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A Research on Some Modeling and Thermal Analysis of Diesel Engine Piston

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Abstract – Piston is a segment of responding engine and responding pumps and other comparative instruments. Piston is an indispensable part in an engine. Piston goes about as a valve by covering and revealing ports in the cylinder wall. Piston can be fabricated in two different ways: Casting and Forging. The exhibition of the piston primarily relies on the design and materials chose for assembling it. Information of piston and cylinder wall temperature is important to appraise the thermal stresses at various focuses; this gives a plan to the designer to deal with more fragile cross segment region. Alongside that, this temperature likewise permits the figuring of heat misfortunes through piston and cylinder wall. The proposed method has been adequately associated with a water-cooled four-stroke direct-mixture diesel motor and it allows the estimation of the piston and chamber wall temperature. A speculative assessment has been endeavored to focus working temperatures, heat transitions and radial thermal stresses in the valves of a cutting edge diesel motor with and without air-opening. Temperatures, heat motions and radial thermal stresses were assessed speculatively for the two cases under all of the four thermal loading conditions. By making an air depression inside the valves stem, it goes about as a securing medium and neutralizes the warmth flow, thus the need of giving insurance coating on valves is constrained. The basic method of reasoning of this is to diminish the weight of motor and cost related with thermal coating.

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INTRODUCTION

Automobiles comprises of different number of parts, out of which piston is one of the most fundamental segment. It is a fundamental part in round and hollow engine. Essentially pistons are moving parts which are contained in the cylinder. The fundamental motivation behind the piston is to transfer power from extending gas in the cylinder to the crankshaft through piston bar or interfacing pole. There are essentially four kinds of pistons: Trunk piston, Crosshead piston, Slipper piston and Deflector piston. The utilizations of different kinds of pistons are: Trunk pistons are utilized in marine diesel engines, Crosshead pistons are utilized in steam trains, Slipper pistons are utilized in petroleum engines like in Formula1 and MotoGP where elite is required and Deflector pistons are utilized where gas flow in cylinder must be carefully guided so as to give productive rummaging. In this present work three materials were chosen for carrying out analysis, they are Aluminum, Gray Cast iron and Structural steel.

Lately, because of the rising costs of oil and the developing natural worry, there has been an expansion sought after for productive and clean IC engines. To satisfy this need, automobile ventures have step by step created engines which are all the more spotless and proficient. In the specific instance of diesel engines, amazing advancement has been made, this can be shown by the way that offers of diesel vehicles have as of late overwhelmed gasoline car. Exhaust gas treatment technologies have likewise assumed a noteworthy job in making vehicle much more clean. The solidness and yield capability of such engines is still unequivocally connected to the operating temperature of a few key parts, for example, cylinder exhausts, exhaust valves, valve spans, valve seats and piston crowns. The thermal stresses created in these key parts can possibly diminish the strength and yield of the engine.

In the light of above issue, inquire about networks have drawn their consideration on new patterns of engine designs for example making it adiabatic by making air holes in cylinder wall, piston body and valves. The air hole made inside the valves goes about as a protecting medium and averts the heat flow, thus the need of giving protection coating on valves is limited. The primary intention of this is to

decrease weight of engine and cost related with thermal coating.

A model is proposed by Singh et al. (1986) to consider the heat transfer in cylinder and piston gathering. By plotting the different diagrams like variety of radial temperature from piston crown fringe, presumes that piston rings have higher thermal stresses and misfortunes heat in water cooled engines. A PC recreation of the turbo-charged turbo-aggravated direct-infusion diesel engine framework has been created by Assanis and Heywood (1986), in their examination work they depict the fundamental framework models and their alignment and approval against accessible test engine test information. Prasad and Samria (1990) planned the arrangement of equations with the assistance of isotherms and dependent on finite distinction estimate of an aluminum alloy piston and valves of a diesel engine delights that temperature increments with protection coating and subsequently the thermal stresses grew additionally increments.

Rakopoulos and Mavropoulos (1996) built up a model for the figuring of the temperature field and heat flow in the combustion chamber segments of internal combustion piston engines, which happen both under consistent and transient engine operating conditions. Two and three-dimensional finite-element examinations were actualized for the portrayal of the mind boggling geometry metal parts (piston, liner and cylinder head) and found an acceptable level of understanding between hypothetical expectations and exploratory estimations. An exploratory model is set up by Sakhrieh et al. (2010) to decide the heat discharge in a diesel engine have presumed that early infusion timings prompts larger amount of pressure and temperature in cylinder. Temperature and stress distribution were investigated in a fractional covered SI Engine's piston by Muhammet Cerit (2011) and found that the ideal coating thickness was observed to be close to 1 mm and with increments in coating thickness the surface temperature increments in a diminishing rate.

A piston is a barrel shaped bit of metal that goes all over inside the cylinder which applies a power on a fluid inside the cylinder. Pistons have rings which serve to keep the oil out of the combustion chamber and the fuel and freshen up of the oil. Most pistons fitted in a cylinder have piston rings. For the most part there are two spring pressure rings that go about as a seal between the piston and the cylinder wall, and at least one oil control ring s beneath the pressure rings. The head of the piston can be level, lump or generally formed. Pistons can be produced or cast. The state of the piston is regularly adjusted however can be extraordinary.

A unique kind of cast piston is the hypereutectic piston. The piston is a significant segment of a piston engine and of pressure driven pneumatic frameworks. Piston heads structure one wall of an expansion chamber inside the cylinder. The contrary wall, called the cylinder head, contains gulf and exhaust valves for gases. As the piston moves inside the cylinder, it transforms the energy from the expansion of a burning gas typically a blend of oil or diesel and air into mechanical power as a responding direct movement. From that point the power is passed on through an interfacing pole to a crankshaft, which transforms it into a revolving movement, which typically drives a gearbox through a grip.

For appropriate working of the internal combustion diesel engine, exact piston temperature distribution is required on the grounds that piston temperature has a significant effect on start procedure of engine, start time delay, pace of burning, thermal proficiency, and generation of toxins. Learning of heat transfer in internal combustion engines is imperative to see such frameworks. It adds to engine advancement and design, forms reenactment, and emissions decrease. In engine piston encounters high powers because of combustion chamber pressure and thermal load, which originate from combustion process and from the colossal temperature angle among admission and exhaust gas flows along these lines, it is imperative to ensure the strength of engine parts like piston, piston rings, valves, and cylinder wall, to evade engine body contortions and to improve engine design identified with weight and assistant energy utilization.

On account of the engine piston and cylinder, such learning is vital to have an intensive comprehension of heat flux, temperature, and the distribution of these parameters. A typical technique utilized by certain creators is to surmised the mean temperature of the distribution with at least one (not many) nearby estimations acquired by thermocouples. These methodologies certainly expect mistakes that can be worthy for heat adjusts yet can prompt vulnerabilities in reproduction cycles or temperature distribution investigations. Huge numbers of these models incorporate the gas-side wall temperature as a variable to acquire the heat flux through the cylinder walls. Various scientific models have been proposed including relationships dependent on dimensional analysis, which are broadly acknowledged. Despite the fact that the models propose distinctive heat fluxes, their development over the cycle is comparable. Likewise, finite element strategy (FEM) codes utilized for heat transfer reenactments require the estimation of temperature to give boundary conditions where union is accomplished through an iterative procedure . A finite element model of gasoline sparkle engine is effectively created and recreated and had examined heat transfer during combustion process and acquires temperature distribution over the significant engine segment.

Furthermore, thermal investigations require the gas-side wall temperature to assess temperature distribution and the thermo mechanical conduct of

parts with the utilization of thermal boundary coating. Different specialists, having recognized one relationship for one little scale air-cooled engine, recognize that these connection parameters are not legitimate for another small scale air-cooled engine with comparable attributes. In most heat transfer investigations the outer surface temperatures from which heat is removed are not estimated. This is the situation for water-cooled engines, where this temperature is regularly thought to be equivalent to the coolant temperature or is determined from speculations that are explicit for water-cooled engines and typically expect steady temperature for all operating points. This approach can't be extrapolated to air-cooled engines in light of the fact that the temperature field in the inward surface changes with the operating conditions. A few investigations concerning heat transfer in air-cooled engines have been distributed and the majority of them think about two-stroke or potentially sparkle start engines.

THERMOMECHANICAL FE ANALYSIS

The technique depends on the subdivision of the structures into elements with mathematically characterized qualities. Characters of the mind boggling structure are then explained with the guide of PC utilizing grid variable based math. The information comprise of loading conditions on subdivided structures or work imperatives with physical properties of the material. Thermal loading includes the underlying computations of temperatures utilizing boundary conditions on gas side, coolant side, and air side of piston cylinder. The analysis introduced in this paper is isolated into two segments, the temperature field distribution and the thermal stresses. The finite element method with triangular element is utilized to diminish the variational plan to a lot of arithmetical equations. The articulations to figure nodal temperatures and the relating thermal stresses at each element are determined. The development of finite element approach begins from the variational explanation of the issue and afterward utilizing legitimate shape work various logarithmic equations are created which are equivalent to the quantity of nodal elements in the issue space. At that point by limiting the rough work a lot of overseeing equation is produced for the piston and cylinder get together.

Nodal point	1	2	3	4	5	6	7
r (radial) (m)	0.0360	0.0360	0.0360	0.0	0.0480	0.0480	0.0480
z (axial) (m)	0.0075	0.0375	0.0675	0.075	0.090	0.0500	0.0050

Table 1: Nodal points with coordinates.

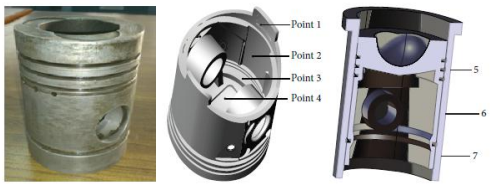

Figure 1: AV1 diesel engine piston.

These equations are fathomed by utilizing PC. PC calculation and a FORTRAN program code are created to explain these equations so as to locate the obscure parameters, that is, temperature at various nodal purposes of the piston. PC program depends on heat transfer through conduction, convection, grid increase, network reversal, heat flow, and firmness. By utilizing these subroutine and fundamental program, temperatures and heat flow field were determined.

MODELING

The piston was modeled in CATIA and analysis was carried out in Ansys workbench. For modeling the essential profile is attracted CATIA part drawing and afterward shaft activity is connected for 360o. At that point for drawing Piston stick one of the stage is chosen and piston stick measurements are given and pocket activity is carried out. Further, cushioning activity is done with the goal that stick position is held accurately. The determinations are:

1. Thickness of piston head (th) = 4.3mm
2. Thickness of rib (tr) = 2.4mm
3. Piston ring radial width (b) = 2.916mm
4. Piston barrel = 10.5mm (top end), 3.6mm (bottom end)
5. The distance from the top of the piston to the first ring groove (h1) = 4.16mm
6. The Distance between two consecutive ring grooves (h2) = 3.5mm

Fig.2 shows the completely modelled piston in CATIA.

Meshing -

The component drawn in CATIA is imported to Ansys and then meshing is done for the component. For meshing fine mesh is selected. Fig.3 shows meshing of the piston in Ansys.

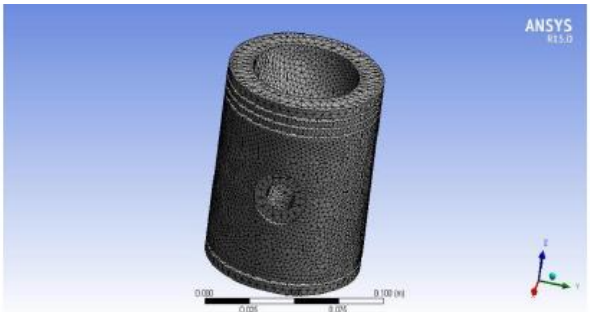

Fig.3 Meshed Piston Model.

Analysis -

Once the meshing is done then analysis is done on the piston by applying the three materials and there properties on the piston. Specifications assumed for carrying out analysis are:

Cylinder bore (D): 87.5mm, Stroke length (S)=(L): 110mm, Compression ratio: (17.5:1) N= 1500rpm, Rated Power = 5.2KW, No. of cylinders = 1, No. of strokes = 4.

$$Bmep = \frac{P \times 60000 \times 10^{-5}}{\frac{\pi}{4} \times D^2 \times L \times \frac{N}{2}}$$

$$Bmep = 6.289 bar.$$

A pressure of 6.289 bar is connected at the highest point of the piston head limiting the piston stick and the normal cycle pressure is 80 bar for the full load condition which is taken from the open writing will be connected on the piston head. Individually the material was connected on the piston and after that the analysis results are demonstrated as follows. Static analysis was carried out and results are arranged beneath. All out twisting and Von-mises stress are determined and discovered what materials suits for the accepted conditions.

Aluminum analysis-

The all out disfigurement is determined dependent on Bmep and normal cycle pressure connected on piston head. Also the stress distribution in the wake of applying Bmep and normal cycle pressure on piston head.

LINER MATERIAL THERMAL ANALYSIS FOR DIESEL ENGINES

These days the principle extent of the car business is to upgrade, the engine design, so as to meet the decrease in heat misfortune and simultaneously to keep up the engine execution at abnormal states. To this degree, PC reenactment engine models are widely used to research how every engine parameter influences engine execution and effectiveness. As PC power expands, the job of Computational Fluid Dynamic (CFD) models is winding up increasingly noteworthy, utilizing definite submodels for the different procedures and better lattices together with astounding unique work strategies. In Internal Combustion engine, heat transfer from the working gas to the cooling arrangement of a traditional Diesel engine represents up to 30% of the fuel energy. About half of this energy is lost through the piston and 30% through the head. When all is said in done, the combustion council of an internal combustion engine is shaped by cylinder wall, head and piston, where the temperature distributions are distinctive for each surface. Regularly, the temperature of each surface is thought to be, where this isn't predictable with the genuine circumstance happening on the surface of the combustion chamber. A cylinder liner or otherwise called sleeve is a round and hollow segment that is set in an engine square to shape a cylinder. It is a significant part since it gives a wear defensive surface for piston and piston rings. There are two kinds of liner which are wet liner and dry liner. Wet liner will contact with coolant while dry liner will contact legitimately with cylinder square. Among significant elements of cylinder liners are to frame a sliding surface, to transfer heat and to pack a gas.

For the extension, five material are viewed as, for example, Gray cast iron ASTM grade 60, Inconel 713C and Cast SS17-PH,H1100, Carbon steel AISI 1095, Nickel aluminum bronze alloy. The liner 3D modeling has been done in Solid Works 2012. The decrease in heat misfortune and simultaneously to keep up the engine execution at abnormal states. To this degree, PC reenactment engine models are widely used to explore how every engine parameter influences engine execution and proficiency. As PC power builds, the job of Computational Fluid Dynamic (CFD) models is winding up increasingly huge, utilizing nitty gritty sub-models for the different procedures and better networks together with fantastic unique work systems.

THERMO-MECHANICAL COUPLING ANALYSIS TO THE PISTON

Mechanical load analysis to the piston-

Select the most extreme blast pressure conditions as the count condition. Select the load of the gas pressure inside the cylinder is pressure, make the highest point of piston to get the high pressure. from Figure 4. the stress fixation parts of the piston are appropriated inside the piston stick supervisor and the point where the stick manager contacts the inward cylinder, with the most extreme stress the forward way is 18.9MPa. The stress focus happens in light of the fact that uprooting imperative is connected to this part, therefore the stress is changed strongly and meanwhile, no adjusted comer treatment is carried out during the import technique ofthe model; in the real condition, the stress inside the piston structure will be littler, in this manner the piston is sheltered.

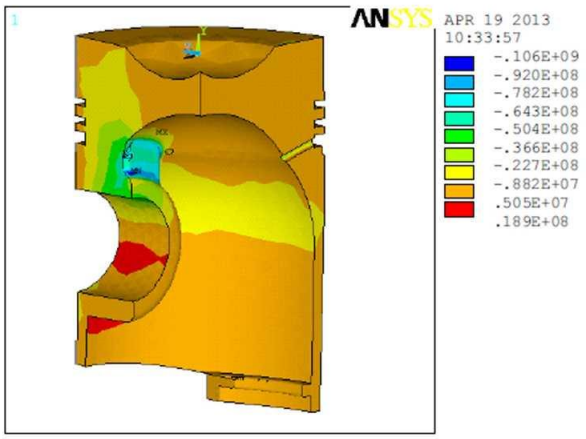

Figure 4. Mechanical stress nephogram

Coupling Analysis to the Piston-

Piston bear the coupling impact of the high-temperature gas and mechanical pressure, in a similar plane of balance imperatives, and is compelled at the base of connection. Piston achieves the coupled stress. In spite of the fact that the thermal load and mechanical load are two sorts of various loads following up on the piston, the two of them will influence the dependability and continuance of the activity of the piston. Distortion jumps out at the piston under the impact of the thermal load and the piston disfigurement will influence the transfer of heat, the thermal stress and the mechanical stress, so it is important to coordinate the double capacity of the thermal stress and the mechanical stress of the piston to carry out coupling analysis and settle to all the more likely mirror the stress field distribution and misshapening state of the piston in the activity condition.

CONCLUSION

As engine load expands, temperature of the piston and cylinder wall increments exponentially and has a positive relationship. The piston temperature for each engine load condition tried was evaluated and great understanding was gotten with the normal outcomes. These outcomes are additionally predictable with those depicted in the specialized writing. By thermo-mechanical coupling analysis, we can get the stress distribution and the disfigurement condition for each piece of the piston. The most extreme thermal stress of the piston is 250MPa and the greatest mechanical stress is 18.9MPa. The most extreme disfigurement under the impact of the thermal stress is 0.402mm. With the thermo-mechanical coupling analysis, we can understand that the limit of the stress to the piston is 144MPa, the stress an incentive inside the reasonable range, so the piston is protected. The most extreme stress worth shows up in the region of the stick manager, so in this locale must have the correct Chamfer, to avert stress focus. Thermal stress overwhelms in this piston, temperature is the primary explanation behind thermal stress is created in the piston, so to attempt to diminish the temperature, the stress beneath the rigidity of the piston, so the piston wellbeing. The fundamental point of this work was to design a piston and further by applying three chose materials the all-out disfigurement and stress distribution was to be resolved and out of that which material suits best for the piston was to be researched. What's more, from the analysis carried out and the outcomes we can presume that Aluminum is productive under stipulated conditions.

REFERENCES

1. Ariz Ahmad (2014). “Analysis of Combustion Chambers in Internal Combustion Engine’,Gobal Science and Technology Journal, Vol. 2, No 1, pp. 12-21

2. Assanis, D. N. and Heywood, J. B. (1986). Development and use of a computer simulation of the turbocompounded diesel engine performance and component heat transfer studies, SAE Technical Paper 860329.

3. Ayoub N. S. and Rolf D. Reitz (1995). “Multidimensional Modeling of Fuel Composition Effects on Combustion and Cold Starting of Diesel Engines”, SAE No. 952425.

4. B. Zhao (2012). “Thermal stress analysis of ceramic-coated diesel engine pistons based on the wavelet finite-element method,” *Journal of Engineering Mechanics*, vol. 138, no. 1, pp. 143–149.

5. D.Descieux and M. Feidt (2007). “One zone thermodynamic model simulation of an ignition compression engine,” *Applied Thermal Engineering*, vol. 27, no. 8-9, pp. 1457–1466.

6. E. Buyukkaya and M. Cerit (2007). “Thermal analysis of a ceramic coating diesel engine piston using 3-D finite element method,” *Surface and Coatings Technology*, vol. 202, no. 2, pp. 398–402.

7. Haworth D. C. (2005). “A Review of Turbulent Combustion Modelling for Multidimensional In-Cylinder CFD”, SAE No. 2005-01-0993.

8. J. Chang, O. Guralp, Z. Filipi et. al. (2004). “New heat transfer correlation for an HCCI engine derived from measurements of instantaneous surface heat flux,” SAE 2004-01-2996.

9. Mahdi Hamzehei, Manochehr Rashidi: “Determination of Piston and Cylinder Head

Temperature Distribution in a 4-Cylinder Gasoline Engine at Actual Process".

10. Muhammet Cerit (2011). Thermo mechanical analysis of a partially ceramic coated piston used in an SI engine, Surface & Coatings Technology, Vol. 205, pp. 3499–3505.

11. P. O'Haraa, C. A. Duartea and T. Easonb (2009). Generalized Finite Element Analysis of Three- Dimensional Heat Transfer Problems Exhibiting Sharp Thermal Gradients Comput. Method. Appl. M. 198 1857–71

12. Prasad, R. and Samria, N.K. (1990). Heat transfer and stress fields in the inlet and exhaust valve of a semi-adiabatic diesel engine, Computers & structures, Vol. 34, No. 5, pp. 165-711.

13. Prasad, R. and Samria, N. K. (1990). Transient heat transfer analysis an internal combustion engine piston, Computers & Structures, Vol. 34, No. 5, pp. 781-193.

14. Rakopoulos, C.D., Antonopoulos, K.A., Rakopoulos, D.C. and Giakoumis, E.G. (2004). Investigation of the temperature oscillations in the cylinder walls of a diesel engine with special reference to the limited cooled case, International Journal of Energy Research, Vol. 28, pp. 977–1002.

15. Ravindra R. Navthar (2012). 'Design and Analysis of Cylinder and Cylinder head of 4-stroke SI Engine for weight reduction',International Journal of Engineering Science and technology, Vol. 4, No 3.

16. S. K. Sharma, P. K. Saini, and N. K. Samria (2013). "Modelling and analysis of radial thermal stresses and temperature field in diesel engine valves with and without air cavity," *International Journal of Engineering, Science and Technology*, vol. 5, no. 3, pp. 111–123.

17. Sakhrieh, A., Abu-Nada, E. and Akash, B. (2010). Computational thermodynamic analysis of compression ignition engine, International Communication in Heat and Mass Transfer, Vol. 37, pp. 299-303.

18. Sanjay Shrivastva, Kamal Shrivastava, Rahul S. Sharma and Hans Raj K. (2004). "Presented Finite Element Modeling an Analysis of Automotive Piston", *Journal of Scientific & Industrial Research*, Vol. 63, December, pp. 997-1005.

19. Singh, V.P., Upadhyay, P.C. and Samria, N.K. (1986). Some heat transfer studies on a diesel engine piston, International Journal of Heat Mass Transfer, Vol. 29, No. 5, pp. 812-814.

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