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Review of Literature Survey on Effect of Thermal Coating on Cylinder and Piston Crown

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Abstract— The desire to reach higher efficiencies, lower specific fuel consumptions and reduce emissions in modern internal combustion (IC) engines has become the focus of engine researchers and manufacturers for the past three decades. The global concern over the decreasing supply of fossil fuels and the more stringent emissions regulations has placed the onus on the engine industry to produce practical, economical and environmentally conscious solutions to power our vehicles.

Over the years, a variety of different approaches have been taken to attain improvements in efficiency and reduce emissions in existing engine designs. The introduction of new technologies has played a role in making advancements to this century-old technology. Lighter and stronger materials, advanced manufacturing processes, improved combustion chamber designs, advanced exhaust after-treatment technologies, and new computational means for designing, analyzing and optimizing the internal combustion engine are just a few of the advancements we have made to achieve significant improvements in performance, efficiency and emissions. The review of different research paper is reflected different methodology such as thermal barrier coating, HVOF (High velocity oxygen fuel) coating, Particle image velocimetry (PIV), Coating thickness and roughness effect etc. And such system they had applying such kind of coating process those are metal sheet, gas turbine, parabolic reflector, automobile industry etc. Some research paper indicated about optimization method applied coating structure and FEA analysis or CFD analysis. In CI and SI engine, they were done component level coating as per design requirement for surface roughness and life of component. There was not work done on energy saving during power stroke and there is not any provision for inside coating method from above research paper survey.

Keywords— Internal Combustion (IC) Engines, Performance, Manufacturing Processes, Cylinder, Emission, Efficiency, Compression.

INTRODUCTION

The quantity of the energy acquired from the fuel is not an intended level because of the factors in the combustion chamber of the engine. Some of the factors are, design of the combustion chamber, lack of adequate turbulence in the combustion chamber, poor oxygen at the medium, lower combustion temperature, compression ratio and advance of injection timing. It is thought that combustion temperature is the one of the most important factor among the aforementioned factors. All of the hydrocarbons cannot be reacted with oxygen chemically at the during combustion time. With this aim, coating combustion chamber components with low thermal conductivity materials becomes a more important subject at these days. For this reason, combustion chamber components of the internal combustion engines are coated with ceramic materials using various methods.

The efficiency of most commercially available diesel engine ranges from 38% to 42%. Therefore, between 58% and 62% of the fuel energy content is lost in the form of waste heat. Approximately 30% is retained in the exhaust gas and the remainder is removed by the cooling, etc. More than 55% of the energy which is produced during the combustion process is removed by cooling water/air and through the exhaust gas. In order to save energy, it is an advantage to protect the hot parts by a thermally insulating layer. This will reduce the heat transfer through the engine walls, and a greater part of the produced energy can be utilized, involving an increased efficiency.

The major promises of thermal barrier coated engines were increased thermal efficiency and elimination of the cooling system. A simple first law of thermodynamics analysis of the energy conversion process within a diesel engine would indicate that if heat rejection to the coolant was eliminated, the thermal efficiency of the engine could be increased.

Thermal barrier coatings were used to not only for reduced in-cylinder heat rejection and thermal fatigue protection of underlying metallic surfaces, but also for possible reduction of engine emissions.

Thermal insulation brings, according to the second law of thermodynamics, to engine heat efficiency improvement and fuel consumption reduction. Exhaust energy rise can be effectively used in turbocharged engines. Higher temperatures in the combustion chamber can also have a positive effect in diesel engines, due to the ignition delay drop and hardness of engine operation.

LITERATURE SURVEY

Abdullah Cahit Karaoglanli, Kazuhiro Ogawa,Ahmet Türk and Ismail Ozdemir, “Thermal Shock and Cycling Behavior of Thermal Barrier Coatings (TBCs) Used in Gas Turbines” [**1**] has presented Gas turbine engines work as a power generating facility and are used in aviation industry to provide thrust by converting combustion products into kinetic energy. Basic concerns regarding the improvements in modern gas turbine engines are higher efficiency and performance. Increase in power and efficiency of gas turbine engines can be achieved through increase in turbine inlet temperatures. The materials used should have perfect mechanical strength and corrosion resistance and thus be able to work under aggressive environments and high temperatures. The temperatures that turbine blades are exposed to can be close to the melting point of the super alloys. Internal cooling by cooling channels and insulation by thermal barrier coatings (TBCs) is used in order to lower the temperature of turbine blades and prevent the failure of super alloy substrates.

L. Wang, X.H. Zhong, Y.X. Zhao, S.Y. Tao, W. Zhang, Y. Wang, X.G. Sun, “Design and optimization of coating structure for the thermal barrier coatings fabricated by atmospheric plasma spraying via finite element method” **[2]** has presented fabricating the thermal barrier coatings (TBCs) with excellent performance is to find an optimized coating structure with high thermal insulation effect and low residual stress. This paper discusses the design and optimization of a suitable coating structure for the TBCs prepared by atmospheric plasma spraying (APS) using the finite element method. The design and optimization processes comply with the rules step by step, as the structure develops from a simple to a complex one. The research results indicate that the suitable thicknesses of the bond-coating and top-coating are 60–120 μm and300–420 μm, respectively, for the single ceramic layer YSZ/NiCoCrAlY APS-TBC.

D. Freiburg, D. Biermann, A. Peukera, P. Kersting,H. -J. Maier, K. Möhwald, P. Knödler, M.Otten, “Development and Analysis of Microstructures for the Transplantation of Thermally Sprayed Coatings” **[3]** has presented thermally sprayed coatings and tribological surfaces are a point of interest in many industrial sectors. They are used for better wear resistance of lightweight materials or for oil retention on surfaces. Lightweight materials are often used in the automotive industry as a weight-saving solution in the production of engine blocks. It is necessary to coat the cylinder liners to ensure wear resistance. In most cases, the coating is sprayed directly onto the surface. Previous research has shown that it is possible to transfer these coatings inversely onto other surfaces. This was achieved with plasma sprayed coatings which were transplanted onto pressure-casted surfaces.

Mr. Atul A. Sagade, Prof. N.N. Shinde, Prof. Dr. P.S. Patil, “Effect of receiver temperature on performance evaluation of silver coated selective surface compound parabolic reflector with top glass cover”**[4]** has presented the experimental results of the prototype compound parabolic trough made of G.I and silver coated selective surface. The performance of collector has been evaluated with three kinds of receiver coated with two kinds of receiver coatings black copper and black zinc and top cover. This line focusing parabolic trough yields instantaneous efficiency of 60 %with top cover. A simple relationship between the parameters has been worked out with the regression analysis. [Latitude: 16.42° N, Longitude: 74.13°W]

Andrew Roberts, Richard Brooks, Philip Shipway, “Internal combustion engine cold-start efficiency: A review of the problem, causes and potential solutions” **[5]** has presents vehicle emissions continues to become more stringent in an effort to minimise the impact of internal combustion engines on the environment. One area of significant concern in this respect is that of the cold-start; the thermal efficiency of the internal combustion engine is significantly lower at cold start than when the vehicle reaches steady state temperatures owing to sub-optimal lubricant and component temperatures. The drive for thermal efficiency (of both the internal combustion engine and of the vehicle as a whole) has led to a variety of solutions being trialed to assess their merits and effects on other vehicle systems during this warm-up phase (and implemented where appropriate). The approaches have a common theme of attempting to reduce energy losses so that systems and components reach their intended operating temperature range as soon as possible after engine start. In the case of the engine, this is primarily focused on the lubricant system. Lubricant viscosity is highly sensitive to temperature and the increased viscosity at low temperatures results in higher frictional and pumping losses than would-be observed at the target operating temperature.

T. Karthikeya Sharma, "Performance and emission characteristics of the thermal barrier coated SI engine by adding argon inert gas to intake mixture" **[6]** has investigates Dilution of the intake air of the SI engine with the inert gases is one of the emission control techniques like exhaust gas recirculation, water injection into combustion chamber and cyclic variability, without scarifying power output and/or thermal efficiency (TE). This paper investigates the effects of using argon (Ar) gas to mitigate the spark ignition engine intake air to enhance the performance and cut down the emissions mainly nitrogen oxides. The input variables of this study include the compression ratio, stroke length, and engine speed and argon concentration. Output parameters like TE, volumetric efficiency, heat release rates, brake power, exhaust gas temperature and emissions of NOx, CO_2 and CO were studied in a thermal barrier coated SI engine, under variable argon concentrations. Results of this study showed that the inclusion of Argon to the input air of the thermal barrier coated SI engine has significantly improved the emission characteristics and engine's performance within the range studied.

J. Barriga, U. Ruiz-de-Gopegui, J. Goikoetxeaa, B. Coto, H. Cachafeiro, "Selective coatings for new concepts of parabolic trough collectors" **[7]** has presented the CSP technology based on parabolic trough solar collector for large electricity generation purposes is currently the most mature of all CSP designs in terms of previous operation experience and scientific and technical research and development. The current parabolic trough design deals with a maximum operating temperature around 400ºC in the absorber collector tube but some recent designs are planned to increase the working temperature to 600ºC increasing the performance by 5-10% to attain the improved productivity that the market demands .These systems are expected to be working during 20-25 years. One of the key points of the receiver is the stack of layers forming the selective absorber coating. With this new design the coating has to fulfill new requirements as the collector will be working at600ºC and in a low vacuum of 10-2 mbar.

V.D. Zhuravlev, V.G. Bamburov, A.R. Beketov, L.A. Perelyaeva, I.V. Baklanova,O.V. Sivtsova, V.G. Vasil'ev, E.V. Vladimirova, V.G. Shevchenko, I.G. Grigorov, "Solution combustion synthesis of a-Al_2O_3 using urea" **[8]** has presents processes involved in the solution combustion synthesis of a-Al2O3 using urea as an organic fuel were investigated. The data describing the influence of the relative urea content on the characteristic features of the combustion process, the crystalline structure and the morphology of the aluminum oxide are presented herein. Our data demonstrate that the combustion of stable aluminum nitrate and urea complexes leads to the formation of a-alumina at temperatures of approximately 600–800°C. Our results, obtained using differential thermal analysis and IR spectroscopy methods, reveal that the low-temperature formation of a-alumina is associated with the thermal decomposition of an α-AlO (OH) intermediate, which was crystallized in the crystal structure of the diaspore.

Helmisyah Ahmad Jalaludin, Shahrir Abdullah, Mariyam Jameelah Ghazali, Bulan Abdullah, Nik Rosli Abdullah, "Experimental Study of Ceramic Coated Piston Crown for Compressed Natural Gas Direct Injection Engines" **[9]** has presents High temperature produced in a compressed natural gas with direct injection system (CNGDI) engine may contribute to high thermal stresses. Without appropriate heat transfer mechanism, the piston crown would operate ineffectively. Bonding layer NiCrAl and ceramic based yttria partially stabilized zirconia (YPSZ) were plasma sprayed onto AC8A aluminium alloy CNGDI piston crowns and normal CamPro piston crowns in order to minimize thermal stresses.

Vinay Kumar. D, Ravi Kumar.P, M.Santosha Kumari, "Prediction of Performance and Emissions of a Biodiesel Fueled Lanthanum Zirconate Coated Direct Injection Diesel engine using Artificial Neural Networks" **[10]** has presented different techniques are being attempted over the years to use low pollution emitting fuels in diesel engines to reduce tail pipe emissions with improved engine efficiency. Especially, Biodiesel fuel, derived from different vegetable oils, animal fat and waste cooking oil has received a great attention in the recent past. Trans esterification is a proven simplest process to prepare biodiesel in labs with little infrastructure. Application of thermal barrier coatings (TBC) on the engine components is aseriously perused area of interest with low grade fuels like biodiesel fuels. Artificial neural networks (ANN) are gaining popularity to predict the performance and emissions of diesel engines with fairly accurate results besides the thermodynamic models with considerably less complexity and lower computing time.

Nitesh Mittal, Robert Leslie Athony, Ravi Bansal, C. Ramesh Kumar, "Study of performance and emission characteristics of a partially coated LHR SI engine blended with n-butanol and gasoline" **[11]** has describes to meet the present requirements of the automotive industry, there is continuous search to improve the performance, exhaust emission, and life of the IC engines. The meet the first two challenges, researchers are working both on newer engine technologies and fuels. Some of the published work indicates that coating on the combustion surface of the engine with ceramic material results in improved performance and reduced emission levels when fueled with alternate fuel blended fuels, and this serves as a base for this work. Normal-Butanol has molecular structure that is adaptable to gasoline, and it is considered as one of the alternative fuels for SI engines.

Helmisyah A.J., Ghazali M.J., "Characterisation of Thermal Barrier Coating on Piston Crown for Compressed Natural Gas Direct Injection (CNGDI) Engines" **[12]** has presented the high temperature and pressure produced in an engine that uses compressed natural gas with direct injection system (CNGDI) may lead to high thermal stresses. The piston crown fails to operate effectively with insufficient heat transfer. In this study, partially stabilized zirconia (PSZ) ceramic thermal barrier coatings were plasma sprayed on CNGDI piston crowns (AC8A aluminium alloys) to reduce thermal stresses. Several samples were deposited with NiCrAl bonding layers prior to the coating of PSZ for comparison purposes. Detailed analyses of microstructure, hardness, surface roughness, and interface bonding on the deposited coating were conducted to ensure its quality. High stresses were mainly concentrated above the pinhole and edge areas of the piston. In short, the PSZ/ NiCrAl coated alloys demonstrated lesser thermal stresses than the uncoated piston crowns despite a rough surface. Extra protection is thus given during combustion operation.

Ming SONG, Yue MA, Sheng-kai GONG, "Analysis of residual stress distribution along interface asperity of thermal barrier coating system on macro curved surface" **[13]** has presented the Royal Automotive Club of Victoria (RACV) Energy Breakthrough annual event is to provide an opportunity to school students to design and develop human powered vehicles (HPVs) and race a nonstop 24 hours event that requires energy conservation, endurance and reliability. The event involves primary and secondary school students, teachers, parents and local industry to work together on the design and use of energy efficient vehicles. The key areas with interest of HPVs are the significance of aerodynamic design and ways to improve overall aerodynamics as most HPVs are designed with minimal or no aerodynamic consideration.

A. Moridi, M. Azadi and G.H. Farrahi, "Coating thickness and roughness effect on stress distribution of A356.0 under thermo-mechanical loadings" **[14]** has presented Cast aluminium-silicon alloy, A356.0, is widely used in automotive components such as diesel engine cylinder heads and also in aerospace industries because of its outstanding mechanical, physical, and casting properties. Thermal barrier coatings are applied to combustion chamber in order to reduce fuel consumption and pollutions and also improve fatigue life of components. However, studies on behaviour of A356.0 with thermal barrier coating are still rare. The purpose of the present work is to simulate stress distribution of A356.0 under thermo-mechanical cyclic loadings, using a two-layer elastic-visco-plastic model of ABAQUS software. The results of stress strain hysteresis loop are validated by an out of phase thermo-mechanical fatigue test. Ceramic coating thickness effect on stress distribution of test specimens is investigated. Different thicknesses from 300 to 800 microns of top coat and also roughness of the interfaces are simulated to get best stress gradient which can cause an improvement of fatigue life.

M. Fadaei, H. Vafadar, A. Noorpoor, "New thermo-mechanical analysis of cylinder heads using a multi-field approach" **[15]** has presented a thermo-mechanical analysis of a natural gas, internal combustion engine cylinder head are presented in this paper. The results are pertinent to the evaluation of overheating damage in critical areas. The three-dimensional geometries of the cylinder head and the water jacket were modeled by means of a computer-aided engineering tool. Commercial finite element and computational fluid dynamics codes were used to compute details of mechanical stress in the head and flow details in the cylinder and cooling jacket, respectively. A six-cylinder, four-stroke diesel engine and a spark-ignition natural gas engine were modeled over a range of speeds at full load. Computed results, such as maximum allowable cylinder pressure, output power, BMEP and BSFC, were validated by experimented data in the diesel engine model. The results were in good agreement with experimental data. The results show high stresses at the valve bridge. Cylinder head temperatures and comparison of output power with high stress measurements, often exceeding the elastic limit, were found at the valve bridge.

B. Murali Krishna and J.M. Mallikarjuna, "Effect of Engine Speed on In-Cylinder Tumble Flows in a Motored Internal Combustion Engine-An Experimental Investigation Using Particle Image Velocimetry" **[16]** has presented the stratified and direct injection spark ignition engines are becoming very popular because of their low fuel consumption and exhaust emissions. But, the challenges to them are the formation and control of the charge which is mainly dependent on the in-cylinder fluid flows. An optical tool like particle image velocimetry (PIV) is extensively used for the in-cylinder fluid flow measurements. The experimental investigations of the in-cylinder fluid tumble flows in a motored internal combustion engine with a flat piston at different engine speeds during intake and compression strokes using PIV. The two-dimensional in-cylinder flow measurements and analysis of tumble flows have been carried out in the combustion space on a vertical plane at the cylinder axis. To analyze the fluid flows, ensemble average velocity vectors have been used.

A.Triwiyanto, E. Haruman, M. Bin Sudin. S. Mridha and P.Hussain, "Structural and Properties Development of Expanded Austenite Layers on AISI 316L after Low Temperature Thermo chemical Treatments" **[17]** has presented low temperature thermo chemical treatments in fluidized bed furnace involving nitriding, carburizing and hybrid treating, sequential carburizing-nitriding, have been conducted with the aim to improve surface properties of AISI 316L. The resulting layer is expanded austenite which is responsible to the higher hardness and better wears properties. Characterization of this expanded austenite layer were performed including XRD analysis, SEM and SPM and micro hardness indentation were used to reveal the characters of the produced thin layers.

B.M. Krishna and J.M. Mallikarjuna, "Characterization of Flow through the Intake Valve of a Single Cylinder Engine Using Particle Image Velocimetry" **[18]** has investigations of the in-cylinder flow pattern around the intake valve of a single-cylinder internal combustion engine using Particle Image Velocimetry (PIV) at different intake air flow rates. The intake air flow rates are corresponding to the three engine speeds of 1000, 2000 and 3000 rev/min., at all the static intake valve opening conditions. In-cylinder flow structure is characterized by the tumble ratio and maximum turbulent kinetic energy of the flow fields. Two specified lines of the combustion chamber, the radial and axial velocity profiles have been plotted. It is found that the overall airflow direction at the exit of the intake valve does not change significantly with the air flow rate and intake valve opening conditions.

F.S. Silva, "Fatigue on engine pistons – A compendium of case studies" **[19]** has presented engine pistons are one of the most complex components among all automotive or other industry field components. The engine can be called the heart of a car and the piston may be considered the most important part of an engine. There are lots of research works proposing, for engine pistons, new geometries, materials and manufacturing techniques, and this evolution has undergone with a continuous improvement over the last decades and required thorough examination of the smallest details. Notwithstanding all these studies, there are a huge number of damaged pistons. Damage mechanisms have different origins and are mainly wearing, temperature, and fatigue related. Among the fatigue damages, thermal fatigue and mechanical fatigue, either at room or at high temperature, play a prominent role.
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Nitesh Krishnan J, Hariharan P, "Influence Of Hardness By WC Based Coating on Alsi Alloy And Grey Cast Iron using HVOF Coating Method" **[20]** has presented Grey Cast Iron and AlSi alloy are the more commonly used materials for cylinder liner applications in automobiles. With the upcoming need for an efficient utilization of fuel resources and alternate fuel resources, there is a subsequent need for the improvement of surface properties as well as to reduce the engine weight. Hard Chromium coatings exhibit attractive properties such as high hardness and excellent wear resistance and have been widely used in the automotive, aerospace and manufacturing industries.

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CONCLUSION

The recent trend in Four Stroke Diesel Engine performance of engine depend on their heat losses in inside engine but from review of following paper were given different methodologies and formulation for try to reduced losses and more efficient vehicle.

The research survey was implied to author to justified their research area in direction of engine performance and try to make new experimental set up for same which given support reduced heat losses and improve fuel consumption rate with respect their efficiency.
The research survey was reflected different methodology such as thermal barrier coating, HVOF (High velocity oxygen fuel) coating, Particle image velocimetry (PIV), Coating thickness and roughness effect etc. and such system they had applying such kind of coating process those are metal sheet, gas turbine, parabolic reflector, automobile industry etc.

Some research paper indicated about optimization method applied coating structure and FEA analysis or CFD analysis.

In CI and SI engine, they were done component level coating as per design requirement for surface roughness and life of component. There was not work done on energy saving during power stroke and there are not any provision for inside coating method from above research paper survey.

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