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Simulation and Experimental Investigation on Engine Piston to Reduce Noise

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Abstract: In this paper, the commercial engine piston is studied with the aim to minimize the vibration arises at the time of reciprocate motion of the piston. Hence, the damping effect is provided in the piston by using Magnesium alloys which are the lightest materials of all commonly available in the market. Initially, the simulation is performed to investigate the effect of damping thickness on the deformation and stress distribution of engine piston using finite element analysis. The master piston without damping effect is made to compare by the piston with damping thickness of 5mm, 7.5mm and 10mm. In addition, the modal analysis is performed to determine the modes of shapes and its natural frequencies. The simulation study results that the deformation and stress distribution is lower at the damping thickness of 7.5mm. So, the experiment is carried out to validate the simulation results in which the master piston and the piston with 7.5mm damping thickness are compared. The accelerometer (Sendig 911) is used to capture the waveform in order to calculate the vibration. The results are clearly indicated that the damping effect is effectively used to reduce the vibration and noise in the engine piston.
Keywords: Finite element analysis, vibration reduction, damping effect, engine piston, modal analysis

I. INTRODUCTION

Magnesium alloy is the lightest of commercially available structural metal which offers high specific strength over other engineering alloy materials [1]. It also possesses good damping capacity, excellent castability and good electromagnetic shielding properties. In engine, the vibration phenomena are one of the issues that is not evaded completely. There are several factors involved in producing the vibration of piston. Hence, the ample studies are undertaken to reduce the vibration and to evaluate the structural behavior of the engine sub components. The different piston profile is compared to evaluate the frictional wear between piston and cylinder, gas leakage [2]. The selection of piston material is one of the key factors that causes to vibration. Therefore, the finite element analysis is carried out to evaluate the deformation and stress distribution in the piston. Manisha et al. [3] compared the piston made of Al alloy A2618, Al-GHY1250 and Al-GHS1300 using static structural analysis. This investigation resulted that Al-GHS1300 piston experienced lower structural deformation. Senthil kumar et al. [4] conducted simulation study for different materials of piston such as Cast Aluminum, Nickel Chromium Alloy, cast steel, Carbon steel and four different Aluminium Alloy Compositions. They concluded that Aluminium alloy is the alternative material for the piston. The thermal analysis is conducted on piston head to determine the critical region of the component using finite element analysis [5]. Rajam et al. [6] investigated finite element analysis in engine piston and optimized the process parameters using graphics software. Shirisha et al. [7] have analyzed the thermal barrier coated IC engine piston. They have done coupled thermal and structural analysis on piston with thermal coating and without coating. Bhagat et al. [8] performed optimization to reduce the stress concentration on the piston head, skirt and sleeve. Wu et al. [9] have conducted the thermal analysis to validate the thermal distributions of the piston for burning diesel and Dimethyl Ether (DME) fueled diesel engines separately. Buyukkaya et al. [10] have studied conventional piston made of aluminum silicon alloy and piston coated with MgO-ZrO2 material by performing thermal analysis. Shrirao et al. [11] have coated 0.5mm thickness of 3Al2O3. SiO2 on piston crown, cylinder and valves, and evaluated the performance of heat transfer rate. It is possible to reduce the vibration in the engine piston by providing damping effect on the surface of piston. Kanda et al. [12] have designed piston-pin structure integrated with the dynamic damper to absorb the vibration induced in the piston. Morsy et al. [13] evaluated damping capacity and mechanical properties of Mg-6Al-Zn alloy. They compared damping characteristics between un heat treated, solution treated and aged Mg-6Al- Zn specimens. Trojanová et al. [14] dealt with the damping of mechanical vibrations and their heat conversion in Mg alloys and Mg alloys-based composites. Lim et al. [15] have designed engine cylinder pressure damping device to reduce the vibration and noise. It is resulted that the significant reduction in engine surface vibration and noise radiated has been found particularly at high frequencies above 4000 Hz. Li et al. [16] have developed three-dimensional finite element model to evaluate the thermal characteristics and also friction.

In this paper, the damping effect is provided using Magnesium alloys in the engine piston surface to reduce the vibration and noise. The finite element analysis is used to evaluate the effect of damping thickness on the deformation and stress distribution of the piston. In addition, the experiments are carried out to validate the theoretical study.

II. MATERIALS AND METHODS

The piston is the primary component in the engine block which reciprocates in the cylinder bore for a complete cycle. A cast aluminium alloy (LM13 alloy) is selected as piston material that affords efficient thermal properties for achieving improved heat transfer rate. However, its expansion coefficient is significantly contributed during combustion process, the desirable clearance is provided in the piston to avoid seize in the cylinder. The Table 1 shows the chemical composition of LM13 alloy [17].

TABLE I
The Chemical Composition Of Lm13 Alloy

Elements	Zn	Mg	Si	Ni	Fe	Mn	Al
Wt%	0.5	1.4	12	1.5	1.0	0.5	Bal

The selection of damping material involves several factors such as specific strength, damping capacity, cast ability, etc. Hence, AM-SC1 is the magnesium alloy, chosen as the damping materials which is the lightest of structure metals and it has gratified properties required for damper. The Gas Tungsten Arc Welding (GTAW) is used to join the damping materials with the piston.

III.FINITE ELEMENT ANALYSIS

In this paper, the static structural analysis is carried out to determine the displacement and stress distribution of engine piston under different damping conditions. The damping thickness is considered as 5mm, 7.5mm and 10mm for the analysis. And also, the modal analysis is performed in order to determine the mode shapes of vibration.

A. FEA Modelling

Master piston of single cylinder diesel engine is modelled using SOLIDWORKS which is shown in Fig. 1. In order to minimize the solution time and enhancing accuracy of the solution, the piston model is simplified. But it is ensured that this simplification does not affect the damping characteristics of the piston.

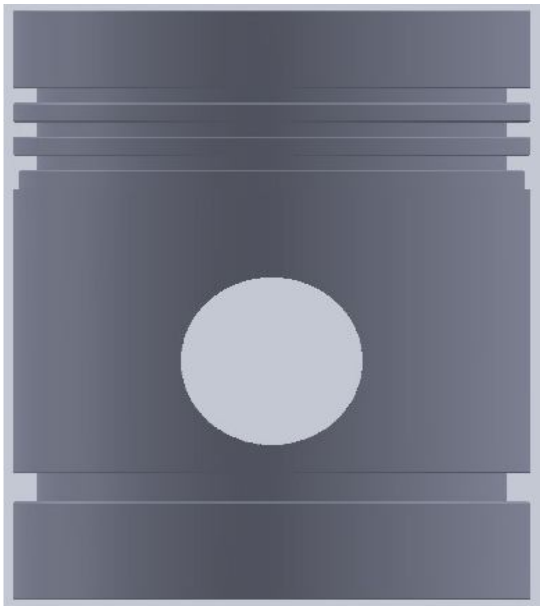
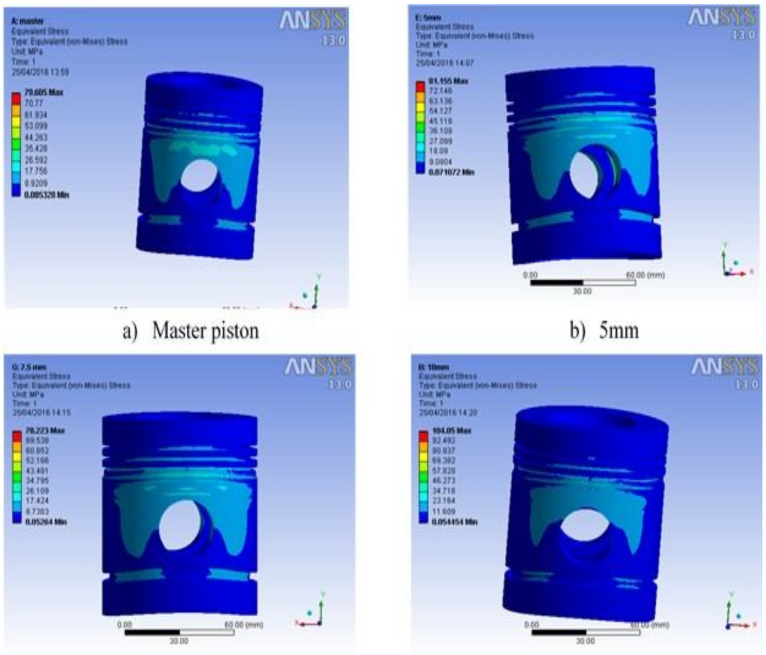


Fig. 1. 3D model of master piston

The small area is grooved above the pin hole and filled with high damping materials. In this analysis, the piston with damping thickness of 5mm, 7.5mm and 10mm considered which are shown in Fig. 2 (a-c).



a) Master piston

b) 5mm

d) 7.5mm

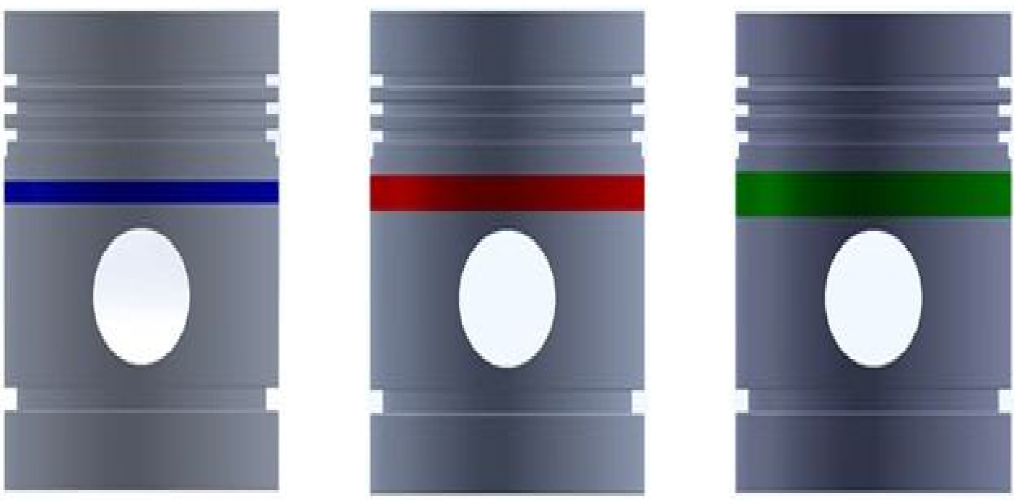
c) 10mm

Fig. 2. The piston under different damping thickness

B. Static Structural Analysis

The static structural analysis is performed to evaluate the maximum stress and maximum displacement attained in the four different pistons during the engine cycle. The pressure acting on the piston head is taken as 35x10^5 N/m^2 which act as mechanical load due to explosion of gas. In addition, the surface of pin hole is fixed and the outer surface of piston is given as frictionless support.

1) *Stress Distribution:* The Fig. 3 shows the contour plots of stress distribution for piston with different damping conditions. It is seen that the maximum stress attained near the pin hole due to its pivoted position.



a) 5mm

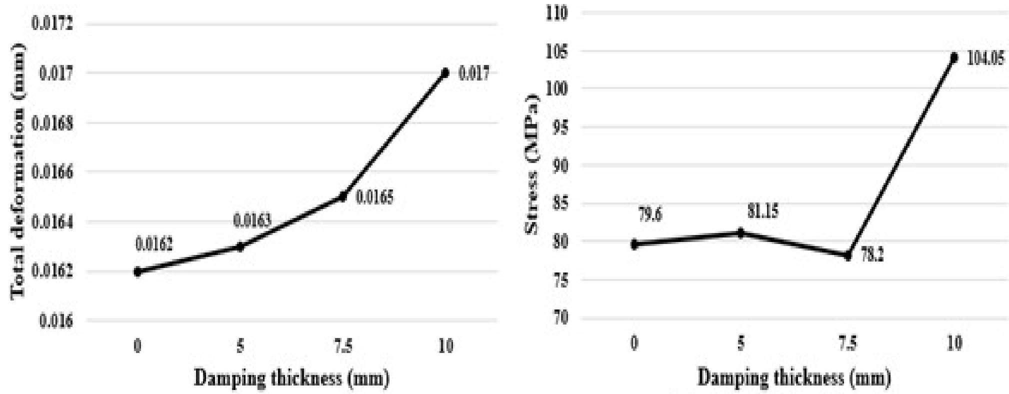
b) 7.5mm

c) 10mm

Fig. 3. The stress distribution of piston at different damping thickness

The stress induced in the master piston is 79.605 MPa and it is increased considerably when the damping thickness is increased from 7.5mm to 10mm. However, it can be seen that there is no significant difference between the stresses attained at the damping thickness of 7.5mm and at the master piston.

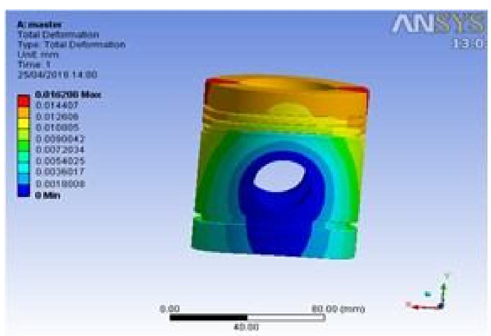
2) *Total Deformation:* The Fig. 4 shows the contour plots of total deformation for piston with different damping conditions. It is seen that the maximum deformation is occurred near the top surface of piston.



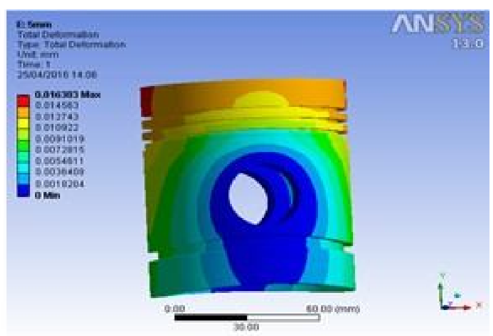
a) Total deformation

b) Stress distribution

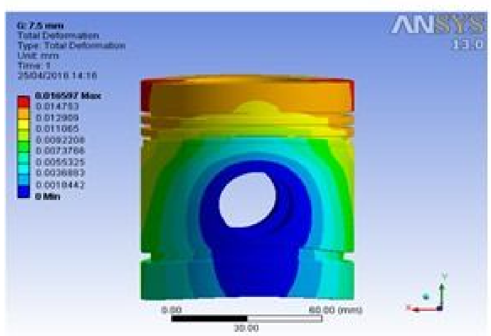
Fig. 4. The total deformation contour plots of piston at various damping thickness



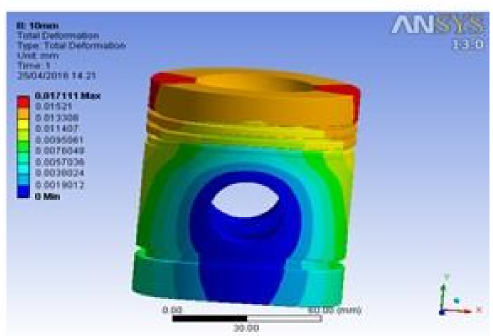
a) Master piston



b) 5mm



c) 7.5mm



d) 10mm

Fig. 5. The effect of damping thickness on a) total deformation and b) stress distribution in the piston

The Fig. 5 (a, b) shows the effect of damping thickness on total deformation and stress. From the Fig. 5 (a), the deformation induced in the master piston is 0.0162 mm and there is slight increment in the deformation when the damping thickness is increased. The Fig. 5 (b) shows that the stress induced is minimum of 78.2 MPa at 7.5mm damping thickness. The stress is drastically increased for 10mm damping thickness. From the static structural analysis, it is concluded that the piston experiences minimum deformation and stress at 7.5mm damping thickness.

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C. Modal Analysis

The modal analysis is carried out to determine the natural frequency of the structure when vibration load is applied. In this analysis, the pin hole is fixed in all directions and number of mode shapes is 6.

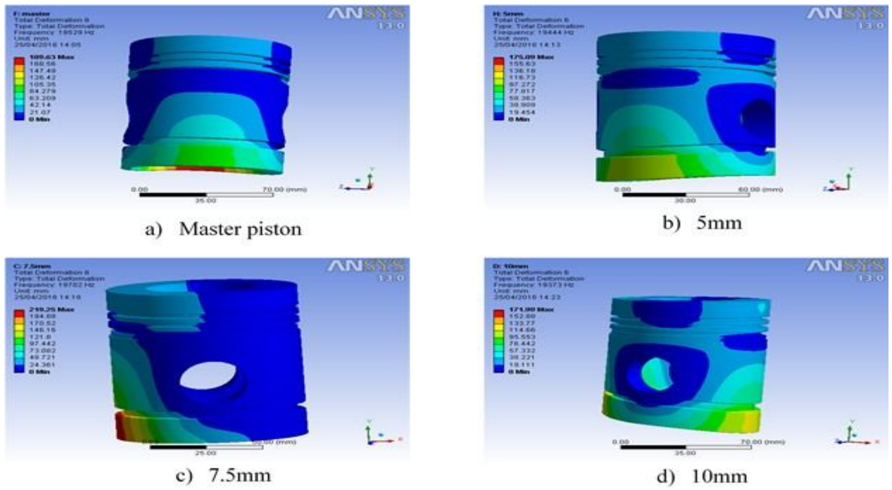

Fig. 6. The contour plots for 6th mode of vibration for piston with different damping thickness

The natural frequency for three different configurations of piston is shown in Table 2. From the Table. 2, it is evident that the piston at 7.5mm damping thickness is having higher natural frequency compared to other three configurations. Which results in less amount of vibration. The contour plots for 6^{th} mode of vibration is shown in Fig. 6 for piston with different damping thickness. The Fig. 7 shows the number of modes vs total deformation graph for four different configurations of piston.

Table 2 frequencies For All Models In Hz

Modes	Without damper	With damper		
		5mm	7.5mm	10mm
1	9099	9046	9236	8961
2	9165	9059	9411	8994
3	11388	11354	11473	11322
4	14326	14258	14512	14182
5	17759	17755	17764	17751
6	19529	19444	19702	19373

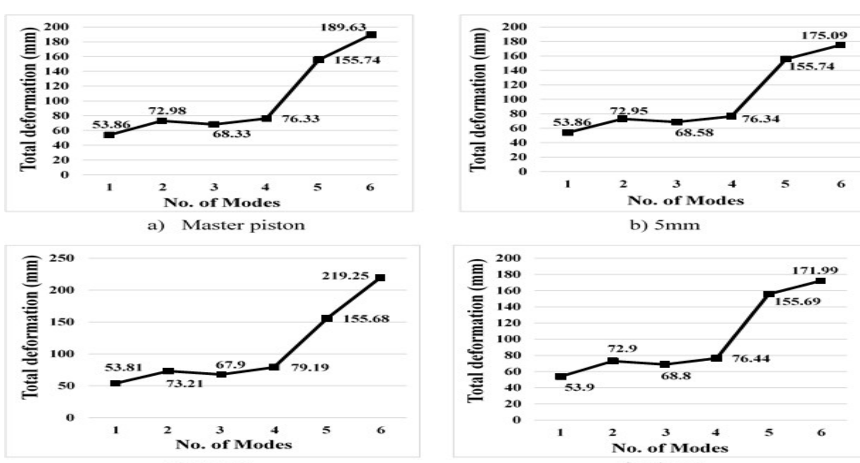

Fig. 7. Number of modes vs total deformation graph for four different configurations of piston

IV. EXPERIMENTAL INVESTIGATION

The experiments are carried out to validate the theoretical results such that the piston without damping and piston at 7.5mm damping thickness are compared in this experimental investigation.

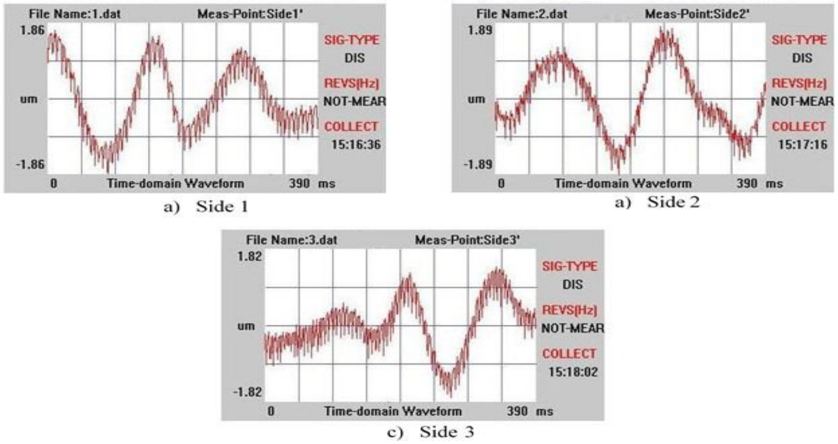

Fig. 8. Experimental setup with accelerometer sensor

The Sendig 911 accelerometer is used to capture the waveform with respect to time. The accelerometer sensor is placed in the cylinder block near piston movement which can be seen from Fig. 8. The time domain waveform shows the displacement in micro level for master piston which can be seen from Fig. 9 (a-c). The mean displacement of 1.87µm is obtained in the master piston. Similarly, the time domain waveform for piston at damping thickness of 7.5mm is shown in Fig. 10 (a-c). The mean displacement of 1.76µm is obtained in the piston at 7.5mm damping thickness.

From the experimental investigation, it is concluded that influence of damping thickness is much in reducing the vibration and structural deformation of the engine piston.

Fig. 9. The time domain waveform for master piston

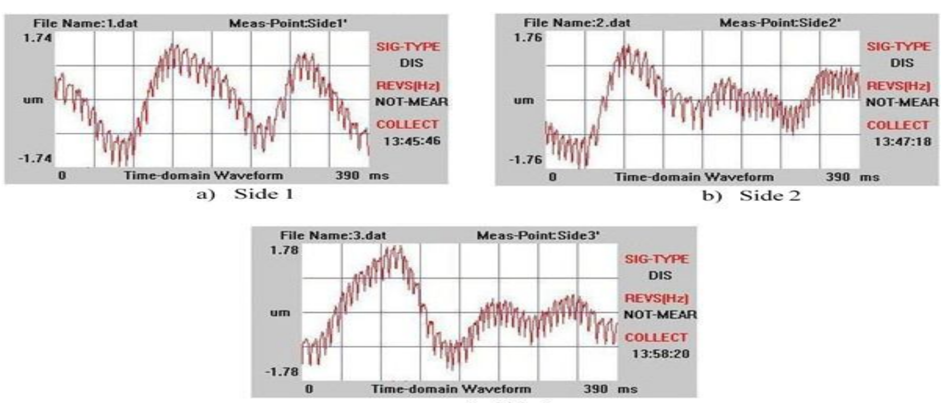

Fig. 10. The time domain waveform for piston at 7.5mm damping thickness

V. CONCLUSION

In this paper, the damping effect is provided in the engine piston to minimize the vibration. The magnesium alloy is used as the damping materials and the study is carried out on the effect of the damping thickness on structural characteristics of the piston. Hence, the structural analysis and modal analysis is performed using finite element method for different configurations of a single cylinder diesel engine piston. The damping thickness is considered as 5mm, 7.5mm and 10mm and it is compared with the master piston which is having no damping effect. From the structural analysis, the total deformation is increasing with the increase of damping thickness. However, the minimum stress is obtained at the damping thickness of 7.5mm. Also, the modal analysis results that the natural frequency of the system is high at 7.5mm damping thickness which causes to reduce the vibration. It is concluded that piston with damping thickness of 7.5mm produces less vibration and experiences less stress distribution.

Experimental investigation is carried out to validate the simulation results. The master piston and piston with 7.5mm damping thickness are compared. From the investigation, it results that the master piston has an increased rubbing action between the piston and cylinder wall than the piston with the damping effect. The mean displacement values for both the case are 1.85µm and 1.76 µm. Thus vibration reduction is possible by reducing displacement and increased frequency. The obtained results shows that welded magnesium alloy in the piston will reduce the displacement and vibration, compared to the existing piston.

REFERENCES

[1] D.W. James, High Damping Metals for Engineering Applications, Mater. Sci. Eng. 4, 1-8. (1969)
[2] S. Periyasamy, T. Alwarsamy, S. Kavin Karthick, "Investigation of Piston Profile Induced Cylinder Displacement in Diesel Engine", International Conference on Innovative Research in Engineering and Technology (Iciret), August 12-14, (2010).
[3] Manisha B Shinde, Sakore T. V and Katkam V. D (2016), Design Analysis of Piston for Four Stroke Single Cylinder Engine Using ANSYS, International Journal of Current Engineering and Technology, Special Issue-6.
[4] M. Senthil Kumar, M. Suresh, P. Kumaravel, V.R. Srinivashan (2017), A Study on Material Selection of IC Engine Piston under Static Loads, International Journal of Advanced Research in Basic Engineering Sciences and Technology (IJARBEST), 3(5).
[5] Calbureanu, M. X., Malciu, R., Tutunea, D., Ionescu, A., & Lungu, M. (2013). The finite element analysis of the thermal stress distribution of a piston head. Int J Mech, 7(4), 467-474.
[6] Rajam, C. V., Murthy, P. V. K., Krishna, M. M., & Rao, G. P. (2013). Design Analysis and Optimization of Piston using CATIA and ANSYS. International Journal of Innovative Research in Engineering & Science, 1(2), 41-51.
[7] Shirisha, S., & Sravan, G. S. (2016). Thermal Analysis of Ic Engine Piston Using Finite Element Method. IJMCA, 4(1), 200-209.
[8] R.Bhagat, Y.M.Jibhakate, "Thermal Analysis and Optimization of I.C. Engine Piston Using Finite Element Method", International Journal of Modern Engineering Research (IJMER), Vol.2, Issue.4, Pp.2919-2921, (2012).
[9] Wu, Yi Zeng, Dongjian Feng, Zhiyuan, "Finite Element Analysis for the Thermal Load of Piston in a Dimethyl Ether Fueled Diesel Engine", IEEE. (2010).
[10] Ekrem Buyukkaya, Muhammet Cerit (2007), "Thermal Analysis of a Ceramic Coating Diesel Engine Piston Using 3-D Finite Element Method", Surface and Coatings Technology, 202(2), 398–402.
[11] P.N.Shrirao, A.N.Pawar, "Experimental Investigation on Performance of Single Cylinder Diesel Engine With Mullite as Thermal Barrier Coating", Journal Of Mechanical Engineering And Technology, Vol. 3 No. 1 (2011).
[12] Kanda, Y., & Mori, T. (2015). Diesel Combustion Noise Reduction by Controlling Piston Vibration. SAE International Journal of Engines, 8(4), 1775-1781.
[13] El-Morsy, A. W., & Farahat, A. I. (2015). Effect of aging treatment on the damping capacity and mechanical properties of Mg-6Al-1Zn alloy. The Scientific World Journal, 2015.
[14] Trojanová, Z., Palček, P., Lukáč, P., & Chalupová, M. (2017). Internal Friction in Magnesium Alloys and Magnesium Alloys-Based Composites. In Magnesium Alloys. InTech.
[15] Lim, M. K., & Low, S. C. (1990). Using an engine-cylinder-pressure-damping device to reduce small spark-ignition engine noise. Applied acoustics, 29(2), 109-115.
[16] Li, C. H. (1982). Piston thermal deformation and friction considerations (No. 820086). SAE Technical Paper.
[17] Ashiri, R., Niroumand, B., Karimzadeh, F., Hamani, M., & Pouranvari, M. (2009). Effect of casting process on microstructure and tribological behavior of LM13 alloy. Journal of Alloys and Compounds, 475(1-2), 321–327.