International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 3.45 (SJIF-2015), e-ISSN: 2455-2585
Volume 4, Issue 5, May-2018

A Review on Design and Analysis of 4 Stroke Petrol Engine Piston by Using Coating Material

Jaydip Jiyani[1], Mayur Maiyani[2], Parth Panchani[3], Nikul Vadsak[4], Priyanka Sharma[5]
[1,2,3,4] *U.G. Student, Automobile Engineering Department, Indus University, Ahmedabad*
[1]*jayjiyani285@gmail.com*, [2]*mayurmaiyani9@gmail.com*, [3]*parthpanchani1996@gmail.com*, [4]*vadsaknikul@gmail.com*
[5]*Assistant Professor, Automobile Engineering Department, Indus University, Ahmedabad*
[5]*priyankasharma.am@indusuni.ac.in*

Abstract— We all know that function of Piston is to convert the thermal energy to mechanical energy under the high temperature and gas pressure. The main objective of this project is to improve the structural and thermal behaviour of the piston and this is done by using a coating of a material on the piston. Model of the piston is developed from Hero Splendor-Pro engine specifications by theoretical calculation. Finite Element Analysis performed using analysis software ANSYS Workbench for the (uncoated) piston of aluminium alloy material and ceramic (Nickel chromium aluminium - NiCrAl and Aluminium oxide - Al_2O_3) coated piston of composite (Aluminium silicon carbide – AlSiC) material. Structural analysis is to evaluate the total deformation, equivalent stress and equivalent elastic strain; and thermal analysis to evaluate the temperature distribution and total heat flux. By the result of analysis, we would be able to find whether ceramic coating for the piston is feasible or not.

Keywords— IC Engine Piston, Ceramic Coating, Composite material, FEA, ANSYS.

I. INTRODUCTION

Automobiles are being a basic necessity in this modern era and we all know very well, because of the increased use of vehicles, there is a requirement to improve performance and reduce cost of automobile components. For the betterment of these components we need to understand the new technologies which are helpful in development of components with improved build quality.

A Piston is a reciprocating component, contained within the cylinder in IC engines. Due to combustion of fuel, piston reciprocates. This reciprocating motion of piston, passes to crankshaft by the connecting rod which it into rotary motion. In this process, high thermal stress acts on the top surface of piston.

Therefore, to reduce the thermal stress acting on the piston head surface, we strive to improve the design or choose the best material for the piston.

II. LITERATURE REVIEW

K. Venkatareddy, V. Chandrashekar Goud [1] designed and analysed the piston by using composite materials. In this research, they worked on improving the efficiency of the engine by applying various composite materials such as grey cast iron, aluminium alloy, Al-SiC, aluminium oxide on piston. The piston is designed for 150 cc petrol engine and modelling is done by using design software SolidWorks 2016. The SolidWorks part file of piston is imported to ANSYS Workbench for the analysis. Boundary Condition of 1.5 MPa pressure force on piston crown for the structural analysis is given and for thermal analysis maximum temperature 400°C at piston crown and minimum temperature 30°C at bottom face are given. The Static structural analysis is to evaluate total deformation, maximum stress, maximum shear stress and maximum strain and steady state thermal analysis is to evaluate temperature distribution and total heat flux. From the resulting analysis they concluded that the aluminium silicon carbide (Al-SiC) is efficient among the other applied materials to piston.

M. Sivanesan, C. Vinothkumar [2] have researched on thermal behaviour and optimization of piston coating material (Al-Si) used in petrol engine. They investigated and analysed the thermal behaviour of coated piston with aluminium silicon alloy material. Structural analysis is explained to reduce the stress on the top surface of the piston. Piston structural model has been developed in SolidWorks by theoretical calculation values.

Aluminium-Silicon alloys for piston and NiCrAl material for coating on piston are chosen. Another upper (last) layer is known as ceramic layer which is coated over the NiCrAl coated piston for 350μm thickness. Zirconium oxide or Mullite or Aluminium oxide are generally used for this layer of coating. Finite Element Analysis is performed in ANSYS software. The mesh generated on CAD model by using FEA technique to predict the higher load and critical region on piston. The structural and thermal analysis of the piston was performed using different types of ceramic coating like zirconium oxide, Mullite and aluminium oxide. The aluminium oxide coating holds a high strength and a high temperature while Mullite coated piston has a less weight than other ceramic coating materials. So, from the detailed study of analysis about different material, they have obtained the aluminium oxide material have a better thermal and structural behaviour.

Molla Shehanaz, Dr. G. Shankariah [3] designed and analysed piston using composite material. The aim of this paper is to analyze effects of the structural and thermal behaviour of piston by applying cast aluminium alloy and titanium alloy. They choose titanium alloy from the literature survey which has light weight, high temperature resistant as well as corrosion resistant and possesses very high tensile strength. Initially, 3D model of piston made in Pro/ENGINEER design software by their dimension of piston. Analysis of the piston are performed under the thermal and mechanical loads as boundary condition in ANSYS software. Described comparison of their calculated analytical results and FEA results for both materials is shown. The analysis result indicates that titanium alloy piston has a good thermal property, better performance in stress and deformation than cast aluminium alloy. So that titanium alloy can help to improve piston qualities. The melting point of titanium is 25% higher than aluminium but titanium is very expensive so it can be used in only some special cases.

Vinod Kumar Yadav, Yogesh Mishra [4] carried out design and structural analysis of ceramic coated petrol engine piston using finite element method. In this paper it is described that how to reduce the thermal and structural intensity of the piston coated by ceramic material. A2618 alloy piston is coated with a 350μm thickness of zirconia based ceramic coatings $MgZrO_3$ over a 150μm thickness of NiCrAl because of low conductivity and high coefficient of thermal expansion. Analytical calculation of piston is done using specification of a single cylinder 4 stroke air cooled 100cc Bajaj Kawasaki petrol engine and 3D models created using UG NX 8 software. The structural analysis of piston (for uncoated and coated) is performed by load variation at 100%, 125%, 150%, 175%, 200%, 225% and 250% of the 12.08 MPa uniform gas pressure using ANSYS 13.0. They concluded from their result of different loading analysis, ceramic coating is good for the uncoated piston under the engine condition.

Vaishali R. Nimbarte, Prof. S. D. Khamankar [5] presented stress analysis of piston using pressure load and thermal load. In this paper, they worked on predicting replacements of damaged or broken parts due to mechanical and thermal stresses in the IC engine. Piston design for cast iron material and CAD modelling done in Pro/ ENGINEER software. FEA of piston is performed with boundary conditions like pressure force on piston head and non-uniform temperature from piston head to skirt, taken according to the type of analysis. Structural analysis, thermal analysis and thermo-mechanical analysis is performed by ANSYS 12.0. From the comparative results of analytical and FE Analysis for cast iron piston, it is found that values are approximately similar. Hence their design of piston is safe.

Narsaiyolla Naresh, P. Sampath Rao [6] discussed about structural analysis of a ceramic coated diesel engine piston using finite element method. This paper describes the optimization of material using FEA technique to predict the higher stress and temperature on the piston component. For the simulation, truck diesel engine piston is taken and flat and curved head piston model developed using Autodesk Inventor software. 3D model of piston meshed by the ANSYS code and FEA is done using DS SOLIDWORKS. Analysis clearly show that curved head piston gave the best results in terms of low resultant force and deformation.

Sundaram.K, Palanikumar.N [7] had investigated and analysed piston by using composite material. In this work, detailed information about use of composite material is helpful for piston which increases hardness, improve corrosion resistance and high temperature resistance as compared to alloy and pure metal. 3D modelling of piston is prepared in Pro/ ENGINEER. Structural static analysis, steady state thermal analysis and transient thermal analysis for existing material (Al alloy) and Al materials with three different SiC composition (Al with 10% SiC, Al with 20% SiC and Al with 30% SiC) is performed using ANSYS Workbench 14.5. From the result discussion of analysis, they obtained the aluminium with 10% SiC material having minimum stress and good temperature distribution in both steady state and transient state thermal analysis. So, AlSiC (Al with 10% SiC) material is suitable for piston than aluminium alloy material.

Deepak Kumar Yadav et al [8] explained design and coupled field analysis of ceramic coated petrol engine piston. This project is carried out to reduce the thermal as well as mechanical stresses on the piston for the long life and this is done by study of materials. Ceramic materials Cordierite [Magnesium iron aluminium cyclosilicates $(Mg,Fe)_2Al_3(Si_5AlO_{18})$] is chosen for coating of piston instead of Al 2618 material because of the extremely good thermal shock resistance of ceramic material. Single cylinder 99.27cc engine specification is taken for the analytical calculation of piston and SolidWorks software is used to create piston model. Structure analysis, structural analysis under coupled field and thermal analysis of both uncoated and coated piston is done using ANSYS 16.0. After analysis comparisons of result explained that cordierite material is not fit for ceramic coating on piston.

Lanka Tata Rao et al [9] reported stress analysis of 4 stroke diesel engine piston. In this article discussion about how to reduce thermal and structural stresses up to safe allowable limits to avoid the failure of the piston due to combustion. Kirloskar 4 stroke, water cooled diesel engine is used to design the piston and 3D model is developed by SolidWorks. The analysis was performed for the aluminium alloy piston using ANSYS 15.0. Analysis is done with three types of boundary conditions. Heat transfer co-efficient and heat flux on different surfaces and 53 bar pressure on the top surface of the piston was given. The result of analysis observation found that stresses within allowable limits and factor of safety is to be around 3 for the piston.

Ekrem Buyukkaya, Muhammet Cerit [10] have done the study of thermal analysis of a ceramic coating diesel engine piston using 3-D finite element method. In this study, thermal analysis is investigated and the comparison of conventional truck diesel engine piston made of aluminium silicon alloy and steel materials, and both the pistons coated with MgO–ZrO_2 material. Analysis of four different 3D piston models by the software, namely ANSYS. Their studies show that thermal conductivity in both the coated pistons is improved approximately 48% for the AlSi alloy and 35% for the steel also strength and deformation improved.

Abino John, Jeason T Mathew, Vasdev Malhotra, Nitin Dixit [11] had designed and analysed piston with sic composite material. They explained that fatigue damage of the aluminium piston like side wear and head cracks are caused by cyclic gas pressure due to poor hot strength and high coefficient of expansion of aluminium material. The material properties of Aluminium Silicon Carbide (AlSiC) collected by literature survey and compared with aluminium and found that AlSiC has better high temperature performance, dimensional stability, abrasion resistance, creep resistance and good stiffness to weight and strength to weight ratios. Initial piston 3D model created in CATIA V6 software. Thermal analysis such as temperature distribution, total heat flux and static structural analysis such as total deformation, normal stress distribution, shear stress distribution, equivalent stress distribution, normal and shear elastic strain distribution of the piston by both the materials were done using ANSYS 14.0. They obtained from the analysis, some of the issues faced by aluminium piston like deformation and temperature distribution can be avoided by the aluminium silicon carbide piston.

III. CONCLUSIONS

By the literature survey of the articles we decide to work on improvement of the structural and thermal behaviour of the piston by using a coating of a material. There are different types of ceramic materials like Mullite or Aluminium oxide or Zirconium oxide that are used for coating on piston but Al_2O_3 has better structural as well as thermal properties. So, for the analysis of piston using ANSYS software, Al_2O_3 was chosen for the upper layer on the NiCrAl layer of coating on piston.

REFERENCES

[1] K. Venkatareddy, V. Chandrashekar Goud, “Design and Analysis of the Piston by Using Composite Materials”, International Journal of Professional Engineering Studies (IJPRES), Vol. 7, Issue 1, Sep 2016.

[2] M. Sivanesan, C. Vinothkumar, “Thermal Behaviour and Optimization of Piston Coating Material (Al-Si) Used In Petrol Engine”, Middle-East Journal of Scientific Research, 24 (Recent Innovations in Engineering, Technology, Management and Applications): 141-147, 2016.

[3] Molla Shehanaz, Dr. G. Shankariah, “Design and Analysis of Piston Using Composite Material”, International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET), Vol. 6, Issue 8, August 2017.

[4] Vinod Kumar Yadav, Yogesh Mishra, "Design and Structural Analysis of Ceramic Coated Petrol Engine Piston Using Finite Element Method", International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET), Vol. 4, Issue 6, June 2015.

[5] Vaishali R. Nimbarte, Prof. S. D. Khamankar, "Stress Analysis of Piston Using Pressure Load and Thermal Load", IPASJ International Journal of Mechanical Engineering (IIJME), Vol. 3, Issue 8, August 2015.

[6] Narsaiyolla Naresh, P. Sampath Rao, "Structural Analysis of a Ceramic Coated Diesel Engine Piston Using Finite Element Method", International Journal of Mechanical Engineering (SSRG-IJME), Vol. 1, Issue 5, Sep 2014.

[7] Sundaram.K, Palanikumar.N, "Investigation and Analysis of Piston by Using Composite Material", IJARIIE, Vol. 2, Issue 6, 2016.

[8] Deepak Kumar Yadav, Suraj Kumar, Y. Ravi Prakash Reddy, G. Veerbhadra, Pothamsetty Kasi V Rao, "Design and Coupled Field Analysis of Ceramic Coated Petrol Engine Piston", International Research Journal of Engineering and Technology (IRJET), Vol. 4, Issue 4, Apr 2017.

[9] Lanka Tata Rao, Katakam Satyanarayana, M. S. S. Srinivasa Rao, T. V. Hanumanta Rao, S. V. Umamaheswara Rao, "Stress Analysis of 4 Stroke Diesel Engine Piston", International Journal of Current Engineering and Scientific Research (IJCESR), Vol. 2, Issue 2, 2015.

[10] Ekrem Buyukkaya, Muhammet Cerit, "Thermal Analysis of a Ceramic Coating Diesel Engine Piston Using 3-D Finite Element Method", Surface & Coatings Technology, 2007.

[11] Abino John, Jeason T Mathew, Vasdev Malhotra, Nitin Dixit, "Design and Analysis of Piston by SiC Composite Material", International Journal for Innovative Research in Science & Technology (IJIRST), Vol. 1, Issue 12, May 2015.

[12] Shirisha, G. S. Dk. Sravani, "Thermal Analysis of IC Engine Piston Using Finite Element Method", International Journal of Mechanical Engineering and Computer Applications, Vol. 4, No. 1, Jan- Feb 2016.

[13] K. S. Mahajan, S. H. Deshmukh, "Structural and Thermal Analysis of Piston", International Journal of Current Engineering and Technology (IJCET), Special Issue 5, June 2016.