector whose value optimizing process reduces the value of cost function and thus proceeds towards advancement in adaptive equalization process. Problem lies in choosing perfect values for the weight vector and preventing equalizer from wrong solutions.

Channel of propagation contains non-deterministic phenomena which causes distortion and other non-linear effects which should be taken into consideration to validate the effectiveness of proposed algorithm. The constant modulus algorithm (CMA), a well-known technique broadly employed in blind equalization whose standing origins from easiness in designing processes as well as robustness in operation. However, it undergoes slow convergence and possesses high probability for improper solutions, if not treated properly, as compared with other blind techniques. The error surface examination for CMA reveals that most designs are based on merged models of channel and equalizer, thus treating solution set in global space. To develop independent operational algorithm, as needed in many scenarios, error surface in terms of error equation needs to be reviewed for tractable analysis of channel. Requirement of an independent nature CMA equalizer arises by considering the fact that computations becomes restricted to complexity and decreases in efficiency with channel-equalizer space. This causes convergence ambiguities in transient behavior and optimization for parameters effecting convergence and MSE which should be addressed for systems demanding high speed data rates promising integrity of information as VDSL and Fiber Curb networks. Focusing the transient and level of error in convergence of the integral part of communication systems, this paper explains the related issues in next section. Discussion on generalizing CMA is organized in section IV with description of proposed approach is presented in section V. Next section expresses the effectiveness of proposed algorithm and proves the speedy convergence and least MSE among other members of CMA family. can put the page in this format as it is and do not change any of this properties.

PROBLEM STATEMENT

CMA and MMA both can lead to a set of wrong solutions at convergence acting as a phase splitter filter used for high data rates. Embedding phase splitting function in coefficients reduces the need of Hilbert Transform or a cross-coupled structure. But this may guide the set of filters. There is no need of carrier phase recovery according to the Godard algorithm eliminates the carrier phase recovery need and thus applicable to fading conditions such as dispersive channels, resulting in considerable equalization results

including an open up eye pattern, indicating very low ISI and phase distortion. Constant Modulus Algorithm belongs to the Godard's extensive work where whose primary reduction in algorithm produces a minimum optimal value, a non-convex cost function stated as

$$J(n) = E\left[\left(|y(n)|^p - R_p\right)^2\right] \quad \text{with} \quad R_p = E\left[|u(n)|^{2p}\right] / E\left[|u(n)|^p\right] \tag{1}$$

With p being a positive integer and represents dispersion constant. It has a major negative aspect that it undergoes slow convergence as compared to training base algorithms. Moreover, cost function of CMA exhibits a non-linear behavior making the implementation complex. CMA with simple assumptions leads to wrong solutions and way out is presented in [3],[4] and [5] with LMS due to less sensitive nature of LMS towards eigenvalue spread in contrast to quadratic error surface of CMA. But LMS filters exhibits slow convergence as the contained information in information signal is insufficient to properly construct I/O mapping and additional noise makes it more worst. Solution of LMS always leads to global minimum convergence as it's a training based algorithm. LMS integrated CMA, any sequence having constant phase offset will be acknowledges and hence cost surface of CMA results in multiple minima. Second problem to be highlight is the amount of MSE generated during the blind adaptive process which is not acceptable for reliable communication. Increase in update taps minimized the MSE but at the cost of increase in convergence time. So this trade-off between transient behavior (convergence rate) and steady state response (amount of MSE) should be treated in an optimized manner and this approach is presented in this paper.

MATHEMATICAL FRAMEWORK OF CMA & MMA

The work of Sato provides the basic idea for blind equalization whose algorithm is BUSSGANG type in which cost function reduces to a minimum optimized solution as mathematically given in the eq.3 in the form of difference between non-memory non-linear estimate of transmitted data and the output of transversal filter as

$$J(n) = E[\left(\alpha\, sgn(y(n)) - y(n)\right)^2]$$

$$\alpha = E[(\alpha\, sgn(y(n))]^2 \Big/ E[(\alpha\, sgn(y(n))] \tag{2}$$

Where the *sgn* represents signum function which roots non-linearity and constant α sets the gain of equalizer. The Tap weight vector *w(n)* for tap input vector *u(n)* is updated with step size *μ* in accord with the stochastic gradient algorithm generally expressed as

$$w(n+1) = w(n) + \mu u(n) e^*(n) \tag{3}$$

Expression for error signal is given by

$$e(n) = y(n)|y(n)|^{p-2}(R_p - |y(n)|^p) \tag{4}$$

The second case of Godard algorithm by taking p=2 reveals that the cost function of Eq.1 minimizes the value to mathematical framework of Constant Modulus Algorithm CMA [2].

$$J(n) = E\left[\left(|y(n)|^2 - R_2\right)^2\right]_{\text{Where}} \; R_p = E\left[|u(n)|^4\right] / E\left[|u(n)|^2\right] \tag{5}$$

The above term provides initial convergence. In terms of carrier phase offset, CMA has distinction over other Bussgang algorithms due to the property of using the cost function *J(n)* for its solution with lesser MSE. The DCT for general training sequence {d(k),. . . . ,d(k-N+1)} is given by

$$d_{DCT,n}(k) = \sum c_{kn} d(k-n) \tag{6}$$

Where c_{kn} are the DCT coefficients. Signed-Error CMA proposes that computations for multiplication process during the update process of tap weight vector can be minimized with replacement of equalizer tap equation coefficients with differential sign, positive or negative depending on the nature of result of summation. The real-valued solution is given by the following equation

$$w(n+1) = w(n) + \mu r(n)\,\mathrm{sgn}(y_n(\gamma - y_n^2)) \tag{7}$$

Signed error methods generally result in rough convergence with high steady state MSE which is encountered by Dithered Sign-Error CMA in which SE-CMA was implemented in a short manner with only few features as design was based on thoughtful merging of standard CMA generated noise [8]. The DSE-CMA algorithm is given by the update equation

$$w(n+1) = w(n) + \mu r(n)\alpha\,\mathrm{sgn}(y_n(\gamma - y_n^2) + \alpha d_n) \tag{8}$$

Where d_n is a uniformly distributed i.i.d, independently indentical distribution, over the interval of (-1, 1]. Multi Modulus Algorithm MMA defines cost function as complex function of real and imaginary components of vector output of equalizer.

$$J_{MMA} = E\{[y_R^2 - R_{2,R}]^2\} + E\{[y_I^2 - R_{2,I}]^2\} \tag{9}$$

Real and imaginary parts consider both modulus and phase of the output to achieve carrier phase recovery. The update for tap-weight vector for MMA is given by

$$w(n+1) = w(n) - \mu.e^*(n)u(n) \tag{10}$$

Where *e(n)* also composes real and parts in MMA.

GENERALIZATION OF CMA

Regularization of a divergent expression drives the expressions to a finite and meaningful value with the aid of a regulating factor. Regularization causes increase in complexity but prevents the process from overfitting and the result is always obtained in the direction of regularization factor. The problems embedded with blind adaptation techniques are mainly their poor convergence property when judged against other conventional techniques deployed with abet of training sequences. Generally speaking, a gradient algorithm integrated in a blind adaptation schemes will give a better solution, an idea that got the shape of well-known Constant Modulus Algorithm (CMA) utilizing the information signal unique property of constant modularity for adapting process [7].

For the schemes using CMA, there exists a trivial solution of phase shift that each minima will experience. Suppose, for an equalizer of length L, constant modulus cost function will have L^2 number of minima, each having a unique phase shift and representing a valid solution. Taking practical conditions in to discussion, all L^2 solutions could not be accepted equally. For M-array PSK signal of differentially encoded source sequence, only M different solutions or M number of sequences are considerable for which solution converges to global minima. Other solutions represent local minima even though all minima have same cost. The method of initialization the equalizer is an important factor to obtain the information of minimum point on which algorithm will force the equalizer to converge to either local or global minimum. So as a depended of initialization, CMA based equalizers may converge to a local or a global minimum with the problem of slow convergence as mentioned earlier. Another important consideration here is that adaptive algorithms are also very much dependent on their cost function for their convergence characteristics and core task during the adaptation process is minimization of cost function. Derivation of expression for cost function includes estimation of error signal between the filter output and desired signal and this derivation can be altered, to achieve any desired response by either changing the whole function or as an alternative, varying the error equation. Varying of error equation involves understanding of basics involved in defining the cost function which is normally defined as MS of error signal but this holds for conditions where noise distribution is Gaussian. To bring the systems in to account having no-Gaussian interfering noise distribution, a Non-MS Error criterion would be advantageous. So in process of varying the definition of cost function, start with changing the error equation and analyzing each obtained expression for convergence and steady state response with some obviously provide improved convergence and other offers elimination of probability to local minima convergence. Few points must be consider to ensure global minima convergence during the adaptation process related to initialization which is discussed below.

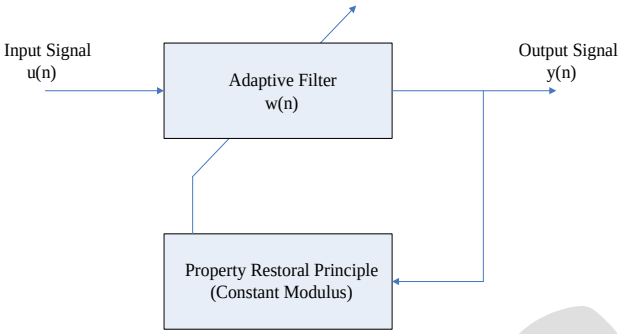

Figure 1. Blind Adaptive Filter Property Restoral Principle

Since, calculated output signal for filter is given as

$$y(n) = w^H(n)u(n) \tag{11}$$

Eq.4 and above equation both depicts explains clearly that basic adaptive filter structure and proposed method have same update rule for coefficients and generation of output samples. Only difference lies in the estimation of the error signal. The evaluation and computation of error signal is primary in the filter coefficient adaptation process from an initially random value to an optimal value. Error equation for proposed design for of constant modulus algorithm is given as

$$e(n) = y(n)(R_p - |y(n)|^2) \tag{12}$$

Putting both error equations side by side with same amount of error we have

$$d(n) = y(n)(R_2 - |y(n)|^2) + y(n) \tag{13}$$

Where *d(n)* represents the generated reference signal for the proposed case. In the contrast of the Eq.12, the proposed equalizer structure is shown in fig.2.

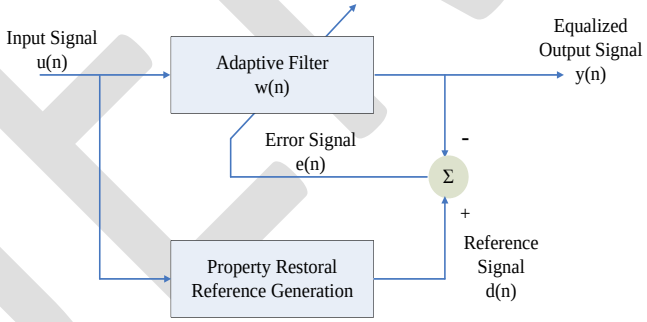

Figure 2. Proposed Equalizer Structure

It can be observed that performance for both techniques is same since reference signal is generated to produce and equivalent error signal as from a blind adaptive process. Another enhancement of selecting this approach includes generation of reference signal at the receiving side instead of transmitter; hence overheads in the transmission are avoided providing increased capacity for bandwidth and gateway to the attached losses with transmission of reference signal. Regularization helped the process of receiver training to cope up the distortion and non-Gaussian noise by comparatively analyzing both generated and known sequence. Second proposed structure comprise multiplexing of Regularized CMA and MMA algorithm in which former algorithm brings the cost to an initial threshold value, then MMA decomposes the constellation into regions and modulus is calculated for each. This approach further reduces the cost with the help of moduli of regions. MMA makes the 2nd adjustment through second coefficient generation.

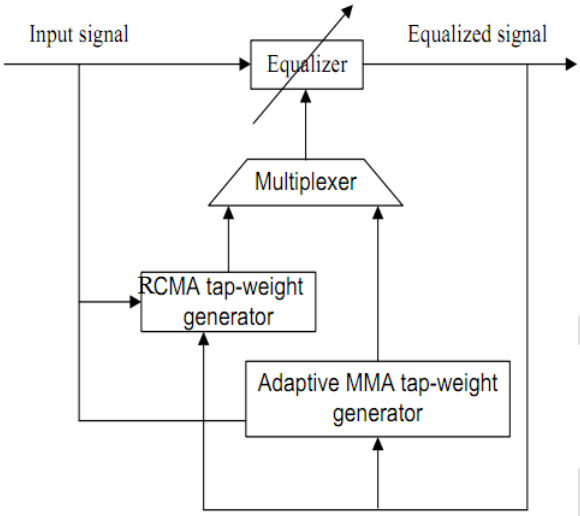

Figure 3. Combining Regularized Constant Modulus Algorithm and Multi Modulus Algorithm

PROPOSED WEIGHT UPDATE TECHNIQUE

Cost function to be minimized in a Recursive least-Square algorithm is termed as $\varepsilon(n)$, where n is the variable length of observable data, given as

$$\varepsilon(n) = \sum_{i=1}^{n} \beta(n,i)\left|e(i)\right| \tag{14}$$

The $\beta(n,i)$ represents weighting factor and is given by

$$\beta(n,i) = \lambda^{n-i}, \quad i = 1,2,3,\ldots,n.$$

With λ<1 a positive constant, which makes the weighting factor $\beta(n,i)$ zero with the passage of time and due to this property it is termed as "forgotten factor". Regularization is explained as under. To solve the issues caused by LMS, the cost function is given as:

$$\varepsilon(n) = \sum_{i=1}^{n} \lambda^{n-i}\left|e(i)\right|^2 + \delta\lambda^n \left\|w(n)\right\|^2 \tag{15}$$

The sum of weighted errors squares is given by:

$$\sum_{i=1}^{n} \lambda^{n-i}\left|e(i)\right| = \sum_{i=1}^{n} \lambda^{n-i}\left|d(i) - w^H(n)u(i)\right|^2 \tag{16}$$

The regularization term is given by

$$\delta\lambda^n \left\|w(n)\right\|^2 = \delta\lambda^n w^H(n)w(n) \tag{17}$$

δ denotes the regularization parameter. Now normal equation are formulated again making the time average N-by-N correlation matrix of the tap input vector $u(i)$ as

$$\Phi(n) = \sum_{i=1}^{n} \lambda^{n-i}u(i)u^H(i) + \delta\lambda^n I \tag{18}$$

Moreover cross-correlation N-by-1 matrix between the tap input and the desired response of transversal filter is given by

$$z(n) = \sum_{i=1}^{n} \lambda^{n-i} u(i) d^*(i) \tag{19}$$

The expression for relation among correlation matrix *Φ(n)* and tap weight vector $\hat{w}(n)$ along with cross correlation vector for recursive least square is given by:

$$\Phi(n)\hat{w}(n) = z(n) \tag{20}$$

Computations of *Φ(n)* and *z(n)* are derived by taking *i=n* which make the corresponding term to be separate from the equation, now it can be written as

$$\Phi(n) = \lambda \left[\sum_{i=1}^{n-1} \lambda^{n-1-i} u(i) u^H(i) + \delta \lambda^n I \right] + u(n) u^H(n)$$

$$= \lambda \Phi(n-1) + u(n) u^H(n) \tag{21}$$

Similarly

$$z(n) = \lambda z(n-1) + u(n) d^*(n) \tag{22}$$

Using matrix inversion lemma

$$\Phi^{-1}(n) = \lambda^{-1}\Phi^{-1}(n-1) - \frac{\lambda^{-2}\Phi^{-1}(n-1)u(n)u^H(n)\Phi^{-1}(n-1)}{1+\lambda^{-1}u^H(n)\Phi^{-1}(n-1)u(n)} \tag{23}$$

For convenience let $P(n) = \Phi^{-1}(n)$, thus Eq.23 becomes

$$k(n) = \frac{\lambda^{-1}P(n-1)u(n)}{1+\lambda^{-1}u^H P(n-1)u(n)} \tag{24}$$

Substituting *P(n)* and *k(n)* in the above equation

$$P(n) = \lambda^{-1}P(n-1) - \lambda^{-1}k(n)u^H(n)P(n-1)$$

Eq.24 implies that

$$k(n) = \lambda^{-1}P(n-1)u(n) - \lambda^{-1}k(n)u^H(n)P(n-1)u(n)$$

$$= \left\lfloor \lambda^{-1}P(n-1) - \lambda^{-1}k(n)u^H(n)P(n-1) \right\rfloor u(n) \tag{25}$$

$$k(n) = P(n)u(n) = \Phi^{-1}(n)u(n) \tag{26}$$

Time updating of tap weight vector

$$\hat{w}(n) = \Phi^{-1}(n)z(n) = P(n)z(n)$$

$$= \lambda P(n)z(n-1) + P(n)u(n)d^*(n) \tag{27}$$

Putting values of *P(n)* only in first term of Eq.5 gives desired recursive updating tap weight vector $\hat{w}(n)$ as

$$\begin{aligned}\hat{w}(n) &= P(n-1)z(n-1) - k(n)u^H(n)P(n-1)z(n-1) \\ &\quad + P(n)u(n)d^*(n) \\ &= \Phi^{-1}(n-1)z(n-1) - k(n)u^H(n)\Phi^{-1}(n-1)z(n-1) \\ &\quad + P(n)u(n)d^*(n) \\ &= \hat{w}(n-1) - k(n)u^H(n)\hat{w}(n-1) + P(n)u(n)d^*(n) \\ &= \hat{w}(n-1) - k(n)\left[d^*(n) - u^H(n)\hat{w}(n-1)\right] \\ &= \hat{w}(n-1) + k(n)\xi^*(n) \end{aligned} \quad (28)$$

$$\begin{aligned}\xi(n) &= d(n-1) - u^T(n)\hat{w}^*(n-1) \\ &= d(n) - \hat{w}^H(n-1)u(n)\end{aligned} \quad (29)$$

Where $\xi(n)$ is the priory estimation error. Thus we have

$$\begin{aligned}\gamma(n) &= P(n-1)u(n) \\ k(n) &= \frac{\gamma(n)}{\lambda + u^H(n)\gamma(n)}\end{aligned} \quad (30)$$

$$P(n) = \lambda^{-1}P(n-1) - \lambda^{-1}k(n)u^H(n)P(n-1)$$

So $\Phi^{-1}(n)$ update equation becomes

$$\begin{aligned}\Phi^{-1}(n) &= \lambda^{-1}\Phi^{-1}(n-1) \\ &\quad -\lambda^{-1}k(n)u^H(n)\Phi^{-1}(n-1)\end{aligned} \quad (31)$$

SIMULATION RESULTS

Results for the quantitative analysis for convergence rate and steady state MSE are presented in this section. The proposed methodology was simulated employing BPSK and 16-QAM modulated signals with parameter values of SNR equal to 25dB and 0.05 of step size. The generated reference signal through blind estimation is also test out to verify its credibility against basic requirements of any reference signal used in the process of equalization. Starting from the correlation between reference signal generated and the source symbols which are transmitted from the source, Fig.4 shows the correlation plot demonstrating clearly the strong relationship of correlation between the two. Hence initial condition is satisfied for the generated sequence to be used as a reference signal.

Generated reference signal must have to satisfy the basic requirements of a standard reference sequence which include correlation with source symbols, zero correlation with channel noise and an above zero DCT plot. Thus, the reference signal has been formed as to hold a constant modulus resulting in a constant modulus output signal. Subsequent requirement for the reference signal is to have zero correlaration with respect to noise. Fig. 4 shows that the channel symbols, which were made to be non-i.i.d, are strongly correlated at zero delay. Another point to be consider is if DCT value for generated sequence becomes zero for a bandgap of size M starting from m_1 to frequency m_2, this spectral gap M ($M = m_1 - m_2$) will freeze all filter weights occurring at these spectral position and finally the updating process of coefficients will discontinue. For this reason, the original tap value is forced to be kept at instances where spectrum value decreases to zero.

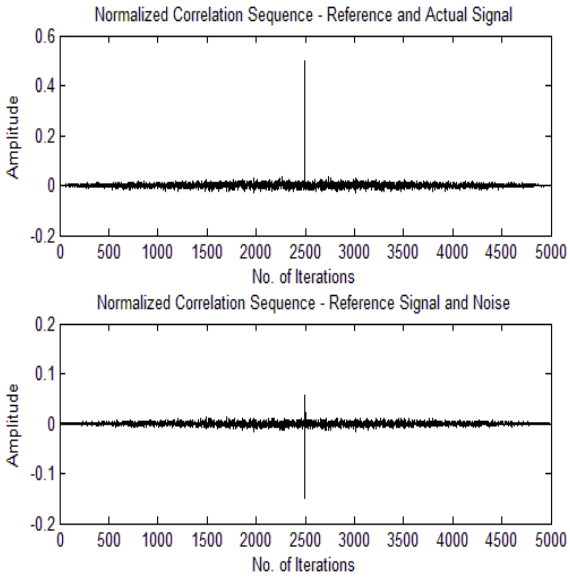

Figure 4.Normalized Correlation Sequence between the Generated Reference Signal and the Noise Sequence

Correlation of the training signal with noise sequence is shown in the below normalized correlation plot showing correctness of selection of reference signal as inverse proportional relation exists between the two. This relation guides much better in the adaption process in the noisy channels. In continuous with these two validations, fig.5 shows that the frequency contents of training sequence well maintains an-above zero DCT (Discrete Cosine Transform) and not hold the zero value for a considerable time even when sometime it touches that. Other generated sequences held zero value at some positions, thus causing problems in adaptation process and increase in convergence time.

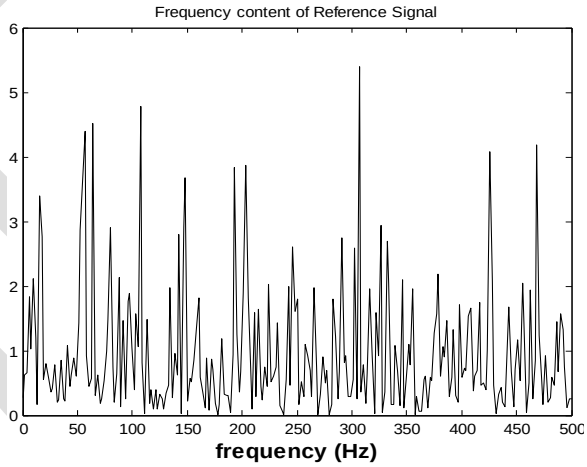

Figure 5. Discrete Cosines Transform of of the Reference Signal

The channel has a time varying impulse response and initialized by h = [-0.001 0.1 -0.45 0.9 -0.45 0.1 -0.001 and is modeled to have Rayleigh fading with complex AWGN noise addition as in [11]. The initial value for MSE is somehow analogous before steady state for all the algorithms, but in contrast with the other algorithms, proposed technique converges to its steady state very quickly.

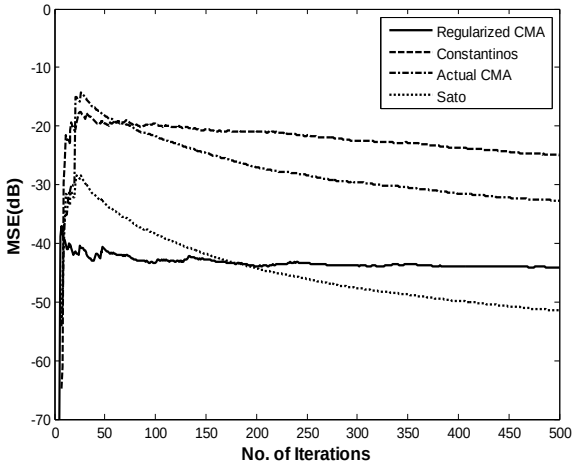

Figure 6. Learning Curves of Different Algorithms for BPSK

For QAM modulated signals, speed of convergence and accuracy of the proposed regularized CMA is shown in Fig.7.

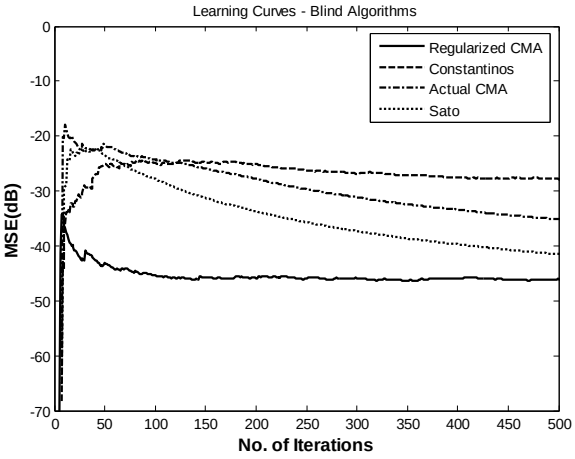

Figure 7. Learning Curves of Blind Algorithms for QAM

Regularized Constant Modulus Algorithm RCMA clearly converges prior to other competitor techniques for the 40dB acceptable value of MSE. QAM scheme is modeled as complex number being two dimensional in nature having real and imaginary parts. Improved performance was achieved by combining the properties of proposed technique with MMA. Multiplexing of RCMA and MMA performs even better for the reason of quick convergence property of RCMA and low value for final steady state mean square error of MMA. A comparison of second proposed architecture of equalizer, mixing sato with regulized CMA, with other algorithms is shown in Fig. 8 which reveals lowest MSE value convergence as compared to work presented in [6], [8] and [9]. This proves that weight coefficients trajectory of equalizer, over any finite time, converges to the ordinary differential equation solution in spite of constant step size and considerable noise in channel. Speedy convergence guarantees the implementation of the algorithm in high speed data rate mobile communication systems employing 4G modulation techniques OFDM and MC-CDMA [11,12].

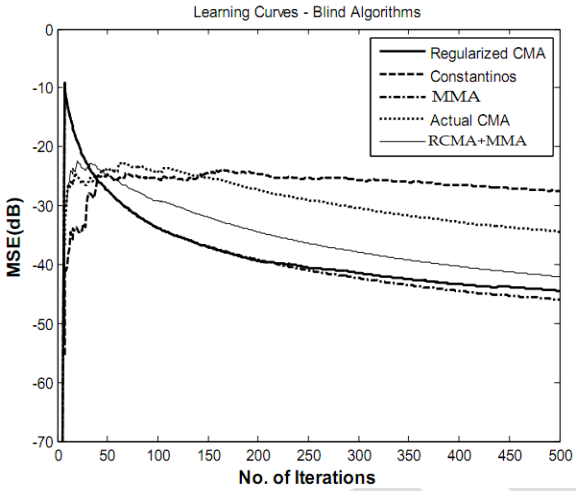

Figure 8. Comparision of Proposed technique with other algorithms

CONCLUSION

Performance of equalizers in modern communication systems is evaluated in terms of convergence rate and mean square error and existing LMS algorithms gives poor convergence where noise level is beyond critical values. The proposed algorithm diminishes the trade-off between the two properties by generating a smart training sequence and blindly using low mean square error property of CMA, thus providing improved performance at a much reduced complexity. The weight updating technique for the regularized CMA was of RLS producing considerable low value for mean error and quick response to optimal solution convergence, hence providing better results than traditional Constant Modulus Algorithm Family algorithms.

Although computer manufacturing industry is progressing toward ultra fast parallel processing day by day, the complexity matters are trivial in wireless communication designs, journey towards optimization and improvement never ends. Prospective applications for the proposed technique in adaptive filter applications are in echo cancellation and signal rejection/ extraction for radar systems etc. To a particular extent, goal for attaining optimal coefficient values through swift convergence rate has been successfully achieved though the effort presented in this research. Some potential future recommendations could be extension of the proposed algorithm to radius-directed equalization RDE, which uses multiple radii to give much smaller value of error than CMA at low orders [1].

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Production of Pulp from Banana Pseudo stem for Grease Proof Paper

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ABSTRACT
Now a day, the dependency of mankind on polythene has grown to larger extent because of its wide applications in storing food without allowing the moisture inside the packing and also as carry bags. But polythene is a non-biodegradable material which when buried in the soil doesn't decompose. Because of this reason the soil looses it's fertility due to the toxic chemicals it release by the action of temperature and also killing the micro organisms that are essential in the soil.
In view of this, several attempts were made in recent years to develop paper that can show the oil proof as that of polythene. This project involves not the production of paper but the basic raw material for paper production that is pulp from banana plant (abundantly available on earth). Later this pulp can be blended with pulp obtained from bamboo which is less abundant, to obtain oil proof paper. The reason behind the selection of banana as raw material is, in banana plantations, after the fruits are harvested, the trunks or stems will be wasted. Billion tons of stem and leaves are thrown away annually.
In this project we are producing pulp from banana waste stem using Kraft's process and Soda process, also analyse the both process based on their yield, energy consumption and propose the best process.

KEYWORDS: Paper, Pulp, Banana Pseudo stem, Pentosan, Lignin, Krafts process, Bleaching

INTRODUCTION

Paper manufacturing mark the beginning of the knowledge revolution. In ancient India knowledge spread verbally through the word of mouth from the teacher to the disciple, hence it was called Shruti. But with the discovery of scripts, written records gradually replaced the verbal transmission of thought.
From then on paper is used as the major source of communication in the form of writing letters, keeping records of valuable information like books, entertaining people in the form of novels and spreading information about the daily happenings in the form of news papers, which is the major revolution in communication that ever happened in the history of mankind.
With various technologies available for production of paper, made itself use full in lots of applications. It not only has role in communication but also to large extent in packing materials (low grade paper), which is reason for selection of this project.
Now a day, the dependency of mankind on polythene has grown to larger extent because of its wide applications in storing food without allowing the moisture inside the packing and also as carry bags. But polythene is a non-biodegradable material which when buried in the soil don't decompose. Because of this reason the soil looses it's fertility due to the toxic chemicals it release by the action of temperature and also killing the micro organisms that are essential in the soil. So, this polythene material can be recycled from wastes rather than forcing it to decompose which is of no use. But at the same time recycling also has become costly with the increase in polythene use.
In view of this, several attempts were made in recent years to develop paper that can show the oil proof as that of polythene. This project involves not the production of paper but the basic raw material for paper production that is pulp from banana plant (abundantly available on earth). Later this pulp can be blended with pulp obtained from bamboo which is less abundant, to obtain oil proof paper.

OBJECTIVES

1. To produce pulp from Banana plant pseudo stem by using both Kraft process and soda process.
2. To analyze the results obtained in the processes and to propose the better process based on yield and consumption of raw material and energy.

LITERATURE REVIEW

T Goswami, Dipul Kalita* & P G Rao[1], North East Institute of Science and Technology (CSIR) investigated the production of grease proof paper from banana pseudo stem. The morphological characteristics of plant and fibre, chemical constituents of the sheath, characteristic of pulp and physical strength properties of hand sheet made from banana pulp alone or in combination with bamboo pulp fibre are presented. And also investigated imparting of grease proof properties by a compound called pentosan (13.5%). The drainage time of banana pulp increases with increase in beating time. The paper made out of this banana pulp showed the characteristics of grease proof paper. The physical strength of the paper can further be improved by incorporating 20% bamboo pulp into banana pulp. Production of pulp and paper on laboratory scale is also presented.

Johansson[2] investigated the simplest procedure to determination pentosan content present in various soft and hard woods by using

hydrochloric acid and furfural as main involved chemicals.

Yuan-Shing Perng and Eugene I-Chen Wang[3] studied the improvement of grease proof properties by addition of certain chemicals (which acts as fillers, binders and refiners) and by mechanical treatment. Certain calibration curves are also generated for strength of papers for various concentrations of binders, fillers and refiners.

Uraiwan Pitimaneeyakul[4] , King Mongkut's Institute of Technology Ladkrabang, Thailand investigated the simplest procedure to extract banana fibre from the pseudo stem without damaging the fibre. And also studied various properties related to fibre strength like percentage elongation, moisture regain and fineness. Composition of fibre is also investigated and presented in this literature.

Sunday Albert Lawal and Benjamin Iyenagbe Ugheoke[5], Department of Mechanical Engineering, Federal University of Technology, Nigeria investigated the cellulose content in both hard woods and soft woods and also described available methods to improve the properties of the fibre like scouring etc,.
Shrieves chemical process industries[6], Dryden's outlines of chemical technology[7] and Wikipedia provided the information about various pulping methods available today such as Mechanical, Thermo mechanical, Chemical, Chemo thermo mechanical pulping and briefly describing about them like types of Chemical pulping and Chemicals required in both of the process.

PULPING

Pulping is the process of production of Pulp using wood material which is a lignocelluloses fibrous material. It is prepared by chemically or mechanically separating cellulose fibres from wood, fibre crops or waste paper.

Raw materials

Generally, woods are two types. Hard woods and Soft woods. Wood from conifers (e.g. pine) is called softwood, and the wood from dicotyledons (usually broad-leaved trees, e.g. oak) is called hardwood. Hard woods are not necessarily hard, and softwoods are not necessarily soft. The well-known balsa (a hardwood) is actually softer than any commercial softwood. Conversely, some soft woods (e.g. yew) are harder than many hardwoods.
These woods contain basically three materials in them. They are:

1. Cellulose
2. Hemi cellulose
3. Lignin, and
4. Pectin

The cellulose present in wood is mostly in the form of fibres. The cellulose fibres are obtained as pulp after pulping process. Cellulose fibre is a long chain of single monomer C6H10O5.

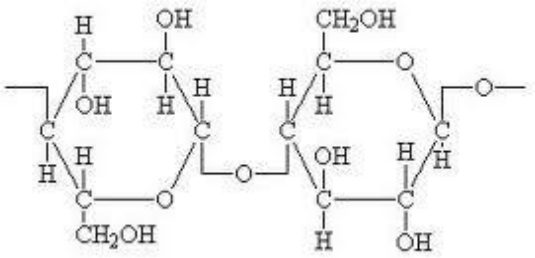


Fig.1: cellulose

Hemi cellulose is made of two compounds, namely Pentosans and Hexosans. The former is responsible for the grease proof properties imparted in the paper.

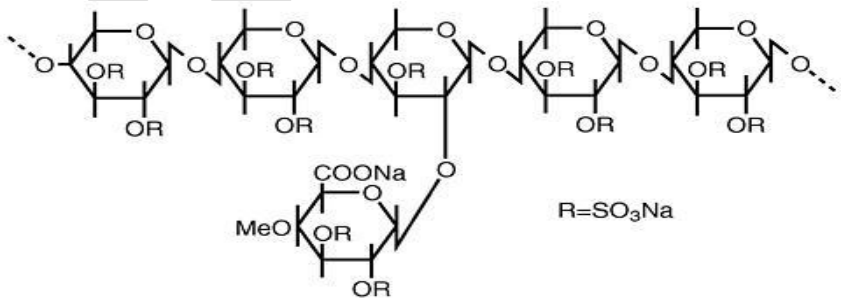


Fig.2: Pentosan structure

In soft woods they are present in about 7-10% where as in hard woods about 19-25%.Lignin and pectin bind the cellulose fibers together in the wood.

The bellow are the chemical compositions of different woods:

Fibre	Latin name	Cellulose (wt.%)	Hemi-cellulose (wt.%)	Lignin (wt.%)	Pectin (wt.%)
Flax	*Linum usitatissimum*	60-81	14-18.6	2-3	1.8-2.3
Jute	*Corchorus capsularis, C. olitorius*	51-72	12-20.4	5-13	0.2
Abaca	*Musa textilis*	60.8-64	21	12	0.8
Sisal	*Agave sisalana Perrine*	43-88	10-13	4-12	0.8-2
Kenaf	*Hibiscus Cannabinus*	36	21	18	2
Ramie	*Boehmeria nivea Gaud, variety tenacissima*	68.6-76	13.1-15.0	0.6-1	1.9-2
Hemp	*Cannabis sativa L.*	70-78	17.9-22	3.7-5	0.9
Cotton	*Gossypium spp.(commonest G. hirsutum)*	82.7-92	2-5.7	0.5-1	5.7
Coir	*Cocos nucifera L.*	43	0.3	45	4.0
Banana	*Musa acuminata L.*	60-65	6-19	5-10	3-5
Henequén	*Agava fourcroydes Lemaire*	60-78	4-28	8-13	3-4
Bagasse	*Saccharum officinarum L.*	40	30	20	10
Pineapple	*Acanas Comosus*	80-81	16-19	12	2-2.5
Wood	-	45-50	23	27	-

Table 1:chemical composition of different woods

INDIAN PULP AND PAPER INDUSTRY

Indian Paper industry has created sustainable livelihood in rural areas and has helped generating employment for the local population especially for women to earn their livelihood. The Indian Paper Industry has emerged as a diversified and specialized industry that produces numerous types of papers that comes in various use such as watermark, filter paper, drawing sheets, etc. Other products including Paper Bags, paper diaries, paper photo Frames, Greeting Cards, Handmade paper Boxes, paper Albums, etc, are manufactured and exported across the world. Today, the Indian exporters export nearly Rs.400cr. worth of paper products per annum to the developed nations.

The Indian Paper Industry has the top 15 global players with an output of more than 8
million tonnes annually with an estimated turnover of Rs. 200,000 millions. Indian Paper Industry is riding on a strong demand and on an expanding mood to meet the projected demand of 12 million tonnes by 2020.

Indian Paper Industry accounts for about 1.6% of the world's production of paper and paperboard. The estimated turnover of the industry is Rs 25,000 crore (USD 5.95 billion). The industry was delicensed effective from July 1997 by the Government of India & foreign participation is permissible. Most of the paper mills are in existence for a long time and hence present technologies fall in a wide spectrum ranging from oldest to the most modern. Paper in India is made from 40% of hardwood and bamboo fibre, 30 % from agro waste and 30 % from recycled fibre. Newsprint and publication paper consumption account for 2 million tonnes, of which 1.2 million tonnes of newsprint paper is manufactured in India and the remaining 0.8 million tonnes is imported.

Demand of Paper has been around 8% and during the years 2002-07 while newsprint registered a growth of 13% and Writing & Printing, Containerboard, Carton board and others registered growth of 5%, 11%, 9% and 1% respectively. So far, the growth in paper industry has mirrored the growth in GDP and has grown on an average 6-7 % over the last few years. India is the fastest growing market for paper globally and it presents an exciting scenario and paper consumption is poised for a big leap forward in sync with the economic growth and is estimated to touch 13.95 million tons by 2015-16. The futuristic view is that growth in paper consumption would be in multiples of GDP and hence an increase in consumption by one kg per capita would lead to an increase in demand of 1 million tons.

The industry provides employment to more than 0.12 million people directly and 0.34 million people indirectly. Some of the paper products are sheet paper, paper boxes, tissues, paper bags, stationery, envelopes, and printed-paper products such as books, periodicals, and newspapers. Specialty papers like sandpaper, blueprint paper, carbon paper are not a part of paper products industry. Stationery includes greeting cards, printing and writing papers, school and office papers, etc. The toiletry products include paper towels, tissue paper, and bath tissue.

The Rs. 22000-crore paper industry in India, rated 15th largest in world engages about 1.5 million people with the help of Rs. 2500cr Government subsidy. Government has given paper industry as one of the 35 high-priority list.

Indian paper and newsprint industry has a huge potentials and prospects in coming future. In our, country, demand for paper and newspaper is rapidly increasing. There are vast demands in the area of tea bags, filer paper, tissue paper, medical-grade coated paper, lightweight online coated paper, etc.

METHODS OF PULPING

Many process came into existence for production of pulp from wood materials in past 2 decades. These methods work different because of the feed they take in, based on the quality of pulp obtained after the process and also based on their efficiencies.

Preparation for pulping

Wood chiping is the act and industry of chipping wood for pulp, but also for other processed wood products and mulch. Only the heartwood and sapwood are useful for making pulp. Bark contains relatively few useful fibres and is removed and used as fuel to provide steam for use in the pulp mill. Most pulping processes require that the wood be chipped and screened to provide uniform sized chips.

Types of pulping

1.Mechanical pulping:

Manufactured grindstones with embedded silicon carbide or aluminium oxide can be used to grind small wood logs called "bolts" to make stone pulp (SGW). If the wood is steamed prior to grinding it is known as pressure ground wood pulp (PGW). Most modern mills use chips rather than logs and ridged metal discs called refiner plates instead of grindstones. If the chips are just ground up with the plates, the pulp is called refiner mechanical pulp (RMP) and if the chips are steamed while being refined the pulp is called thermo mechanical pulp (TMP). Steam treatment significantly reduces the total energy needed to make the pulp and decreases the damage (cutting) to fibres. Mechanical pulps are used for products that require less strength, such as news print paperboards.

2.Thermo mechanical pulping:

Thermo mechanical pulp is pulp produced by processing wood chips using heat and a mechanical refining movement. It is a two stage process where the logs are first stripped of their bark and converted into small chips. These chips have a moisture content of around 25-30% and a mechanical force is applied to the wood chips in a crushing or grinding action which generates heat and water vapour and softens the lignin thus separating the individual fibres. The pulp is then screened and cleaned; any clumps of fibre are reprocessed. This process gives a high yield of fibre from the timber (around 95%) and as the lignin has not been removed, the fibres are hard and rigid.

3.Chemical pulping:

Chemical pulp is produced by combining wood chips and chemicals in large vessels known as digesters where heat and the chemicals break down the lignin, which binds the cellulose fibres together, without seriously degrading the cellulose fibres. Chemical pulp is used for materials that need to be stronger or combined with mechanical pulps to give product different characteristics. These are of three types mainly:

A. Kraft's process:

The Kraft process (also known as Kraft pulping or sulphate process) is a process for conversion of wood into wood pulp consisting of almost pure cellulose fibres. It entails treatment of wood chips with a mixture of sodium hydroxide and sodium sulphide, known as white liquor, which breaks the bonds that link lignin to the cellulose. The Kraft process is the dominant chemical pulping method. It involves following operations:

Impregnation

Common wood chips used in pulp production are 12–25 millimetres (0.47–0.98 in) long and 2–10 millimetres (0.079–0.39 in) thick. The chips normally first enter the pre-steaming where they are wetted and preheated with steam. Cavities inside fresh wood chips are partly filled with liquid and partly with air. The steam treatment causes the air to expand and about 25% of the air to be expelled from the chips. The next step is to impregnate the chips with black and white liquor. Air remaining in chips at the beginning of liquor impregnation is trapped within the chips. The impregnation can be done before or after the chips enters the digester and is normally done below 100 °C (212 °F). The cooking liquors consist of a mixture of white liquor, water in chips, condensed steam and weak black liquor. In the impregnation, cooking liquor penetrates into the capillary structure of the chips and low temperature chemical reactions with the wood begin. A good impregnation is important to get a homogeneous cook and low rejects. About 40–60% of all alkali consumption in the continuous process occurs in the impregnation zone.

Cooking

The wood chips are then cooked in huge pressurized vessels called digesters. Some digesters operate in batch manner and some in continuous processes. There are several variations of the cooking processes both for the batch and the continuous digesters. Digesters producing 1,000 tonnes of pulp per day and more are common with the largest producing more than 3,500 tonnes of pulp per day. In a continuous digester the materials are fed at a rate which allows the pulping reaction to be complete by the time the materials exit the reactor. Delignification requires several hours at 130 to 180 °C (266 to 356 °F). Under these conditions lignin and hemi cellulose degrade to give fragments that are soluble in the strongly basic liquid. The solid pulp (about 50% by weight based on the dry wood chips) is collected and washed. At this point the pulp is quite brown and is known as brown stock. The combined liquids, known as black liquor (so called because of its colour), contain lignin fragments, carbohydrates from the breakdown of hemi cellulose, sodium carbonate, sodium sulphate and other inorganic salts.

Recovery process

The excess black liquor is at about 15% solids and is concentrated in a multiple effect evaporator. After the first step the black liquor is about 20 - 30% solids. At this concentration the rosin soap rises to the surface and is skimmed off. The collected soap is further processed to tall oil. Removal of the soap improves the evaporation operation of the later effects.

The weak black liquor is further evaporated to 65% or even 80% solids ("heavy black liquor") and burned in the recovery boiler to recover the inorganic chemicals for reuse in the pulping process. Higher solids in the concentrated black liquor increases the energy and chemical efficiency of the recovery cycle, but also gives higher viscosity and precipitation of solids (plugging and fouling of equipment). The combustion is carried out such that sodium sulphate is reduced to sodium sulphide by the organic carbon in the mixture:

1. $Na_2SO_4 + 2\ C \rightarrow Na_2S + 2\ CO_2$

This reaction is similar to thermo chemical sulphate reduction in geochemistry.

The molten salts ("smelt") from the recovery boiler are dissolved in process water known as "weak wash". This process water, also known as "weak white liquor" is composed of all liquors used to wash lime mud and green liquor precipitates. The resulting solution of sodium carbonate and sodium sulphide is known as "green liquor", although it is not

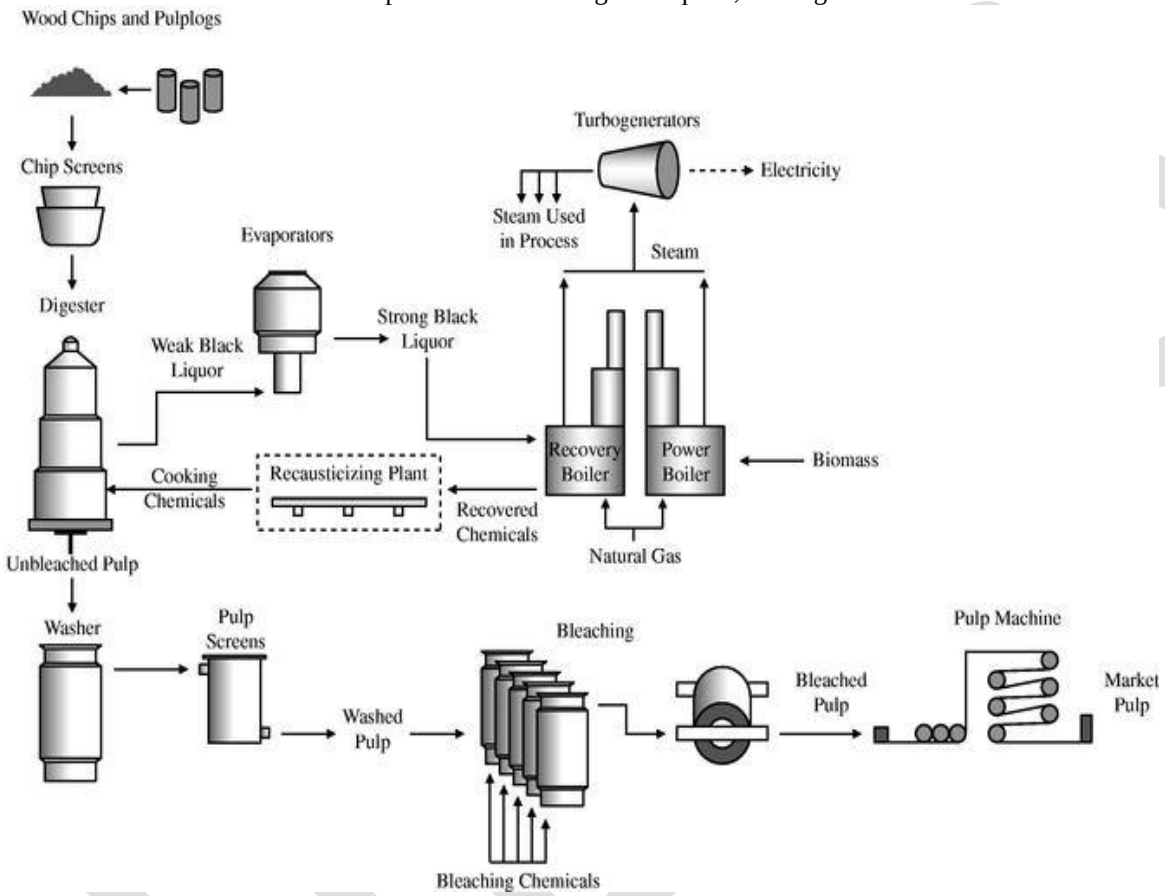


Fig.3:Kraft's process flow sheet

known exactly what causes the liquor to be green. This liquid is mixed with calcium oxide, which becomes calcium hydroxide in solution, to regenerate the white liquor used in the pulping process through an equilibrium reaction (Na_2S is shown since it is part of the green liquor, but does not participate in the reaction):

2. $Na_2S + Na_2CO_3 + Ca(OH)_2 \longleftrightarrow Na_2S + 2\ NaOH + CaCO_3$

Calcium carbonate precipitates from the white liquor and is recovered and heated in a lime kiln where it is converted to calcium oxide (lime).

3. $CaCO_3 \rightarrow CaO + CO_2$

Calcium oxide (lime) is reacted with water to regenerate the calcium hydroxide used in Reaction 2:

4. $CaO + H_2O \rightarrow Ca(OH)_2$

The combination of reactions 1 through 4 form a closed cycle with respect to sodium, sulphur and calcium and is the main concept of the so-called re-causticizing process where sodium carbonate is reacted to regenerate sodium hydroxide.

The recovery boiler also generates high pressure steam which is fed to turbo generators, reducing the steam pressure for the mill use and generating electricity. A modern Kraft pulp mill is more than self-sufficient in its electrical generation and normally will provide a net flow of energy which can be used by an associated paper mill or sold to neighbouring industries or communities through to the local electrical grid. Additionally, bark and wood residues are often burned in a separate power boiler to generate steam.

Blowing

The finished cooked wood chips are blown by reducing the pressure to atmospheric pressure. This releases a lot of steam and volatiles. The steam produced can then be used to heat the pulp mill and any excess used in district heating schemes or to drive a steam turbine to generate electrical power.

Screening

Screening of the pulp after pulping is a process whereby the pulp is separated from large Shives, knots, dirt and other debris. The accept is the pulp. The material separated from the pulp is called reject.

The screening section consists of different types of sieves (screens) and centrifugal cleaning. The sieves are normally set up in a multistage cascade operation because considerable amounts of good fibres can go to the reject stream when trying to achieve maximum purity in the accept flow.

The fibre containing shives and knots are separated from the rest of the reject and reprocessed either in a refiner and/or is sent back to the digester. The content of knots is typically 0.5 - 3.0% of the digester output, while the shives content is about 0.1- 1.0%.

Washing

The brown stock from the blowing goes to the washing stages where the used cooking liquors are separated from the cellulose fibers. Normally a pulp mill has 3-5 washing stages in series. Washing stages are also placed after oxygen delignification and between the bleaching stages as well. Pulp washers use counter current flow between the stages such that the pulp moves in the opposite direction to the flow of washing waters. Several processes are involved: thickening / dilution, displacement and diffusion. The dilution factor is the measure of the amount of water used in washing compared with the theoretical amount required to displace the liquor from the thickened pulp. Lower dilution factor reduces energy consumption, while higher dilution factor normally gives cleaner pulp. Thorough washing of the pulp reduces the chemical oxygen demand (COD).

Several types of washing equipment are in use:

- Pressure diffusers
- Atmospheric diffusers
- Vacuum drum washers
- Drum displacers
- Wash presses

Bleaching

In a modern mill, brown stock (cellulose fibres containing approximately 5% residual lignin) produced by the pulping is first washed to remove some of the dissolved organic material and then further delignified by a variety of bleaching stages.

The pulp produced up to this point is still in brown colour due in the process can be bleached to produce a white paper product. The chemicals used to bleach pulp have been a source of environmental concern, and recently the pulp industry has been using alternatives to chlorine, such as chlorine dioxide, oxygen, ozone and hydrogen peroxide.

In the case of a plant designed to produce pulp to make brown sack paper or linerboard for boxes and packaging, the pulp does not always need to be bleached to a high brightness. Bleaching decreases the mass of pulp produced by about 5%, decreases the strength of the fibres and adds to the cost of manufacture.

Fig.5: Bleaching of pulp

A. Sulphite process:

The sulphite process produces wood pulp which is almost pure cellulose fibres by using various salts of sulphurous to extract the lignin from wood chips in large pressure vessels called digesters. The salts used in the pulping process are either sulfites (SO_3^{2-}), or bisulphites (HSO_3^-), depending on the pH. The counter ion can be Sodium, Calcium, Magnesium or Ammonium.

Pulping liquor preparation

The pulping liquor for most sulphite mills is made by burning sulphur with the correct amount of oxygen to give sulphur dioxide, which is then absorbed into water to give sulphurous acid.

$$S + O_2 \rightarrow SO_2$$
$$SO_2 + H_2O \rightleftharpoons H_2SO_3$$

Care must be taken to avoid the formation of sulphur trioxide since it gives undesired sulphuric acid when it is dissolved in water.

$$2\ SO_2 + O_2 \rightarrow 2SO_3$$
$$SO_3 + H_2O \rightleftharpoons H_2SO_4$$

Sulphuric acid is undesirable since it promotes hydrolysis of cellulose without contributing to delignification.

The cooking liquor is prepared by adding the counter ions as hydroxides or carbonates. The relative amounts of each species present in the liquid depend largely on the relative amounts of sulphurous used. For mono valent (Na^+, K^+ and NH^{4+}) hydroxides, MOH:

$$H_2SO_3 + MOH \rightarrow MHSO_3 + H_2O$$
$$MHSO_3 + MOH \rightarrow M_2SO_3 + H_2O$$

For divalent (Ca^{2+}, Mg^{2+}) carbonates, MCO_3:

$$MCO_3 + 2H_2SO_3 \rightarrow M(HSO_3)_2 + CO_2 + H_2O$$
$$M(HSO_3)_2 + MCO_3 \rightarrow 2\ MSO_3 + CO_2 + H_2O$$

Pulping process

Sulphite pulping is carried out between pH 1.5 and 5, depending on the counter ion to sulphite (bisulphite) and the ratio of base to sulphurous acid. The pulp is in contact with the pulping chemicals for 4 to 14 hours and at temperatures ranging from 130 to 160 °C (266 to 320 °F), again depending on the chemicals used.

Most of the intermediates involved in delignification in sulphite pulping are resonance-stabilized carbocations formed either by protonation of carbon-carbon double bonds or acidic cleavage of ether bonds which connect many of the constituents of lignin. It is the latter reaction which is responsible for most lignin degradation in the sulphite process. The electrophillic carbocations react with bisulphite ions (HSO_3^-)to give sulphonates.

$$R\text{-}O\text{-}R' + H^+ \rightarrow R^+ + R'OH$$
$$R^+ + HSO_3^- \rightarrow R\text{-}SO_3H$$

The sulphite process does not degrade lignin to the same extent that the Kraft's process does and the lignosulfonates from the sulphite process are useful by products.

Chemical recovery

The spent cooking liquor from sulphite pulping is usually called brown liquor, but the terms red liquor, thick liquor and sulphite liquor are also used (compared to black liquor in the Kraft process). Pulp washers, using counter current flow, remove the spent cooking chemicals and degraded lignin and hemi cellulose. The extracted brown liquor is concentrated, in multiple effect evaporators. The concentrated brown liquor can be burned in the recovery boiler to generate steam and recover the inorganic chemicals for reuse in the pulping process or it can be neutralized to recover the useful by products of pulping.

The sulphite process can use calcium, ammonium, magnesium or sodium as a base.

Calcium-based

The earliest process used calcium, obtained as inexpensive calcium carbonate and there was little incentive to recover the inorganic materials.

Ammonia-based

Ammonia-based processes do not allow recovery of the pulping chemicals since ammonia or ammonium salts are oxidized to nitrogen and nitrogen oxides when burned.

Magnesium-based

The recovery process used in magnesium-based sulphite pulping the "Magnefite" process is well developed. The concentrated brown liquor is burned in a recovery boiler, producing magnesium oxide and sulphur dioxide, both of which are recovered from the flue gases. Magnesium oxide is recovered in a wet scrubber to give slurry of magnesium hydroxide.

$$MgO + H_2O \rightarrow Mg(OH)_2$$

from the flue gases producing a magnesium bisulphite solution that is clarified, filtered and used as the pulping liquor.

$$Mg(OH)_2 + 2\ SO_2 \rightarrow Mg(HSO_3)_2$$

Sodium-based

Sodium-based processes use a recovery system similar to that used in the Kraft, except that there is no "lime cycle".

Applications

The sulphite process is acidic and one of the drawbacks is that the acidic conditions hydrolyze some of the cellulose, which means that sulphite pulp fibres are not as strong as Kraft pulp fibres. The yield of pulp (based on wood used) is higher than for Kraft pulping and sulphite pulp is easier to bleach.

B. Soda puling:

this pulping process is entirely similar to Kraft's process. The only difference exists is the cooking chemicals used. In soda pulping process only NaOH or combination of NaOH and Na2CO3 are used. The quality of pulp obtained in soda pulping is low and used for manufacturing low grade paper.

The amount of bleaching agent required is large as the lignin content is not effectively removed.

4.Chemo thermo mechanical pulping:

Wood chips can be pre-treated with sodium carbonate, sodium hydroxide, sodium sulphite and other chemicals prior to refining with equipment similar to a mechanical mill. The conditions of the chemical treatment are much less vigorous (lower temperature, shorter time, less extreme pH) than in a chemical pulping process since the goal is to make the fibres easier to refine, not to remove lignin as in a fully chemical process. Pulps made using these hybrid processes are known as chemo thermo mechanical pulps (CTMP).

5.Recycled pulp:

Recycled pulp is also called deinked pulp (DIP). DIP is recycled paper which has been processed by chemicals, thus removing printing inks and other unwanted elements and freed the paper fibres. The process is called deinking.

DIP is used as raw material in papermaking. Many newsprint, toilet paper and facial tissue grades commonly contain 100% deinked pulp and in many other grades, such as lightweight coated for offset and printing and writing papers for office and home use, DIP makes up a substantial proportion of the furnish.

6.Organosolv pulping:

Organosolv pulping uses organic solvents at temperatures above 140 °C to break down lignin and hemi cellulose into soluble fragments. The pulping liquor is easily recovered by distillation.

Market pulp:

It is any variety of pulp that is produced in one location, dried and shipped to another location for further processing. Important quality parameters for pulp not directly related to the fibres are brightness, dirt levels, viscosity and ash content.

1. **Air dry pulp**

Air dry pulp is the most common form to sell pulp. This is pulp dried to about 10% moisture content. It is normally delivered as sheeted bales of 250 kg. The reason to leave 10% moisture in the pulp is that this minimizes the fibre to fibre bonding and makes it easier to disperse the pulp in water for further processing to paper.[22]

2. **Roll pulp**

Roll pulp or reel pulp is the most common delivery form of pulp to non traditional pulp markets. Fluff pulp is normally shipped on rolls (reels). This pulp is dried to 5 - 6% moisture content.

3. **Flash dried pulp**

Some pulps are flash dried. This is done by pressing the pulp to about 50% moisture content and then let it fall through silos that are 15–17 m high. Gas fired hot air is the normal heat source. The temperature is well above the char point of cellulose, but large amount of moisture in the fibre wall and lumen prevents the fibres from being incinerated. It is often not dried down to 10% moisture (air dry). The bales are not as densely packed as air dry pulp.

Paper production:

In some industries paper production continues after the pulp production rather than storing it as market pulp and exporting it.

In such industries the presence of fourdrinier machine is common for production of paper. It is simply a machine that consists of series if rollers which work on the principles of pressure and heat.

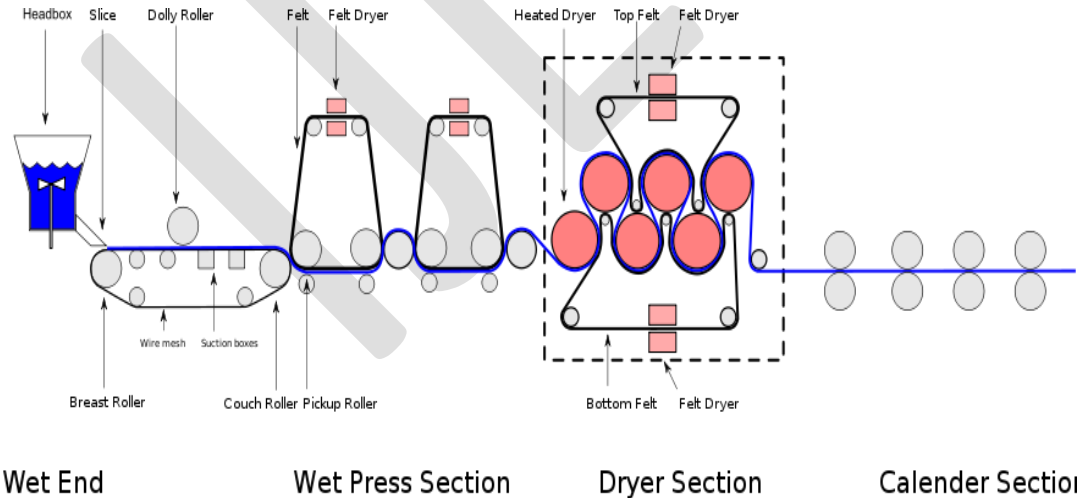


Fig.6: fourdrinier machine

MATERIALS AND CHEMICALS

Why Banana Plant?

Banana is one of the rhizomatous plants and currently grown in 129 countries around the world. It is the fourth most important global food crop. Different parts of banana trees serve different needs, including fruits as food sources, leaves as food wrapping,

and stems for fibre and paper pulp.

Banana is an important fruit crop which belongs to the genus Musa. It grows wild and also cultivated on a large scale as a field crop as well as a backyard crop in households. In India, banana is cultivated in about 1,86,000 hectare of land. The plant shows luxuriant growth in rich well-drained soil with ample moisture and decaying organic matter. It can also flourish on light sandy or gravelly soil as well as on stiff but well drain clay, if the soil is fertile and facilities for irrigation are available.

Fig.6: Banana pseudo stem

The pseudo stem portion of the plant contains fibre suitable for making ropes and twines. Extraction of certain species of banana fibre and its industrial application has also been reported. The fibre is located primarily adjacent to the outer surface of the leaf sheath. Well cleaned and brushed decorticated whole leaf sheath yield 80-85% long (4-6 mm), slender (mean width 17-21 µm) fibres.

Greaseproof paper is a type of non-absorbent paper that is impermeable to oil or grease and can be used for various purposes in the kitchen like layering fragile foods, wrapping food for storage and for lining cake tins. It is suitable for use in fridges, freezers and microwave ovens. It can be used to line baking trays, to wrap foods for packed lunches and to wrap fatty foods such as butter, cheese, smoked fish, cold meats and salami. Use of greaseproof paper to make jam pot covers and lids for separating food into individual portions for freezing is also reported. Grease proof paper is made from wood pulps which are highly hydrated so that the resulting paper is resistant to oil and grease. The timber resources used to make wood pulp are reffered to as pulp wood. Wood pulp generally comes from softwood trees such as spruce, pine, fir, larch, and hemlock, and also some hardwoods such as eucalyptus and birch.

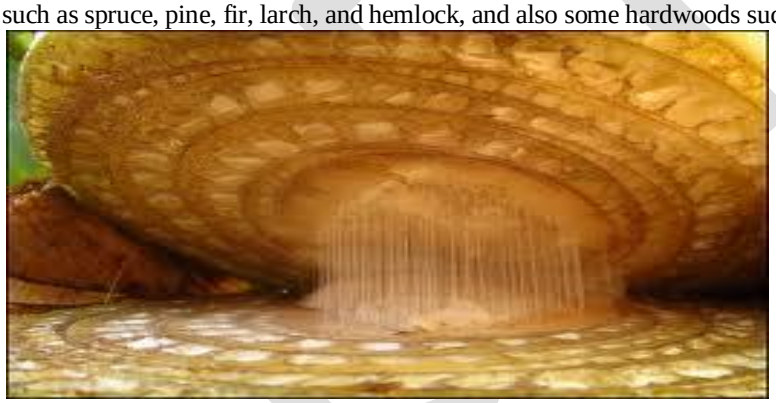


Fig.7: Banana fibre

In recent years, with the growing shortage of wood from the forest, the search for alternative fibre producing plant material has been initiated in many countries of the world. The generation of fast growing high biomass yielding plant is thought to be one of the solutions to meet the shortage of cellulosic material. However, certain agricultural plants producing higher biomass are found to be suitable substitute for certain fibre based industries. Among them banana plant may serve partly as an alternative resource in fibre based industries.

The banana fibres possess good physical strength properties. The higher pentosan content together with gums and mucilage in the sheath of certain species of banana plant may be a suitable source for producing grease proof paper. Although, reports are available on utilization of banana fibre for textile, pulp and paper making, but no reports are available development of greaseproof paper using banana sheath fibre. Considering the higher pentosan, gums and mucilage contents in the sheath of Musa paradisica plant, a detailed investigation was undertaken to study the possibility of making greaseproof paper from this plant and the results obtained from this investigation are presented in this communication.

Table 2: Banana fibre properties

Fibre properties	
Tenacity	29.98 g/denier
Fineness	17.15 denier
Moisture regain	13.0%
Elongation	6.54
Total cellulose	81.80%
Alpha cellulose	61.50%
Residual gum	41.90%
Lignin	15.00%

CHEMICALS

Sodium hydroxide

Sodium hydroxide, also known as lye or caustic soda, has the molecular formula NaOH and is highly caustic metallic base. It is a white solid available in pellets, flakes, granules, and as a 50% saturated solution.

Sodium hydroxide is soluble in water, ethanol and methanol. This alkali is deliquescent and readily absorbs moisture and carbon dioxide in air.

Sodium hydroxide is used in many industries, mostly as a strong chemical base in the manufacture of pulp and paper, textiles, drinking water, soap sand detergents and as a drain cleaner. Worldwide production in 2004 was approximately 60 million tonnes, while demand was 51 million tonnes. Although molten sodium hydroxide possesses properties similar to those of the other forms, its high temperature comparatively limits its applications.

Physical properties

Molar mass	39.997 g/mol
Appearance	White, waxy, opaque crystals
Odour	Odourless
Density	2.13g/cc
Melting point	591 K
boiling point	1661 K

Chemical properties

Sodium hydroxide reacts with protic acids to produce water and the corresponding salts. For example, when sodium hydroxide reacts with hydrochloric acid, sodium chloride is formed:

$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$$

Sodium hydroxide also reacts with acidic oxides, such as sulphur dioxide. Such reactions are often used to "scrub" harmful acidic gases (like SO_2 and H_2S) produced in the burning of coal and thus prevent their release into the atmosphere. For example,

$$2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$$

Production:

Sodium hydroxide is industrially produced as a 50% solution by variations of the electrolytic chloralkali process. Chlorine gas is also produced in this process. Solid sodium hydroxide is obtained from this solution by the evaporation of water. Solid sodium hydroxide is most commonly sold as flakes, prills, and cast blocks.

Uses:

Sodium hydroxide is the principal strong base used in the chemical industry. In bulk it is most often handled as an aqueous solution, since solutions are cheaper and easier to handle. Sodium hydroxide, a strong base, is responsible for most of these applications. Another strong base such as potassium hydroxide is likely to yield positive results as well.

Overall 56% of sodium hydroxide produced is used by the chemical industry, with 25% of the same total used by the paper industry. Sodium hydroxide is also used for the manufacture of sodium salts and detergents, for pH regulation, and for organic synthesis. It is used in the Bayer process of aluminium production.

Sodium hydroxide is used in many scenarios where it is desirable to increase the alkalinity of a mixture, or to neutralize acids.

Sodium carbonate

Sodium carbonate, Na_2CO_3 is a sodium salt of carbonic acid. It most commonly occurs as a crystalline heptahydrate, which readily effloresces to form a white powder, the monohydrate. Sodium carbonate is domestically well known for its everyday use as a water softener. It can be extracted from the ashes of many plants. It is synthetically produced in large quantities from salt (sodium chloride) and limestone in a process known as the Solvay process.

Physical properties:

Molar mass	105.9885 g/mol
Appearance	White solid

Odour	Odourless
Density	2.54 g/cc
Melting point	851 ºC
Boiling point	1633 ºC

Uses:

The manufacture of glass is one of the most important uses of sodium carbonate. Sodium carbonate acts as a flux for silica, lowering the melting point of the mixture to something achievable without special materials. This "soda glass" is mildly water soluble, so some calcium carbonate is added to the pre-melt mixture to make the glass produced insoluble. This type of glass is known as soda lime glass: "soda" for the sodium carbonate and "lime" for the calcium carbonate. Soda lime glass has been the most common form of glass for centuries.

Sodium carbonate is also used as a relatively strong base in various settings. For example, sodium carbonate is used as a pH regulator to maintain stable alkaline conditions necessary for the action of the majority of photographic film developing agents.

It is a common additive in municipal pools used to neutralize the acidic effects of chlorine and raise pH.

In cooking, it is sometimes used in place of sodium hydroxide for lyeing, especially with German pretzels and lye rolls. These dishes are treated with a solution of an alkaline substance to change the pH of the surface of the food and improve browning.

In taxidermy, sodium carbonate added to boiling water will remove flesh from the skull or bones of trophies to create the "European skull mount" or for educational display in biological and historical studies.

In chemistry, it is often used as an electrolyte. This is because electrolytes are usually salt-based, and sodium carbonate acts as a very good conductor in the process of electrolysis. In addition, unlike chloride ions, which form chlorine gas, carbonate ions are not corrosive to the anodes. It is also used as a primary standard for acid-base titrations because it is solid and air-stable, making it easy to weigh accurately.

Domestic use:

In domestic use, it is used as a water softener in laundering. It competes with the magnesium and calcium ions in hard water and prevents them from bonding with the detergent being used. Sodium carbonate can be used to remove grease, oil and wine stains. It is sold as washing soda, soda crystals, or sal soda. Sodium carbonate is also used as a descaling agent in boilers such as those found in coffee pots and espresso machine.

Sodium sulphide

Sodium sulphide is the chemical compound with the formula Na_2S, or more commonly its hydrate $Na_2S{\cdot}9H_2O$. Both are colourless water-soluble salts that give strongly alkaline solutions. When exposed to moist air, Na_2S and its hydrates emit hydrogen sulphide, which smells like rotten eggs. Some commercial samples are specified as $Na_2S{\cdot}xH_2O$, where a weight percentage of Na_2S is specified. Commonly available grades have around 60% Na_2S by weight, which means that x is around 3. Such technical grades of sodium sulphide have a yellow appearance owing to the presence of polysulphides. These grades of sodium sulphide are marketed as 'sodium sulphide flakes'. Although the solid is yellow, solutions of it are colourless.

Production:

Industrially Na_2S is produced by reduction of Na_2SO_4 with carbon, in the form of coal:[3]

$$Na_2SO_4 + 4\ C \rightarrow Na_2S + 4\ CO$$

In the laboratory, the anhydrous salt can be prepared by reduction of sulphur with sodium in anhydrous ammonia. Alternatively, sulphur can be reduced by sodium in dry THF with a catalytic amount of naphthalene:

$$2\ Na + S \rightarrow Na_2S$$

Reactions:

The dissolution process can be described as follows:

$$Na_2S + H_2O \rightarrow 2Na^+ + HS^- + OH^-$$

Sodium sulphide can oxidize when heated to sodium carbonate and sulphur dioxide:

$$2\ Na_2S + 3\ O_2 + 2\ CO_2 \rightarrow 2\ Na_2CO_3 + 2\ SO_2$$

Upon treatment with sulphur, polysulphides are formed:

$$2Na_2S + S_8 \rightarrow 2\ Na_2S_5$$

Uses:

It is primarily used in pulp and paper industry in the Kraft process . It is used in water treatment as an oxygen scavenger agent and also as a metals precipitant, in the photographic industry to protect developer solutions from oxidation, in textile industry as a bleaching, as a de-sulphurising and as a dechlorinating agent and in leather trade for the sulphitization of tanning extracts. It is used in chemical manufacturing as a sulphonation and sulphomethylation agent. It is used in the production of rubber chemicals, sulphur dyes and other chemical compounds. It is used in other applications including ore flotation, oil recovery, food preservative, making dyes, and detergent.

Sodium sulphide is an active ingredient in some over-the-counter ingrown toenail relief products.

EXPERIMENTAL PROCEDURE FOR LAB SCALE PRODUCTION OF PULP

Preparation of raw material:

1. Initially Banana Pseudo stem is taken and washed several times with water to remove dust and soil particles present on it.
2. Later it is cut into 10 cm long pieces.

fig.8: banana stem

3. They are crushed in a sugar cane crusher to remove water content and later dried at 80ºC for about 30 minutes to further reduce the water content.

Fig.9: crushed and dried banana stem pieces

KRAFT PULPING:

Preparation of cooking liquor

For cooking liquor to be prepared chemicals must be taken in right proportions so that effective cooking would happen. Kraft pulping consists of following chemicals-NaOH, Na2SO4, Na2CO3. These three chemicals must combine to give total of 12.5% by weight solution.

In this 12.5% of solution, according to Kraft's pulping solids analysis says-

-58.6% is NaOH,

-27.1% is Na2SO4, and

-14.3% is Na2CO3

If we take basis as 1000 ml solution of cooking liquor, then 12.5% by weight gives 125gr which is the total weight of all three chemicals required. Compositions of solids are given by wt%. If we calculate the individual weight of chemicals required, they would give the following.

NaOH weight=.586*125=73.25gr.

Na2SO4 weight=.271*125=33.875gr.

Na2CO3 weight=.143*125=17.875gr.

4.2.2. Digesting

Once the cooking liquor is prepared 400ml of it is taken separately in a 100ml beaker to which 5 grams of raw material (dried banana stem) is added and the level is marked. The reason for marking the level is described below.

Fig.10: cooking liquor and raw material

Industrially, steam is used for heating purpose. There are two reasons for selecting steam as heating source:

1. Firstly, it would serve as the heating medium for the digester.
2. Secondly, once the steam exchanges heat with the cooking liquor and the raw material the water present in the cooking liquor evaporates due to increase in temperature difference. Then the initial concentration of the cooking liquor is not maintained which would result in weak cooking. So, if steam is used, it condenses into the cooking liquor after exchanging heat, there by maintaining the concentration of the cooking liquor.

Here, we do not use steam as heating source. If heat is continuously supplied the water present in the cooking liquor evaporates there by initial concentration of the cooking liquor is varied. To bring back the concentration to initial we add water up to the marked level in the beaker. This is taken care of throughout the process of digesting.

The heat is supplied by means of hot plate for about 4hr 30min at a temperature of 90ºC. At the same time stirring is done continuously throughout the process.

Fig.11: brown stock and black liquor

In the process of digestion the strong basic cooking liquor and the action of heat combine and help breaking the bonds in lignin molecules. The broken lignin molecules dissolve in cooking liquor there by turning it into dark brown color called as Black liquor and cellulose remaining unaltered is present in the cooking medium as brown stock along with the traces of lignin.

SODA PULPING:

Preparation of cooking liquor

In this process, 20% by weight solution of NaOH is required as cooking liquor.

If we take 1000ml as basis 20% by weight gives 200gr of NaOH. These 200 grams of NaOH is dissolved in water and makeup to 1000ml to give required concentration of cooking liquor.

Digesting

Once the cooking liquor is prepared, 5 grams of raw material (dried Banana stem) is taken in 400ml of cooking liquor in 1000ml beaker and the level is marked.

The reason for the marking the level is already described above in Kraft's process. The same reason applies here too. And water must be added continuously to maintain the initial concentration of the cooking liquor and this process must be repeated entire boiling time.

Fig.12: cooking

Next, It is heated to about 90˚C (boiling) for 4hr 30min with continuous stirring. But the heat is not enough as the cooking liquor is weak basic compared to Kraft process. So, it is heated for one more hour to increase the effectiveness of heat and cooking liquor in breaking the lignin molecules and dissolving in the cooking liquor.

Filtration and washing of pulp:

After digesting, brown stock and black liquor are formed.

Brown stock contains pulp (cellulose and hemi-cellulose) and small amounts of lignin (reason for brown color).

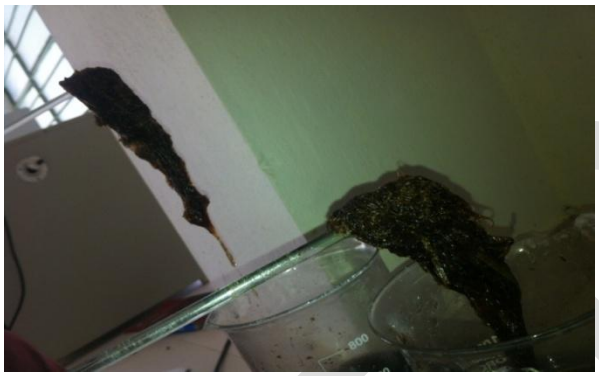


Fig.13: brown stock and black liquor

And the black liquor contains the dissolved lignin and cooking chemicals that are unconverted and can be recovered.

The mixture filtered using cloth to obtain black liquor as waste that contains cooking chemicals that can be recovered. One time filtration doesn't remove the lignin traces completely. So, once the filtration is done it is again washed with water to let lignin and chemicals associated with the brown stock to dissolve in it. And, this mixture is again filtered with the cloth and this process is repeated.

fig.14: washed pulp

It is washed several times with 1000ml of water to reduce the lignin content (about 5 times).

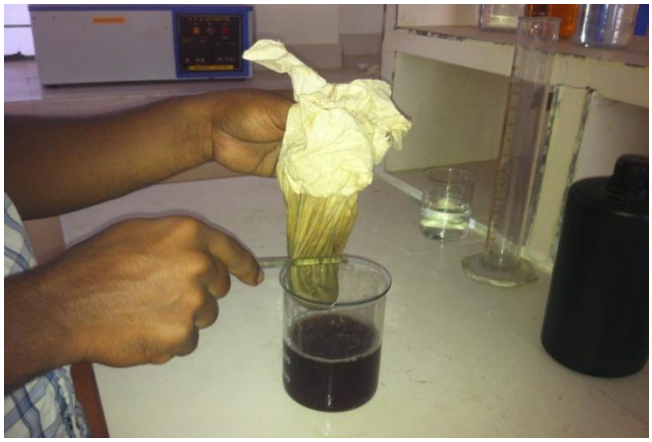


Fig.15: filtration

Finally, the obtained product from the filtration must be in such a way that lignin traces must be less in amounts.

4.5. Bleaching:

Once filtration and washing is completed the washed pulp is dissolved in 200ml of water
to which 5gr bleaching powder is added to completely remove the brown color to obtain white paper grade pulp.

Fig.16: bleaching

Drying:

Drying is done to find the yield in both the processes. To find the yield entire water in the bleached pulp must be removed. To remove entire water content in the bleached pulp, it is dried at a temperature of 100ºC for one hour in hot air oven.

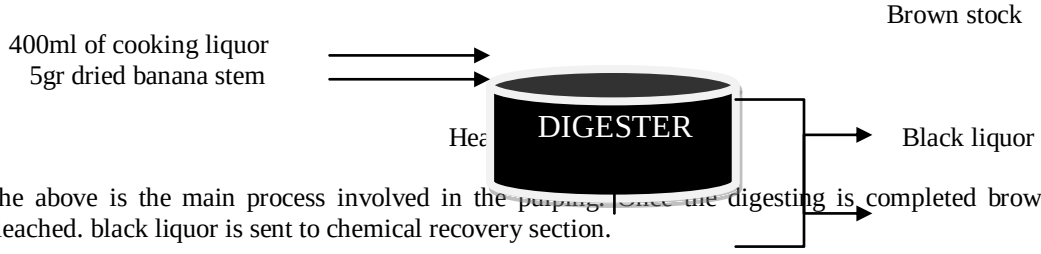
OVERALL VIEW OF THE PROCESS

1. Drying

Banana pseudo stem after washing with water is crushed in sugar cane crusher is sent into drier.

2. Digesting

5 grams of dried Banana stem is taken is sent into beaker along with 400ml of cooking liquor and boiled for 4hr 30min at 90°C. later brown stock and black liquor formed which are separated.



The above is the main process involved in the pulping. Once the digesting is completed brown stock is washed with water and bleached. black liquor is sent to chemical recovery section.

5. OBSERVATIONS

Firstly, describing about the heat required for digesting, Kraft process required only 4hr 30min for breaking lignin molecules. But soda process required more heat for digestion and yet could not obtain effective digestion as banana stem material is still present as it is in the beginning on the water cooking liquor surface.

Secondly, Kraft's process consists of strong cooking liquor which can break the lignin more effectively. Where as soda process consist of weak cooking liquor. Because of this reason we can find the traces lignin is more in Soda process than Kraft process.

Product obtained after washing with water is compared in both the processes.

Fig.17: washed pulp in both Kraft and soda process

The pulp obtained in Kraft process in less dark in colour than pulp obtained in soda process. The reason for this is, pulp obtained in Kraft process contain less lignin content in it due to strong basic nature of the solution which break the lignin effectively. Soda process involves weak basic cooking liquor that acts weak in breaking lignin bonds.

At the same pulp obtained after bleaching is also compared.

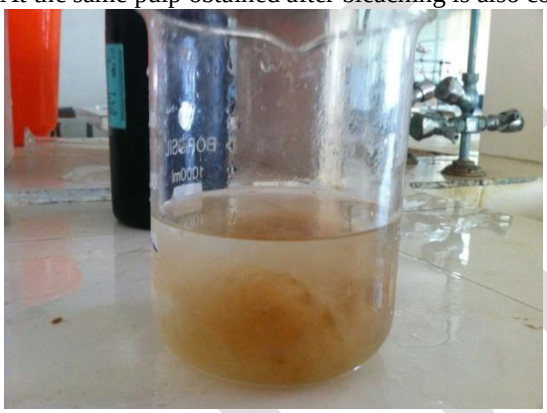


Fig.18:soda pulp after bleaching

Fig.19: Kraft pulp after bleaching

The pulp obtained after bleaching is observed and found that Kraft pulp is whiter in colour compared to soda process, as bleaching agent required breaking the traces of lignin is more in soda process than Kraft process.

Finally describing about the yield obtained, Kraft process gave – 1,735gr of pulp and Soda process gave – 1.273gr of pulp.

CONCLUSION:

After experimenting and observing the entire process of operation, there are certain conclusions made and listed below. They are:

1. Though Soda process require only one chemical but in large amounts to effectively break the lignin bonds. Kraft process requires fewer amounts of different chemicals and also helps in complete lignin molecule breakage. From this we can conclude that Kraft process is more advantageous.
2. In terms of heat requirement Kraft process is more advantage, because the cooking liquor is able to break and dissolve the lignin in it. Soda process is supplied with heat for one hour more and still the cooking liquor could not effectively digest the lignin.

3. Pulp obtained after washing is added with bleaching agent. The amount of bleaching agent required is more in Soda process when compared to Kraft process. So, the pulp obtained in Kraft process can be used for high grade paper production. pulp obtained by Soda process can be used for low grade paper production. But the discussion here is about the packing paper, so, the pulp must be entirely lignin free, because it acts as an impurity and may vary the conditions of the packed material. By this we can conclude that Kraft process is safer.
4. Finally, coming to the yield from the observations Kraft process gave more pulp for fixed amount of raw material when compared with Soda process. So, Kraft process is more advantageous.

From the above observations we conclude that Kraft Process is safer and more efficient based on yield.

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A REVIEW ON THERMAL AND CONTACT STRESS ANALYSIS OF DISC BRAKING SYSTEM

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Abstract- This paper reviews numerical methods and analysis procedures used in the study of automotive disc brake. It covers Finite element Method approaches in the automotive industry, the complex Contact analysis. The advantages and limitations of each approach will examine. This review can help analysts to choose right methods and make decisions on new areas of method development. The complex eigen value method is choose for contact analysis of car disc brake. The essence of such a method lies in the asymmetric stiffness matrix derived from the contact stiffness and the friction coefficient at the disc interfaces. This paper presents the analysis of the contact pressure distributions at the disc interfaces using a detailed 3-dimensional finite element model of a real car disc brake. It is also investigates different levels in modelling a disc brake system and simulating contact pressure distributions at varying load. It points out some outstanding issues in modeling and analysis of disc brake squeal and proposes new research topics. Wear can take place when two or more bodies in frictional contact slide against each other. It is found that the complex Contact analysis is still the approach favored by the automotive industry.

keywords— noise and vibration, automotive disc brake, coefficient of friction, simulation of disc brake,

INTRODUCTION

In general, there are three main functions of a brake system, i.e., to control a vehicle's speed when driving downhill, to minimize a vehicle's speed when necessary and to keep a vehicle stationary when in parking. At present, most passenger vehicles are fitted with disc braking systems. The elements disc brake system are floating caliper design typically consists of a caliper, two pads, two guide pins, a disc, a piston, a carrier bracket. The major requirements of the caliper is to press pads against the disc and it should ideally achieve as uniform interface pressure as possible. It is known that uniform pad wear, brake temperature, and friction coefficient could play vital role in braking action. In addition, to this it also reduces the life of the braking pads. This will cause the customers dissatisfaction and they often required to go to the garage more frequently to replace these brake pads.

As the brake disc, usually made up of cast iron or ceramic composites is connected to the wheel or the axle. To stop the rotation of wheel, friction material in the form of brake pads is forced hydrolytically, mechanically, pneumatically or electromagnetically against both sides of the disc. The friction causes the disc and attached wheel to slow or stop. As soon as the brake applied friction causes which leads to convert into frictional heat. When large amount of heat is generated brakes can't perform satisfactory work.

Brake noise is mainly caused by frictionally induced dynamic instability. There are two main types of numerical methods that are used to solve this problem: (1) transient dynamic analysis and (2) complex eigenvalue analysis. Currently, the complex eigenvalue method is more preferred and widely used in predicting the squeal propensity of the brake system. Since the transient dynamic analysis is computationally expensive and hence not widely used. The main idea of the complex eigenvalue method is to involve symmetry arguments of the stiffness matrix and the formulation of a friction coupling. This method is more efficient and provides more insight to the friction-induced dynamic instability of the disc brake system.

In the present study, an investigation of disc brake squeal is performed by complex eigenvalue method by using FE software. This FE method uses nonlinear static analysis to calculate the friction coupling prior to the complex eigenvalue extraction. Thus, the effect of no uniform contact and other nonlinear effects are incorporated. A systematic analysis is used to investigate the effects of parameters, such as the the stiffness of the disc, hydraulic pressure, the rotational velocity of the disc, the coefficient of frictional contact between the disc and the pads on the disc brake squeal. Hence, the simulations are to be done to reduce the brake noise of the disc braking system.

DESCRIPTION OF BRAKE NOISE

A. Classification of Brake Noise

The According to different vibration frequency range, the brake noise can be divided into low frequency and high frequency vibration noise. The vibration frequency of low frequency vibration noise was 200-400Hz.

B. Brake Noise Generation Mechanism

Brake noise is due to brake vibration during braking. If the change of friction force between friction plate and brake disc is too large and fast during the braking, it can cause the brake disc and the friction plate to vibrate. When the vibration frequency up to a certain value, they will produce different brake noise. At present, there were several opinions about the mechanism of brake noise. Generally, it can be divided into two types: one is “Self-Excitation Theory”; the other is “Hot Spots Theory ". “Self-Excitation Theory" considers the cause of brake noise as self-excited vibration or resonance in brake parts."Hot Spots Theory" considers that the hot spots which generate by brake disc during braking cause vibration noise. Hot spots refer to the spot temperature higher than other regions on the brake disc during braking process. The generation of spot due to the actual contact area is a very small area when brake disc and the friction plate relative velocity reach a certain value, so the friction surface has uneven heating. As the brake disc is a rotating, so hot spot is also changing and brake noise and vibration aroused.

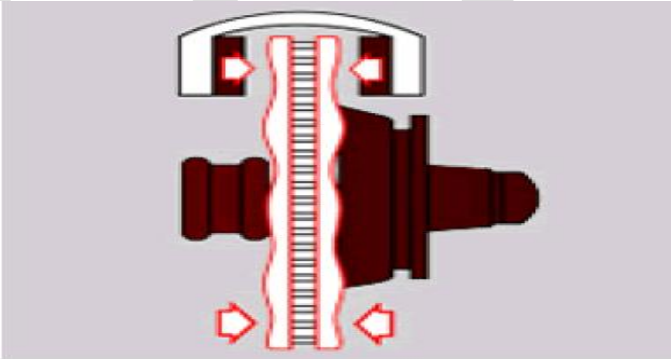

Figure1 **Brake Disc Thickness Variation**

BRAKE TORQUE VARIATION

As the friction force changes between the brake disc and friction plate results in the brake torque fluctuations, this phenomenon called as the brake torque variation. It will cover the following aspects.

A. Brake Disc Thickness Variation

The brake disc thickness variation refers to the brake disc thickness change when brake disc contact with the friction plate along circumference. In the braking process it will always close contact with the brake disc surface at both ends so the disc thickness changing will lead to the both the end. . When the change value of disc thickness over a certain range (generally considered to be when 15 ~ 20 μ m). The change of brake disc thickness mainly generated by following aspects:

1) Manufacturing errors. Mainly refers to the brake disc surface processing errors, including two parallel faces.

2) Using wear and tear. In some situation, the used disc may have different wear everywhere and resulting in uneven thickness.

3) Brake thermal expansion and thermal erosion. The brake disc heat expansion when braking will impact on casting microstructure and result in uneven thickness of the brake disc.

B. Brake Disc Side face Run-Out (SRO)

Brake disc side face run-out refers to the axial direction change along circumference of brake disc. When disc rotating, the ends location of the friction will changes. It will cause brake pressure and brake torque fluctuations. The side face run-out phenomenon will cause the brake disc thickness change because of uneven brake wear. Side face run-out has some the formation situations:

1) Manufacturing errors. Beside the side face run-out, the processing error between vehicle wheel hub and brake disc connected surface will further enlarge DTV.

2) Installation error.

B. Brake Vibrate under High Temperature

Because of the frequent braking action heat is generated as the results in which brake disc temperature raises. Although brake disc thickness variation and brake side face run-out are the main factor in brake vibrate, the brake disc thickness variation and side face run-out meet the requirements under static condition, is still possible occur brake variation during braking. Because braking is heat generated processing. With the brake disc temperature raise, it will cause disc surface thermal expansion and thermal deformation. Temperature differences on disc surface generate different level of thermal expansion and thermal deformation as a result thickness of brake disc may be varies.

Methodology and numerical model

1. Complex eigenvalue extraction

For brake squeal analysis, the most important source of nonlinearity is the frictional sliding contact between the pads and disc. ABAQUS allows for a convenient, but general definition of contact interfaces by specifying the contact surface and the properties of the interfaces. Starting from preloading the brake, rotating the disc, and then extracting natural frequencies and complex eigenvalues, this new approach combines all steps in run. The complex eigen problem is solved using the subspace projection method. The governing equation of the system is as

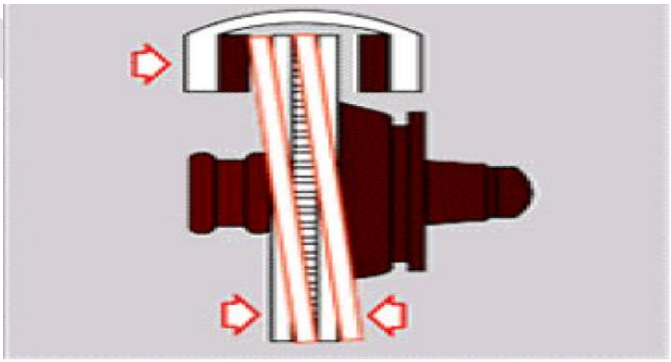

Figure.2 Brake Disc Side face Run-Out

$$Mx + Cx + Kx = 0$$

Where M is the mass matrix, C is the damping matrix, which includes friction-induced contributions, and K is the stiffness matrix.

The governing equation can also be rewritten as

$$(\mu^2 M + \mu C + K)\Phi = 0$$

Where μ is the eigen value and Φ is the corresponding eigenvector. Eigen values and eigenvectors may be complex. In order to solve the complex eigen problem, the system is symmetrised by ignoring the damping matrix C and the unsymmetric contributions to the stiffness matrix K. The N eigenvectors obtained from the symmetric eigenvalue problem are expressed in a matrix as [Φ /1, . . . Φ /N]. Next, the original matrices are projected onto the subspace of N eigenvectors.

$M^* = (\Phi_1,\ldots,\Phi_N)^T M(\Phi_{1\ldots..} \Phi_N)$

$C^* = (\Phi_1,\ldots, \Phi_N)^T C(\Phi_1,...., \Phi_N)$

And

$K^* = (\Phi 1,\ldots., \Phi_N)^T K (\Phi_1,\ldots., \Phi_N)$,

Then,

The projected complex eigen problem becomes

$(\mu^2 M^* + \mu C^* + K^*) \Phi^* = 0$

Finally, the complex eigenvectors of the original system can be obtained by

$\Phi = (\Phi_1,\ldots,\Phi_N)^T \Phi^*$

A more detailed description of the algorithm may be found in. The complex eigenvalue can be expressed as $\mu = \alpha \pm i\omega$ where α is the real part of, indicating the stability of the system, and ω is the imaginary part of μ. The generalized displacement of the disc system x, can then be expressed as

$$X = Ae^{\mu t} = e^{\alpha t}(A_1 \cos \omega t + A_2 \sin \omega t)$$

This analysis determines the stability of the system. When the system is unstable, becomes positive and squeals noise occurs. The term damping ratio is defined as $-\alpha/(\Pi|\omega|)$. If the damping ratio is negative the brake system becomes unstable, and vice versa. The purpose of this analysis is to reduce the damping ratio.

2 Finite element model

A disc brake system consists of a disc that rotates about the axis of a wheel, a calliper– piston assembly where the piston slides inside the calliper that is mounted to the vehicle suspension system, and a pair of brake pads. When hydraulic pressure is applied, the piston is pushed forward to press the inner pad against the disc and simultaneously the outer pad is pressed by the calliper against the disc. The brake model used in this study is a simplified version of a disc brake system which consists of a disc and a pair of brake pads. Two brake pads which consist of the contact plates and back plates are pressed against the disc so as to generate a friction torque to reduce the disc rotation. The contact plates are made of an organic friction material and the back plates are made of steel material. The FE mesh is generated using 3- dimensional continuum elements for the disc and pads, where a fine mesh is used in the contact regions. The contact frictional interactions are defined between both sides of the contact plates of the pads and the disc. A constant angular velocity and constant frictional coefficient of the disc are used for simulation. The disc is completely fixed at the five counter-bolt holes.

METHODS OF CONTROL BRAKE NOISE

It shows some important conclusions and put forward some suggestions about controlling the brake noise based on the analysis of various factors. The conclusions are as following:

1) Using more precise manufacturing and installation demand, reducing the variation of original brake disc thickness and jumpiness of end face to reduce variation caused by the original size;

2) Using good heat dissipation and good heat fading performance materials to manufacture the brake discs or friction plate in order to reduces the deformation caused by temperature changes and braking torque variation;

3) Using appropriate friction plate to reduce the coefficient of friction under keep the enough braking torque, and control the speed stability and temperature stability of the coefficient of friction.

Types of disc brake friction material

A commercial brake lining usually contains more than 20 different constituent. There are four types of brake lining which are commonly used

- Organic brake lining with asbestos material.
- Semi metallic or resin bonded metallic linings :> 50 weight % metal content.
- Low metallic linings: < 50weight % metal content.
- Non metallic linings: non metal content

Design considerations

- Larger diameter rotors more will be brake power with the same amount of clamp force than a smaller diameter rotor.
- The higher the frictional coefficient of the pad, more brake power will be generated.
- Depends upon the type of material used for the brake rotor.
- Speed Sensitive – Coefficient of friction drops as the speed of the vehicle increases.
- Pressure Sensitive - Coefficient of friction typically drops as more clamp force is generated.
- Temperature Sensitive - Coefficient of friction typically drops as the temperature of the brake system increases.
- More surface area of brake system, better heat dissipation via convection.

Conclusion

This paper reviews the studies of the contact pressure distribution of a solid disc brake as a result of structural modifications. Before modifications, the simulation is done on the basis different models of different degrees of complexity for contact analysis and stress analysis. Base on the analysis, it not only just replacing the friction plate, but also change the structural design and careful selection of brake friction parts in order to minimize brake noise. The sequel can be reduced by modifying the shape of the brake pads. The damping material also helps to reduce the brake noise.

SR .NO	TITLE OF PAPER	NAME OF AUTHOR	NAME OF JOURNAL	PURPOSE OF WORK	REMARK
1	Analysis of disc brake squeal using the complex eigenvalue method	P. Liu, H. Zheng, C. Cai, K.H. Ang, G.R	[1] Applied Acoustics 68 [2] (2007) 603–615	In this paper an investigation of disc brake squeal is performed by using the new complex eigenvalue capability of the finite element (FE) software ABAQUS version 6.4	The squeal can be reduced by decreasing the coefficient of friction, increasing the stiffness of the disc, using damping material on the back plates of the pads, and modifying the shape of the brake pads

2	Prediction of Disc Brake Contact Pressure Distributions by Finite Element Analysis	Abd rahim abu bakar & Huajiang Ouyang	Jurnal Teknologi, 43(A) Dis. 2005: 21–36	This paper presents the analysis of the contact pressure distributions at the disc/pad interfaces using a detailed 3-dimensional finite element model of a real car disc brake.	Modifications on the geometry and materials of disc brake components were performed to search for a more uniform contact pressure distribution
3	Analysis of heat conduction in a disk brake system	Faramarz Talati,Salman Jalalifar	2010 IEEE	In this paper analysis of heat conduction in disc brake and factor affecting brake fluid vaporization is observed.	temperature of the pad increases and consequently heat soaking to brake fluid increases and this may cause brake fluid vaporization. Therefore another provision that should be taken into account is to use a brake fluid with an appropriate DOT rating regarding to minimum dry and wet boiling points.
4	Research on Brake Noise of Air Disc Brake	Li Jin, Xu Jianchang, Luo Fang	2010IEEE	to control brake noise of disc braking system.	In this paper different methods are suggested for controlling the noise of disc brake.
5	Performance of a Disc Brake Friction Material	Pradnya Kosbe, Chittaranjan More	2010IEEE	In this paper the performance of disc brake friction material tested on the basis of experience and trial and error method.	This paper investigate the coefficient of friction variation is determined at various speeds and pressures.
6	A Study on Optimal Braking Control Using Adhesion Coefficient	Hanmin Lee & GildongKim	2007IEEE.	In these paper vibration characteristics of automobile disc brake and pad is studied.	Based on the review of researcher four degrees of freedom nonlinear dynamics model of brake disk and pads is established. Numerical method is taken to study the impacts of brake pressure, shape parameter and the brake disk's initial velocity on the vibration characteristics of brake disk and pads. The results show that the vibrations in the tangent directions intensify corresponding to the increase of brake pressure, and decrease when the relatively velocity excels certain values.

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A Review on Material Handling & Clamping System for wear plate welding machine

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Abstract- Wear plate welding machines requires some special raw material handling system as they are heavy to handle.Wear plate welding requires 4-5 workers for handling and clamping of raw material. This paper reviews different material handling equipment used by various industries. As the raw material is heavy, it is very difficult to handle manually. Hence there is requirement of integrated material handling and clamping system to do this heavy task. An integrated approach for material handling and clamping is suggested.

In this paper, various handling mechanisms like scissor lifting mechanism, hydraulic lift platform in scissors type mechanism, hydraulic lifting system based on multistage telescopic cylinder are discussed. Their analysis is done by using various software. Some failure diagnosis points are also discussed by mathematical calculations. Clamping mechanisms like electric power clamping device driven by step motor and screw-toggle-lever force amplifier in series, unilateral fixtures for sheet-metal parts with holes are discussed.
Keywords— Material handling systems, clamping system, mechanisms, analysis, CAD, CAE,wear plate welding machine.

INTRODUCTION

Wear plate welding machines are generally used for depositing material on the metal sheets. This causes increase in the life of the wear plate. These wear plates can be used for making boilers, cement plants, containers, etc. There is no standard provided for building this machine. It consist of one moving bed, welding guns, platform moving welding gun in x-direction. The bed with wheels is allowed to move in y-direction. The welding guns are used to deposit material on the surface of the wear plate in order to improve its life period.

Figure 1 shows the generalize structure of wear plate welding machine.

Fig 1: Wear plate welding machine[9]

In some industries weight of wear plate is always above 100kgs. Handling of wear plates in industry is big task. As the wear plate weight is high, more than one man gets involved for handling metal plates. These machines are local made machines so there is no such arrangement provided for handling the metal sheets. Most of the companies use crane system for lifting these plates.

Clamping of the wear plate in most of industries is done manually. They use C-clamps, L-clamps, nut and bolts for clamping. Even though the clamps are used, some packing materials always require for filling gap between clamps and wear plate surface. The size of the bed is fixed but the size of wear plate always varies. For the sizes less than the bed, there is always need of some temporary welding for fixing the clamps. These welded clamps are removed when the welding is over. For this one welder is always needed for every single cycle of welding.

So, this is very tedious work and takes nearly one hour for loading and unloading of these heavy wear plates. So, there is scope of automation up to certain extent.

BACKGROUND OF IDEAS

For designing a system for material handling and clamping, work is divided into two parts.1) Study of Handling mechanisms.2) Study of clamping devices and systems. Handling mechanism consists of loading of raw material and unloading of finished product. All the parameters like weight of raw material, size, etc are to be considered while studying.

A) MATERIAL HANDLING MECHANISMS

Various material handling equipment ideas are suggested by experts. These mechanisms can be considered while developing handling mechanism. First one is optimal design of Scissor Lifting Mechanism [5]. In this paper, a mathematical model is established for the research on scissor elevator by Tao Liu and Jian Sun. The kinematical and kinetic simulation analysis was carried out with MATLAB/Simulink. 3-D modeling of scissor lifting mechanism was developed. Pro/E software is used for modeling. The author suggested that the design was scientific and reasonable. It can be ideal document for one who is interested in modeling design of scissor lifting mechanism. Figure 2 shows scissor lifting mechanism.

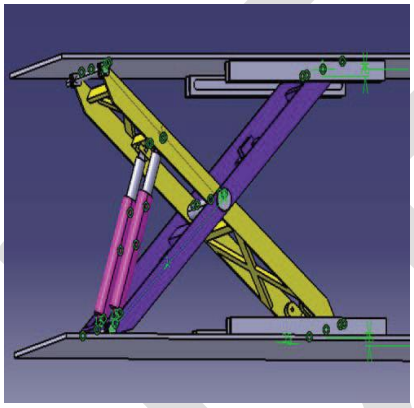

Fig 2: Scissor lifting mechanism [5]

Design and Simulation Based on Pro/E for a Hydraulic Lift Platform in Scissors Type is carried out by Tian Hongyu and Zhang Ziyi [4]. CAD software is used for modeling scissors lift platform. For the height of 8m the modeling is done. For that Pro/E software is used. This technique makes the possibility of assemble and the using performance analyses in front of manufacture. Figure 3 shows design of lift platform model.

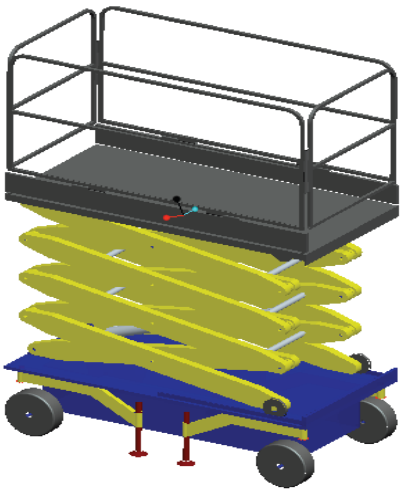

Fig 3: Lift platform model [4]

Taoping Yan [1] presented Analysis and Design on Air Controlled Hydraulic System about Dump Truck Lifting Mechanisms. In this paper, a lifting mechanism of hydraulic control system is discussed. By calculating the main technical parameters like control of power take, distance of lift , carriages stop, upward and downward motion of platform, lifting mechanism can be developed. The lifting mechanism has a hydraulic system of air control equipment, and other different characteristics. So while designing one should take into account for all these factors.

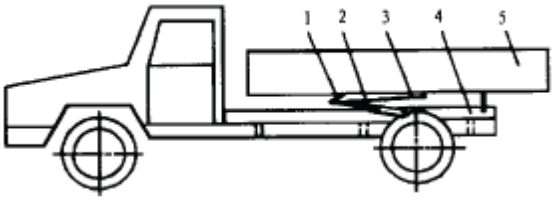

Fig 4: 3201Z-type lifting mechanisms [1]

As shown in figure 4, the air controlled hydraulic lifting mechanism used by 3201Z-type dump truck consists of the carriage (5), the Deputy Frame (4), lever (1, 3) and the lifting tanks (2).

Yang Miao and Shaoping Wang [2] presented Failure Diagnosis of Hydraulic Lifting System Based on Multistage Telescopic Cylinder. Failure modules and collaborative failure simulation platform for hydraulic lifting system based on multistage telescopic cylinder is discussed. This paper can simulate the detailed failure mode and its performance. It can also provide the design modification. The main factor for the design process is inappropriate bearing surface between two stages of multistage telescopic cylinder. Also proper alignment should be considered. The simulation results can suggest the nature of failure of multistage telescopic cylinder. Thus, fault diagnosis for lifting system can be done.

Sheet and pallet lifters can also be used for material handling. Various pallet lifters like sheet lifter with pin-on angle extensions, sheet lifter with adjustable position lifting feet and many more special purpose pallet lifters are also best for material handling. One of the examples is as shown in figure 5.

Fig 5: Pallet Lifter[10]

Up to this various material handling equipments are discussed. This can be helpful for designing handling system. Next step is study of clamping devices.

B) CLAMPING DEVICES AND MECHANISMS

As clamping on wear plate welding machine is challenging task, there are various mechanisms suggested by experts. Sun Chengfeng & Zhong Kangmin [3] suggested the electric power clamping device driven by step motor and screw-toggle-lever force amplifier in series. Its working principle is, the rotary motion of the step motor is changed into linear motion of the clamping component. It can always be maintained the clamping force acting on the work piece during manufacturing process. Figure 6 bellow shows the working principle of basic device.

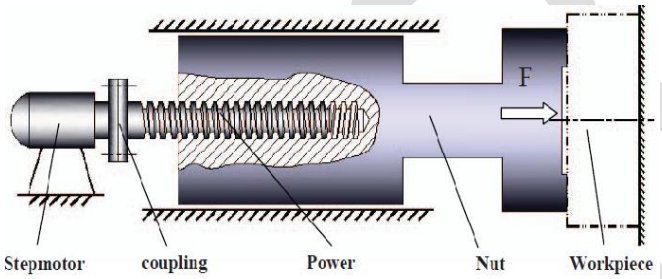

Fig 6: The working principal of basic device [3]

On the basis of above structure, there are four types of clamping derived which can be used for clamping as per requirement. These are as follows.

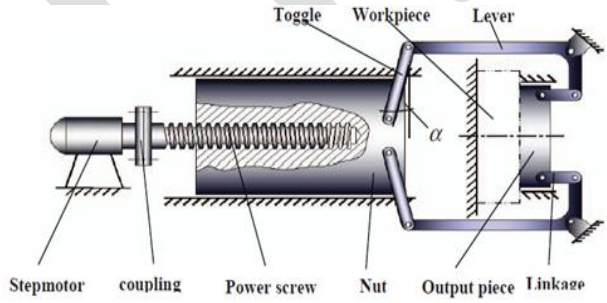

Fig 7: The one way inner clamp device [3]

Above figure 7 shows inner clamping device arrangement. It can be useful when clamping should be on inner side.

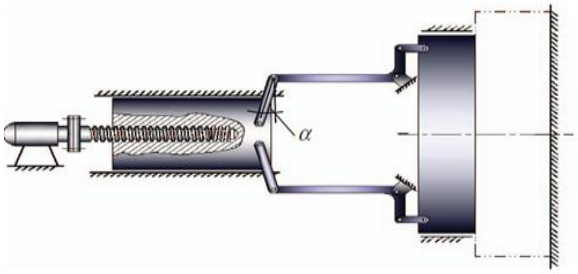

Fig 8: The one way outside clamping device [3]

After that, figure 8 showing outer clamping device is displayed. It can be useful when clamping should be from one side of work piece and from outside.

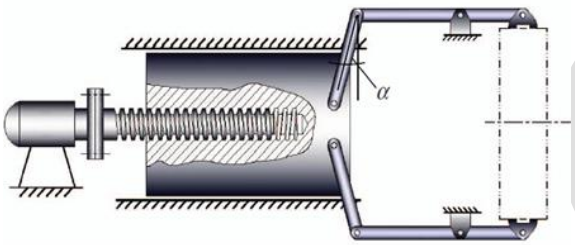

Fig 9: Bidirectional inner clamp device [3]

Bidirectional inner clamping device arrangement is shown in above fig 9. It is useful when inside clamping is required from both the sides of work piece.

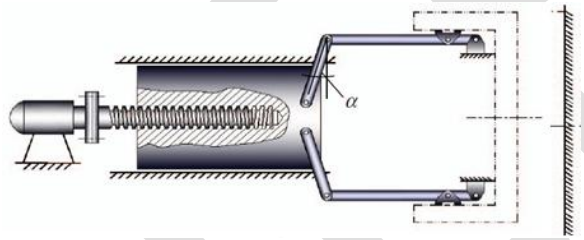

Fig 10: Bidirectional outer clamp device [3]

Lastly, bidirectional outer clamp arrangement as in above. It can be useful when clamping is required in both directional and from outside.

Detailed working of the four types of fixtures are discussed in the paper. These types of electrically operated clamps are useful as they are pollution free.

Cai-Hua Xiong, Michael Yu Wang, and You-Lun Xiong [7] suggested on clamping planning in work piece-fixture systems. In this paper a method for determining the optimal clamping forces is suggested. Also its magnitudes and positions can be suggested. A set of equations are derived. These equations are used to describe the relationship between the displacement of the work piece and the deformations at contacts. Further, a locally elastic contact model to characterize the nonlinear coupling between the contact force and elastic deformation at the individual contact is developed. It gives the minimum norm of the elastic deformations at contacts as the objective function, then suggested optimal clamping forces which guarantees that the fixturing of the work piece is force closure.

Gopalakrishnan K., Ken Goldberg,, Gary M. Bone, Matthew J. Zaluzec[8] presented unilateral fixtures for sheet-metal parts with holes. This paper introduces new way of holding sheet-metal with holes. A pairs of grooved cylinders, from only one side of the part is used for fixture. The cylinders mates with opposite corners of holes in the part. Also they are push apart to hold the sheet in

tension. It has both locators and clamps. It gives technical calculations for a unilateral fixture to hold a given part. An algorithm is specified for selecting unilateral fixtures automatically.

Jialiang Zhang, Jianguo Yang, Beizhi Li [6] suggested new type welding fixtures. It is reconfigurable. The parts having same type of features can be mounted on this fixture. Main advantage of this fixture is that, even if the dimensions of the features in the part changes, fixture is ready to adapt as per the dimensions. It consist of platform with number of holes in X and Y directions, supporting columns, locators and pneumatic control system. Software used for designing the fixture is UG. Analysis for displacement, stiffness, interference is done by using ANSYS and ADAMS. The modular mechanism is as in fig 11. bellow.

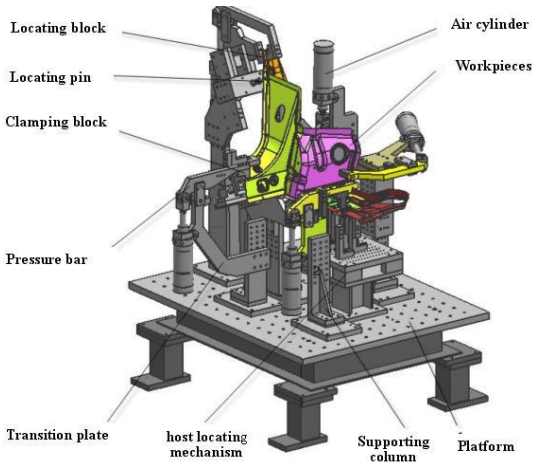

Fig 11: Modular Mechanism [6]

CONCLUSION

It is seen that by using various handling mechanisms, as per the conditions it can be helpful for welding process. As the wear plates are heavy, safety is all time priority. Clamping systems plays an important role during welding. By using such types of techniques which are discussed, it will lead to reduction in cycle time required for loading and unloading of part which is nearly one hour. Also automation provides less use of human efforts and indirectly leads to the safety of the operator.

Some concepts like electric power clamping device driven by step motor and screw-toggle-lever force amplifier in series, unilateral fixtures for sheet-metal parts with holes suggest new approach in their field. Significant improvement can be assured if modern CAE, CAD and computational techniques are used in designing the systems.

Summary of previous work done.

SR. NO	TITLE OF PAPER	NAME OF AUTHOR	NAME OF JOURNAL	PURPOSE OF WORK	REMARK
1)	Analysis and design on air controlled hydraulic system about dump truck lifting mechanisms	Taoping Yan	IEEE 2011	A lifting mechanism of hydraulic control system is discussed and suggested procedure for calculating it`s technical parameters.	Technical parameters like control of power take, distance of lift , carriages stop, motion of platform are calculated mathematically

2)	Failure diagnosis of hydraulic lifting system based on multistage telescopic cylinder	Yang miao and Shaoping wang	IEEE 2011	For analysis of hydraulic lifting system based on multistage telescopic cylinder, various possibilities of failures discussed.	Failure analysis of MTC is done with factors like hydraulic power supply, damage of bearing surfaces, wear and tear of piston, leakage, creeping & jam.
3)	Simulative calculation & optimal design of scissor lifting mechanism	TaoLiu, Jian Sun	IEEE, 2009	The kinematical and kinetic simulation analysis of scissor lifting mechanism for automobiles at high altitude work was carried out	Simulation analysis is done by using MATLAB/Simulink. Modeling is done by using Pro E.
4)	Design and Simulation Based on Pro/E for a Hydraulic Lift Platform in Scissors Type	Tian Hongyu, Zhang Ziyi	Elsevier Ltd. 2010	A design based 3D software Pro/E with 8m high scissors lift platform, which gives a entire platform dimension with 1800 × 900mm2.	Pro/E software is used for modeling lift platform for material handling.
5)	The Electric Power Clamping Device Driven by Stepmotor and Screw-Togge-Lever Force Amplifier in Series	Sun Chengfeng & Zhong Kangmin	IEEE 2011	A new type of electrical power clamping device is developed and its 4 basic models are suggested for clamping.	Four different clamping devices can be used as per requirement. The rotary motion of the step motor is converted into linear motion of the clamping component.
6)	On Clamping Planning in Workpiece-Fixture Systems	Cai-Hua Xiong, Michael Yu Wang, and You-Lun Xiong	IEEE, 2008	A general method for determining the optimal clamping forces including their magnitudes and positions is suggested.	It will help to calculate different clamping forces. Also it will help to find magnitude and position of clamping forces mathematically.
7)	Unilateral Fixtures for Sheet-Metal Parts With Holes	Gopalakrishnan K., Ken Goldberg,, Gary M. Bone, Matthew J. Zaluzec	IEEE, 2004	A new approach using pairs of grooved cylinders, activated from only one side of the part (hence “unilateral”).	Mathematically characterized the mechanics and conditions for a unilateral fixture to hold a given part. But it is not yet tested in CAD system

8)	Development of a Reconfigurable Welding Fixture System for automotive body.	Jialiang Zhang, Jianguo Yang, Beizhi LI.	ASME, 2009	Reconfigurable welding fixtures is designed for work pieces having same features but different dimension.	Modeling of fixture is done by UG software.For analysis of displacement and interference ANSYS and ADAMS are used.

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A Review on Optimization of Gating System for Reducing Defect

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Abstract- In the current global competitive environment there is a need for the casting units and foundries to develop the components in short lead time. Defect free castings with minimum production cost have become the need of foundry. The gating and riser system design plays an important role in the quality. Due to the lack of existing theoretical procedures the designing processes are normally carried on a trial-and-error basis. This paper review casting produced by foundry with internal shrinkage as a major defect was analyzed and identified that gating and risering system was improperly designed. The designed gating system reduced defect and increase yield. Finally, a more reasonable gating system was obtained by analysis of simulation results.

Keywords: Optimization; Casting design; Optimized casting design; Gating system; gating and riser design; Casting defects.

Introduction

Two major considerations in the casting design are the quality of the final product and the yield of the casting. Production of sound & quality casting mainly depend on gating system. In Casting design the gating & riser system design has a direct influence on quality of cast component. Most engineering problems, casting design is done trial and error basis. Availability of modern software tool give designer an insight into the detail of fluid flow, heat transfer. Gating/riser system design is critical to improving casting quality[1]. Casting as a manufacturing process to make complex shapes of metal materials in mass production may experience many different defects such as porosity, shrinkage, blowhole and incomplete filling. Improving the casting quality is important.

In casting there are two main stages, which are filling process and solidification process. In filling process consist of gating system composed of pouring cup, runner, sprue, and gate. Risers serve dual function, they compensate for solidification shrinkage and heat source so that they freeze last and promote directional solidification. Risers provide thermal gradients from a remote chilled area to the riser. Casting process design is important for production quality and efficiency. It is unavoidable that many different defects occur in casting process, such as porosity and incomplete filling. Casting quality is heavily dependent on the success of gating/riser system design, which currently is conducted mainly relied on technician's experience. Therefore there is a need for the development of a computer-aided casting process design tool with CAD, simulation, and optimization functions to ensure the quality of casting. Gating system is referred as all channels by means of which molten metal is delivered to mould cavity. Clean metal implies preventing the entry of slag and inclusions into the mould cavity, and minimizing surface turbulence.

Casting processes are widely used to produce metal parts in a very economical way, and to obtain complicated shapes with minimal machining for intended end use. A riser or a feeder is a reservoir to feed the molten metal to the casting to compensate the shrinkage during solidification. Riser is a passage made in the cope through which the molten metal rises after the mould is filled up. Risering in casting involves the determination of such size and location of risers which will enable the production of favorable temperature gradients for the directional solidification to take place effectively. Chills are achieving directional solidification. It is used preferably when the intricate shape of the casting does not allow placing of risers on all the thick sections or in which the large sections are so located that it is impossible to place risers over them. In such cases there will be different cooling rate for different section, giving rise to internal stresses causes cracks.Simulation is the process of imitating a real phenomenon using a set of mathematical equations implemented in a computer program. Using casting simulation visualization of mould filling, solidification and prediction of the location of internal defects such as shrinkage porosity, cold shuts and sand inclusions can be done. Moreover it is not only used for existing castings but also used in developing new castings without shop-floor trials.

Computer aided casting and design

Chokkalingam, Sidharthan[1] used a Pro-E software to build a casting model. They redesigned feeding system which is developed by Cast Calci in C using standard formulas available from the standard literature to do the calculation for the design of gating and risering system. Thoguluva Raghavan Vijayaram[2] used Boundary Element Method to get accurate result output and this is considered as an advanced technique by engineering scientists and engineering. Casting solidification simulation process is used to identify the

defective location in the casting from the generated time-temperature contour, which provide time-temperature data, temperature contours, hot spot location degree of rescalescene, latent heat of fusion and solidification time. Baha' I. Malaeb [3] use of CFD as a design tool for mould casting was demonstrated for a steel cast of an "ice cleat". The solidification model in FLUENT was used to model the solidification processes. The solidification throughout the mould was simulated using FLUENT for a number of different design scenarios. Based on the simulation an optimum feeder placement was chosen. Furthermore the use of CFD to improve yield by minimizing feeder volume was also demonstrated.

S. M. Yoo, J. K. Choi [4] Z-Cast™ was used to simulate the fluid flow in a sand mold. The optimal processing parameters for the cooling were obtained from the analysis of fluid flow and solidification. Numerical simulations of mold filling and solidification were used to optimize the casting process. The simulations were used to predict the temperature distributions and solidification sequences in the casting to optimize the casting conditions.B. Ravi [5] used intelligent assistant for casting engineers (AutoCAST) and describes how it assists in designing, modeling, simulating, analyzing and improving cast products over electronic networks providing a glimpse of the way castings will be designed in future. intelligent software can automate casting design, modeling, simulation, analysis and suggestions for improvement while allowing the user ultimate control over all decisions.

Optimization approaches

1. Multi-Objective Evolutionary Algorithm (MOEA)

Kor, Chen, Hu[6] used An optimization method Multi-Objective Evolutionary Algorithm (MOEA) is developed to overcome complexity. The proposed optimization framework is applied to the gating and riser design of a sand casting. It was shown that the MOEA method yields good results and provides more flexibility in decision making. In a multi-objective problem, the aim is to find a set of values for the design variables which optimizes a set of objective functions simultaneously. Multi-objective evolutionary algorithm (MOEA) is a vector optimization approach that tries to find as many different Pareto-optimal solutions as possible and spread them over the entire Pareto optimal front. The main advantage of this method is that the results are independent of any decision making process. Using this approach, inconsistencies in the problem formulation (e.g. weight settings, penalty formulations etc.) caused by the variation of individual knowledge and experience can be eliminated.

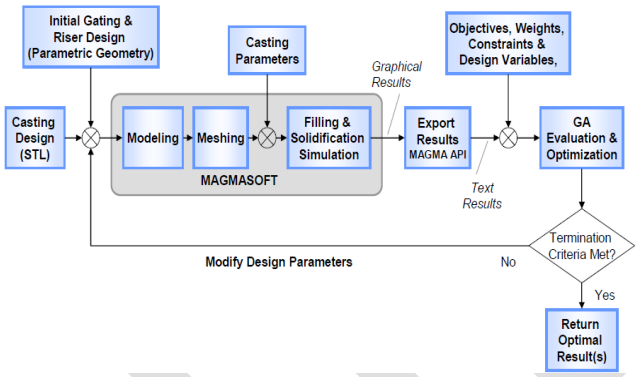

Fig.1. Schematic view of the CAD/CAE system[6].

2. Theory of Inventive Problem Solving (TRIZ)

Feng and Yi[7] Used the systematic method for identifying contradiction of casting process, which enhanced the conversion capability from specific problem to standard problem whilst improved the feasibility of TRIZ. It was observed that the integration of the systematic method and solving tools of TRIZ increased the efficiency of casting process optimization.The Theory of Inventive Problem Solving (TRIZ).Optimization of casting process is divided into problem analysis and contradictions identification, and problem solving and process optimization. It describe the casting defect, ascertainment the root cause, analyze and identify the factors in all levels, analyze the basic lowest level sub-problem using S-field model, and identify the contradictions. Define the problem. It is one of the most important innovation theories, which is suitable for complex multi-factors casting process problem.

3. Design of Experiments(DOE)

Senthilkumar.[8]used DOE as a tool to optimize the influencing factors. DOE is a series of ordered tests in which purposeful changes are made to input factors to identify the corresponding change in the output response variables. DOE is a statistical technique used to study the effect of the outcome of multiple variables simultaneously.Gating system is one of the influencing factor, the feeding system can be designed and dimensional once the optimal pouring temperature has been established, if the casting modulus is less than 0.3cm.However ensure that ingate does not froze off too early and thereby blocks the flow of feed metal from the pouring cup. It was concluded that, after employing the optimal factor values, the number of castings with pull-down defects were reduced. The approved percentage of castings had improved from 86.22% to 96.17%. Thus, by controlling pull-down defects, productivity was well improved.

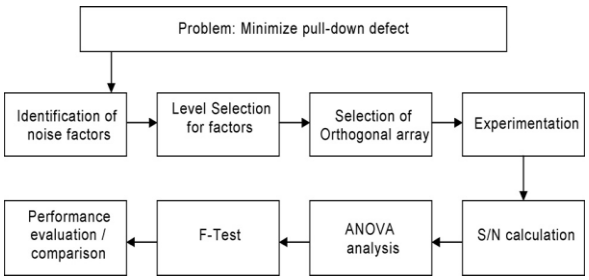

Fig.2 Factor optimization using Taguchi's DOE[8]

Sun, Hu, Chen[9] proposed an optimization technique for design of a casting based on the Taguchi method with multiple performance characteristics. As a result of this they found that the multiple performance characteristics such as shrinkage porosity, yielding in product can be simultaneously considered and improved through this optimization technique.

Feeder design rules

Designing a proper feeding system to account for the solidification shrinkage for a cast is guided by six main feeding rules [3]. These rules can be summarized as follows:
1. Heat transfer criterion: The feeder must solidify at the same time or later than the casting.
2. Mass transfer criterion: The feeder must contain sufficient liquid to meet the volume-contraction requirements of the casting.
3. The junction requirement: The junction between the feeder and the casting should not create a hot spot, i.e. be the last to solidify.
4. There must be a path to allow feed metal to reach feeding points.
5. There must be sufficient pressure differential requirement to cause the feed material to flow in the right direction.
6. There must be sufficient pressure at all points in the casting to suppress the formation of cavities.

Guided by these rules, the designer has to decide on the appropriate design parameters such as the position and the shape of the feeder for each particular case. These design decisions usually require skilled and experienced personnel and are iterative where different options are tried in the foundry and the valid one is chosen. This process gives priority to finding a sound design.
Tavakoli and Davami[10] have presented a method for automatic optimal feeder design in steel casting processes. Design of each feeder contains determination of the feeder-neck connection point on the casting surface, feeder shape optimization and feeder topology optimization.

Gating & Risering System

Gating system is to lead clean molten metal poured from ladle to the casting cavity, with less turbulence. Risers are used to compensate for liquid shrinkage and solidification shrinkage.[11]
1)No shrinkage defects: Risers have been designed and placed such that the whole casting is free from shrinkage.
2)Steady metal front rises up in the casting. There is no turbulence in the metal flow.
3)Initial dirty metal doesn't enter casting cavity neither does the slag.
4)Economy : Maximum yield. Weight of gating parts and risers is minimum.
5)Gating parts can be easily removed without affecting casting.
6)Pattern and gating parts fit on the match-plate with sufficient sand clearance.
7)Risering calls for a thermal analysis of the part. Gating parts calls for the fluid flow analysis.

Chills

Chills are metallic inserts placed in the mould at strategic places to extend the feeding distance. The ductile iron allows longer feeding distance than steel, so one can use less number of risers or avoid use of chills.[11]
1)Chill should be sufficiently thick so as not to fuse with the base metal.(0.6*T)
2)Chill should be clean, free from dents and dry. A rusty chill is highly prone to promote blow-holes near the contact area.
3)Chills in cope: It should be firmly locked in the mould .
4)If smaller chills are used than the requirement, shrinkage porosities will be observed.

Conclusion

Casting simulation technology has become an essential tool for casting defect troubleshooting and optimization method. It improves quality product without shop-floor trials.With the use of optimization techniques gating system of the casting are improve and increase the yield percentage of the casting. This would result reduction in cost and material saving. Many design rules, are developed over the years through experience and study. But For wide spread application, simulation programs must be easy to use, fast, and reliable. This can been achieved by integrating method design, solid modeling, simulation techniques. The Simulation software has proven its reliability and accuracy in predicting internal defects which help to reduced shop floor trials, and optimization using a single software program.

Review of papers

S.No	Title	Author	Published	Workdone	Remarks
1	Elimination of Defect & Increasing the Yield of a Ductile Iron Castings by Redesigning the Feeding System	B.Chokkalingam L.M.Lakshmann and I.V.Sidarthan	Indian Foudry Journal VOL.52, NO.6/JUNE,2006	Redesign gating and riser using Cast Calci in C language.	Defect reduced, and yield increases to 72% from 56%
2	Computer Simulation Of Solidification Of Casting Processed in Metallurgical Engineering Foundries	Thoguluva Raghavan Vijayaram	Indian Foundry Journal Vol.51, No. 4/April, 2005	BEM Simulation process help to identify defect location from the geometrical feature of component	It is use to identify the defective location in casting from time-temp. contours to eliminate defect
3	Integrating computer simulation of solidification in design process of feeding systems of castings	Malaeb B.	Integrating 3rd Faculty of Engineering and Architecture Student Conference, Beirut Lebanon, May 27-28,2004	Use of CFD as a design tool for mould casting was demonstrated for a steel cast of an “ice cleat”	It is found that use of CFD technology improve yield by minimizing feeder volume was also demonstrated.
4	Optimization of Casting Process for Heat and Abrasion Resistant Large Gray Iron Castings	S.M. Yoo, Y. S. Cho, C.C. Lee ,J. H. Kim , C. H. Kim, J. K. Choi	2008TSINGHUA SCIENCE AND TECHNOLOGY ISSN 1007-0214 07/20 pp152-156 Volume 13, Number 2, April	Z-Cast™ was used to simulate the fluid flow in a sand mold. Numerical simulations of mold filling and solidification were used to optimize	The simulations were used to predict the temperature distributions and solidification sequences in the casting to

				the casting process.	optimize the casting conditions.
5	Computer-Aided Casting Design – Past, Present and Future	Dr. B. Ravi	Indian Foundry Journal, 45(1), 65-74, 1999.	used intelligent assistant for casting engineers (AutoCAST) and describes how it assists in designing, modeling, simulating, analyzing and improving cast products	Autocast software can automate casting design, modeling, simulation, analysis and suggestions for improvising while allowing user to control all decision.
6	Multi-Objective Optimal Gating and Riser Design for Metal-Casting	Jean Kor, Xiang Chen, and Henry Hu	IEEE International Symposium on Intelligent Control, Part of 2009 IEEE Multi-conference on Systems and Control, Saint Petersburg, Russia, July 8-10, 2009	Vector optimization approach that tries to find as many different optimal solutions.	Yields good results and provides more flexibility in decision making after applied to the gating and riser design of a sand casting.
7	A systematic method for identifying contradiction of casting process	Liu Feng, Yang Yi	International Conference on Digital Manufacturing & Automation. 2010	One of the most important innovation theory used to eliminate the contradictions existing in technical systems.	Increased the efficiency of casting process optimization.
8	Process factor optimization for controlling pull-down defects in iron castings	B. Senthilkumar, S.G.Ponnambalam, N. Jawahar	2009 journal of materials processing technology 209 554–560,2009	Statistical technique used to study the effect of the outcome of multi variables simultaneously.	Pull-down defect was reduced. Productivity Improved.
9	Numerical optimization of gating system parameters for a magnesium alloy casting with multiple performance characteristics	Zhizhong Sun, Henry Hu, Xiang Chen	journal of materials processing technology 1 9 9 (2 0 0 8) 256–264.	Used an optimization method for design of a casting based on the Taguchi method for multiple performance characteristics.	It is found that the multiple performance characteristics such as shrinkage porosity, yielding in product can be simultaneously considered and

					improved through this optimization technique.

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