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Parts Handling Systems for Machine Shops of Small and Medium Enterprises

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Abstract— Low cost automation provides cost effective architectures and development approaches for transportation of components that properly integrate human skills and technical solutions. Most appropriate and judicious use of low cost material handling techniques become necessary to reduce the manufacturing cost, manufacturing cycle time, smooth material flow and remain competitive. This paper focuses on various issues typically faced by SMEs in handling parts during different stages of processing in a machine shop that houses a variety of machine tools.

Keywords— Low cost automation; Conveyors; Belt Conveyors; Roller Conveyors; AGV; Robots; Pallet Truck .

1. Introduction

The contribution of the small and medium sized enterprises (SMEs) to the industrial growth and economic well being of the nation often goes unnoticed and unappreciated despite of the fact that this sector provides for a large proportion of employment and feeds essential components to larger organizations. SMEs are also said to be responsible for driving innovation and competition in many economic sectors [1]. However, most SME's have to work with the following constraints from manufacturing stand point [2]:

- Less number of technically skilled manpower
- Limited funds available for the improvement
- Limited plant area
- Lack of advanced machineries & expertise

Automation is a means to improve the competitiveness by enhancing the productivity of the manpower and the equipment. This assumes special significance in the present context where small scale industries are facing high interest rates, shortage of skilled manpower and adherence to quality standards delivery schedules[3]. Procurement of sophisticated and highly automated new equipment becomes an expensive option as most SMEs invariably face financial crunch. They normally need lower budget modifications within the functional plant to improve the productivity. Focused efforts are thus required to improve the performance of this sector in respects of product quality and organizational productivity.

2. Low cost automation (LCA)

Low cost automation is an approach that permits enhancing the performance of existing facilities by incorporating simple mechanical, pneumatic, hydraulic or electrical systems and devices with low investments. The term ‘low cost’ is a relative quantification of cost incurred on renovation project [4][5].

Consistency of good quality and improvement of quality are the dominating demands of the time for survival of small scale and medium scale industries. Appropriate systems can be devised for parts handling automation on process machines or between operations for achieving smooth production flow, reducing manpower requirements, more consistent performance, reduced labour cost, achieving higher productivity and so on. This paper is aimed at providing a few guidelines in this context. It discusses merits, demerits and application situations for various material handling systems like conveyors, robotic handling systems, pneumatic systems, hydraulic systems, hoisting equipment, PLC based automation, retrofitting etc., currently used by various small scale industries, to reduce the inventory, for improved safety, for reducing damage and to improve material flow [6][7][8].

The real potential of low cost automation is not yet fully recognized in the small and medium scale industries. SME's are still dependent on manual work which causes drop in productivity. Low cost automation can be applied where manual work is being done for operations like material transfer, inspection etc. LCA is a continuous attempt to control mechanization and automation of certain work elements and is focused on prolonging the life and productivity of existing machine tools. It can be used to achieve quality in production, to lower the physical efforts of workers, where high skilled labor is required, to get rid of manual loading and unloading and to lower the rejection rate. It has wide variety of application which depend on the type of SME's we are dealing with [9].

Selecting the right kind of systems thus assumes great importance when evaluated in terms of the returns on investment. A wrong decision may lead to lowering production rate, ineffective utilization of available space etc. Choosing a material handling system within a machine shop is one of the toughest things to do. Small scale industries may design new material handling systems which requires lower setup cost or they may do small modification in current setup of material handling system.

3. Material handling systems for SMEs.

The shop floor supervisor is the best agency to identify the potential areas of the application of LCA. Some of the low cost automated parts handling systems which are widely used in SME's are explained below.

3.1. Conveyors

Conveyors are primarily horizontal-movement, fixed-path, constant speed material handling systems. However, they often contain inclined sections to change the elevation of the material as it is moving, switches to permit alternate paths and 'power-and-free' capabilities to allow the temporary slowing, stopping, or accumulating of material [1].

Broad variety of conveyors is being used in industries for handling the products. Flat belt conveyors, troughed belt conveyors, closed belt conveyors, metallic belt conveyors, portable conveyors and submerged belt conveyors are the types of belt conveyors which are being used within the industries to transfer material between two machines or to travel the material to some destination. Similarly wide variety of chain and roller conveyors are also used in industries. These include apron or pan conveyors, cross bar or arm conveyors, car type conveyors, carrier chain & flat top chain conveyors, trolley conveyors, suspended tray conveyor (swing tray conveyors), unpowered / idle roller conveyors and powered / live roller conveyors. All the above systems are costly, huge in size and occupy large space besides reducing easy accessibility and free movement space between machines. This is a vitally important concern for SMEs considering the fact that they have few less floor space, limited work force and limited resources. Evidently, all type of conveyors can't be used. Conveyor systems which occupy less floor area, are light in weight and are easy to operate only need be used by the SME's[10][11].

3.2 Portable conveyors

Short length flat conveyors carried on a wheeled structure is termed portable conveyor. Portable conveyors are light in weight and compact in design and can easily moved to desired places as we need. Portable conveyor has features like high durability, high efficiency, sturdy construction and precision functioning.

Loading and unloading on trucks / transport vehicles can be easily done with portable conveyors. They are suitable for parts handling between adjacent processing machines. Portable conveyor's inclination can be adjusted to suit the need [1].

Fig.1. Portable conveyor

3.3 Roller conveyors.

A roller conveyor features unit type of load on a number of rollers in series, mounted on bearings. Rollers are resting at equally spaced side frames which are fixed to stands or trestles placed on floor at certain intervals. A roller conveyor essentially coveys unit loads with at least one rigid, near flat surface to maintain stability while conveying. Products like boxes, sheets etc. can be easily conveyed with the help of roller conveyors [1] [12].

Roller conveyors are classified into two groups according to the principle of conveying action. These are:

3.3.1. Unpowered or idle roller conveyor

Roller conveyors which don't need any external power source for the conveying are nothing but the unpowered or idle roller conveyors. Please see fig.2. The loads roll over the series of rollers either by manual push or push from an endless moving chain or rope fitted with pusher dogs, rods or clamps. Generally inclination of 1.5% to 3% is provided for easy rolling of the products. Products are conveyed with the help of gravitational force. Such conveyors are termed 'gravity roller conveyor' [13].

These are particularly used between machines, buildings, in warehousing as storage racks, docks, foundries, rolling mill plants, manufacturing, assembly and packaging industry. They are also used for storage between work stations and as segment of composite handling system. Rollers conveyors have few disadvantages like only flat surfaced objects can be conveyed, material can be transferred to only short distances etc. [14][15].

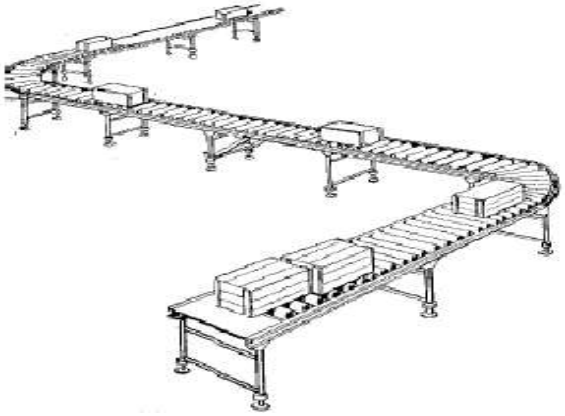

Fig.2. General view of an unpowered roller conveyor [1].

3.3.2 Powered roller conveyor

Powered roller conveyors, also called as live roller conveyors, have all or a few of the rollers (generally the first, the last and a few middle rollers) driven by one or multiple motors through associated transmission system like chain drives and belt drives. The loads on the roller conveyor are moved by the frictional force caused between the loads and the driven rollers supporting the loads.

Powered roller conveyors are intensively used where heavy weights are to be conveyed for long distances on the shop floor, especially in industries where there is problem of availability of work force [1]. Plant layout is required to be designed to optimize the length of the conveying system. Such systems can be used for SMEs for dedicated material handling when volume of production is high and product variability is very low [16].

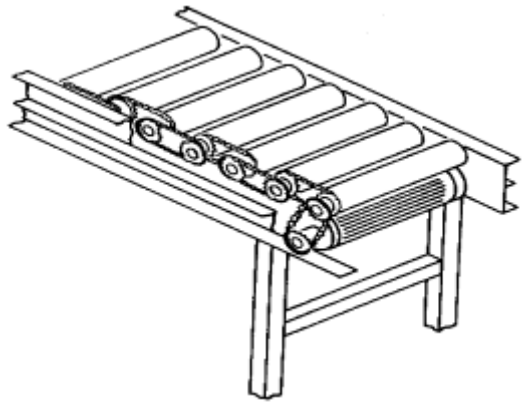

Fig.3. Powered roller conveyor

4. Automatic guided vehicles

An automated guided vehicle system (AGVS) is a material handling system that uses independently operated, self propelled vehicles guided along defined pathways. Driverless towing tractors guided by wires embedded into or affixed onto the floor have been available since the early 1950s. Today AGV's are competing with conveyors and other material handling system due to their advanced features like sensors, ability to take decisions, automatic path changing mechanisms etc. Most AGVs have only horizontal motion capabilities. Any vertical motion is limited [2][17].

Power for the automatic guided vehicle is usually a battery, like that of the electric industrial truck. Path guidance may be provided in several ways such as optical guidance, embedded wire system, laser beam guidance system, electrical guidance or magnetic guidance can be implemented in AGV's [2].

The directions that an AGV can travel may be classified as unidirectional (one way), bidirectional (forward or backward along its path) or omnidirectional (all directions). The AGVS which can travel along all directions and equipped with advanced technologies like microprocessors and sensors are also called as self guided vehicles (SGV's) and are provided with anti-collision systems to prevent damage to equipment and parts they carry[18].

AGVs and SGVs are not a convenient option to use for SMEs since they require dedicated isle spaces and often cost significantly. However, for manufacturing cells with CNC machines arranged in linear layout, simple AGV's systems can be a boon to SMEs. This would be particularly suited to cells where the CNCs perform multiple operations with a single parts setting and the station's total processing time (cycle time) is large. During this period, an AGV may be considered to work as shuttle for transporting parts from one machine to another while machines are busy processing parts.

5. Robots

Use of robots in industries is a common seen today albeit in SMEs. An industrial robot is an assemblage of links joined so that they can be articulated into desired positions by a reprogrammable controller and precision actuators to perform a variety of tasks like material transfer and inspection. Robots range from simple devices to very complex and ''intelligent'' systems by virtue of added sensors, computers, and special features [2][3]. The most obvious anthropomorphic characteristic of an industrial robot is its mechanical arm, which is used to perform various industrial tasks. Robots are of several types and models and are readily available in a wide range of shapes, sizes, speeds, load capacities, and other characteristics. Robot must be selected and specified to suit the kind of processing or handling application. Care must be taken to select a robot to match the requirements of the SME after thorough evaluation of the tasks to be done. Or else, it becomes one more case of selecting robot wrongly. Sensing and control technologies are well established and must be appropriately incorporated considering the application on hand. Robots, being programmable multi-jointed machines, fall between humans and fixed-purpose machines in their utility. In hazardous conditions like working in very high temperature or cold humans can't work properly. Humans can be replaced by an industrial robot which can work perfect in such conditions without spoiling quality of work [2][19].

For small and medium scale industries robots can be the best option over the other automated system. In SME's robots can be used to transfer materials in between two machines, within the single machine or for any kind of repeatable work. An industrial robot can increase the productivity of SME's to great extent rather they can reduce human interference within the production. Cost is the dominating reason for its not being favoured much. However, for situations where production rate is high (low cycle time) and the operation is largely pick & place type, use of simple robot is suggested for low weight components. By middle of this decade, many of the SME's may think of setting up robots within their manufacturing facilities [20].

6. Hydraulic pallet trucks

Pallet trucks are either motor operated or manual low-lift machines designed to raise loaded pallets sufficiently off the ground to enable the truck to transport the pallet horizontally. Pallet trucks are widely used material handling device and well known for its flexibility [2] [21].

The hydraulically operated pump and handle assembly enables the operator to manually operate and propel pallet truck, raise the truck forks, and push/pull the load. Electric-battery-powered pallet trucks, available in motorized versions, are equipped with dc electric motors to electrically raise and transport parts. The power supply for these trucks is an on-board lead-acid traction battery that is rechargeable when the truck is not in use [2].

Extensive use of pallet trucks in SMEs is recommended in view of their low cost, easy availability, low maintenance and suitability to handle a wide variety of jobs. Human effort for handling heavy jobs is considerably reduced. Even if manual pallet trucks don't provide any automation, they still remain the most accepted material handling device in SMEs.

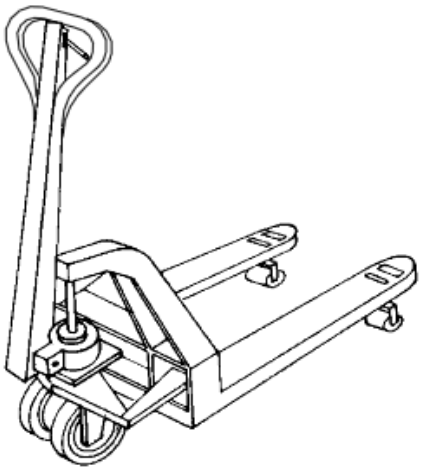

Fig.4. Manually operated and propelled pallet truck [2].

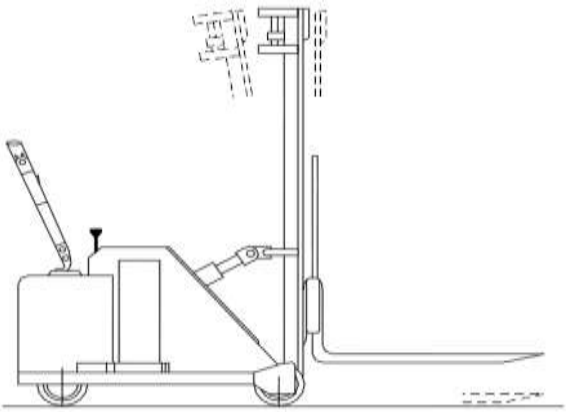

Fig.5. Counterbalanced electric-battery-powered pallet truck [2].

7. Hydraulic and pneumatic parts handling systems

The rapid development of electronic interfacing technology had seen the proliferation of electro-hydraulics and electro-pneumatics devices. Fluid, electric and solar powers are some of the energy technologies used for driving modern automated systems. Of these technologies fluid power is mainly reserved for traditional utilization. Hydraulic power is normally used in mechanisms and pneumatic power for sequential automated process.

Various combinations of hydraulic and pneumatic attachments can be used to bring the automation in SME's like pneumatic or hydraulic clamping devices, hydraulic pallet trucks for material handling, rotary indexing tables etc. SME's can implement these types of hydraulic and pneumatic attachment devices to either existing machines or in completely new setup.

7.1 Hydraulic parts handling systems

Hydraulic systems usually convert the mechanical energy from an electric motor to fluid power. A positive displacement pump is used to increase the pressure of a hydraulic oil, generally petroleum based.

Hydraulic material handling system includes devices like electric hoists, scissor lifts, portable cranes, hydraulic pallet trucks, jib cranes, drum trolleys, fork type drum trolleys, trolleys and weavers beam trolleys. By using high pressure, the size of component becomes small and the system becomes very compact which is good for small scale industries where work area is limited.

7. 2 Pneumatic parts handling systems

Availability of high pressure air for operating clamping devices, various tools, cleaning etc in a manufacturing establishment is universal. Extensive use of compressed air for actuating mechanical systems for gripping, pushing, tilting, lifting and similar several operations is suggested. Pneumatically powered mechanical handling are required to be built for handling machine parts and components on machine tools and between machines, by the SMEs.

In pneumatic systems, instead of oil under very high pressure, air at a much lower pressure is used. Similar to hydraulic systems, here too valves, pipes and cylinders are needed. Pneumatic systems are very popular for low cost automation since the cost is much less than that of hydraulic systems. Apart from this, pneumatic material handling systems are easily distinguished for various advantages such as abundant availability of the operating medium (air) in contrast to costly oils used for hydraulic systems, easy control over leakage problem, safety in operation, high speed of operations etc [22].

Pneumatic material handling systems such as vacuum transport (used to transport powder and granulated materials), air slide conveyors (used to transport fined grained particles with high capacity) etc are used in hi-tech industries. Vacuum systems can be manufactured for single or multipurpose applications. System can be also built as independent portable units. Materials most suited for handling are ash and cement.

Pneumatic material handling would be money consuming for small and medium sized enterprises because of high initial investment in equipment. It still, in some special cases, would be the most effective and productive method of handling machined parts. In fact, pneumatic systems present a plethora of ideas on which innovative parts handling systems can be developed for any machine shop. All that is needed is identifying a problem situation and finding standard pneumatic manipulating system to match the need.

8. PLC (Programmable Logic Controller) for LCA

Early PLC's were only capable of ON/OFF control, being specifically developed for applications limited to repetitive processes like automated transfer lines, SPMS (special purpose machines), and batch process sequencing. A programmable logic controller can be defined as microcomputer based controller that uses stored instructions in programmable memory to implement logic, sequencing, timing, counting and arithmetic functions through digital or analog input/output modules, for controlling machines and processes [3][23].

To meet the demands of harsh industrial environments, PLCs are designed to be extremely robust, often capable of withstanding extreme temperatures, humidity, vibration, and electrical noise. Logic controllers are commonly tasked with monitoring and controlling a very large number of sensors and actuators, and are therefore distinct from other computer systems in their extensive input/output (I/O) arrangements.

High-speed sorting on conveyors, image-processing inspection, bottle filling control, air cleaner control, sheet feeding control in packing machine, testing equipment, conveyor positioning control, basic conveyor rail width positioning, production line conveyor shift unit etc. are few of the hundreds of applications of PLC's [24].

PLC system can be easily implemented in small and medium scale industries to improve the production rate to great extent. PLC systems are well developed and easily obtainable from service providers at reasonable cost. It’s a definite and sure way to control production machines, automate inspection and achieve repeatability.

9. Conclusion

It is seen that umpteen opportunities exist in SMEs to upgrade and improve existing facilities by making use of low cost automation strategies. Most of the material handling systems in SMEs continue to function for several years, as initially installed, just because the same remain uninvestigated with an eye on improving quality and productivity. Scenario can be improved drastically through simple solutions and making use of some innovative ideas and available resources.

Application of LCA calls for systematic data collection, its analysis and finding a technical solution for every conceivable problem area across the plant. This however is not a simple job. Various factors are required to be considered by dedicated task teams for selecting a material handling system for a machine shop and other possible LCA solutions. Part geometries, weight of parts handled, distance between workstations, time required for manufacturing, cycle time, available work space etc. are some of the important factors which must be assessed to evaluate the cost benefits as also various tangible and intangible gains, as outcome of the proposed strategy.

It would be readily noticed that, with relatively low investments, LCA systems certainly enable the managements to lower the workers involvement in material handling. This automatically lowers the part rejections, improves safety and reduces accident rate, nurtures productive ambience and contributes significantly to product quality and organizational productivity.

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