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A Pure Thermal Analysis of 3D Printing for Different Laser Powers for Optimization Thermal Distribution

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ABSTRACT: Engine pistons arrangement are one of the most complex components among all automotive and other industry field components. The engine can be called the heart of a vehicle and the engine head 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. Not with standing all these studies, there are a huge number of damaged engines. Damage mechanisms have different origins and are mainly wear, temperature, and fatigue related. But more than wear and fatigue, damage of the engine head is mainly due to stress development, namely- Thermal stress, Mechanical stress. Considering the complexity of the component, manufacturing of engine head and other parts of engine cylinder will become very complex. To avoid this we have choose the metal additive manufacturing process to build the engine head but before going for the printing process we have simulated the 3D printing process to optimize the process parameter which is best suited for the printing of engine head. The paper describes the FEA technique to predict the higher stress and critical region on the component to study the displacement, plastic strain, von mises stresses during the printing process. With the help of solid works software, the structural model of a engine arrangement will be developed. Using Altair Inspire software, thermos mechanical simulation has been performed for different laser powers. By performing AM simulation laser power has significant role in quality and dimensional accuracy of the AM build parts. Laser power directly effect the surface roughness and dimensional accuracy of the part.

Key words: 3D Printing,, Thermal Analysis, Optimization, Stress, strain

I. INTRODUCTION

Increasing the performance of an internal combustion engine requires the transformation of total fuel energy to useful energy at the highest as possible. Increase of inner cylinder heat plays important role in the increase of engine performance and decrease of exhaust emissions. It is understood as a result of literature studies that coating combustion chamber elements with thermal barriers contributes a lot to the increase of inner cylinder heat. This study includes an evaluation of experimental studies and its results carried out upon the methods applied on coating with thermal barrier in diesel engines, the effects of coating on the performance of engine and exhaust emissions.

Ceramic coatings applied to diesel engine combustion chambers are aimed to reduce heat which passes from in-cylinder to engine cooling system. Engine cooling systems are planned to be removed from internal combustion engines by the development of advanced technology ceramics. One can expect that engine power can be increased and engine weight and cost can be decreased by removing cooling system elements (coolant pump, ventilator, water jackets and radiators etc.

It is important to calculate the piston temperature distribution in order to control the thermal stresses and deformations within acceptable levels. The temperature distribution enables the designer to optimize the thermal aspects of the piston design at lower cost, before the first prototype is constructed. As much as 60% of the total engine mechanical power lost is generated by piston ring assembly

Most of the internal combustion (IC) engine pistons are made of aluminium alloy which has a thermal expansion coefficient 80% higher than the cylinder bore material made of cast iron. This leads to some differences between running and the design clearances. Therefore, analysis of the piston thermal behaviour is extremely crucial in designing more efficient engines. The thermal analysis of piston is important from different point of views. First, the highest temperature of any point on piston should not exceed 66% of the melting point temperature of the alloy .

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This limiting temperature for the current engine piston alloy is about 370 °C. This temperature level can be increased in ceramic coating diesel engines.

Ceramics have a higher thermal durability than metals; therefore it is usually not necessary to cool them as fast as metals. Low thermal conductivity ceramics can be used to control temperature distribution and heat flow in a structure. Thermal barrier coatings (TBC) provide the potential for higher thermal efficiencies of the engine, improved combustion and reduced emissions. In addition, ceramics show better wear characteristics than conventional materials. Lower heat rejection from the combustion chamber through thermally insulated components causes an increase in available energy that would increase the in-cylinder work and the amount of energy carried by the exhaust gases, which could be also utilized

II. LITERATURE SURVEY

This topic shows review on design analysis of piston on the basis of improving strength according to the material properties. Vibhandik et. al . (2014), studied that Design analysis and optimization of piston and deformation of its thermal stresses using CAE tools, he had selected I.C. engine piston from TATA motors of diesel engine vehicle. He had performed thermal analysis on conventional diesel piston and secondly on optimized piston made of aluminum alloy and titanium alloy material. Conventional diesel piston made of structural steel. The main objective of this analysis is to reduce the stress concentration on the upper end of the piston so as to increase life of piston. After the analysis he conclude that titanium has better thermal property, it also help us to improve piston qualities but it is expensive for large scale applications, due to which it can be used in some special cases.

Ch. Venkata Rajam et. al . (2013), focused on Design analysis and optimization of piston using CATIA and ANSYS. He had optimized with all parameters are within consideration. Target of optimization was to reach a mass reduction of piston. In this analysis a ceramic coating on crown is made. In an optimization of piston, the length is constant because heat flow is not affected the length, diameter is also made constant due to same reason. The volume varied after applying temperature and pressure loads over piston as volume is not only depending on length and diameter but also on thickness which is more affected. The material is removed to reduce the weight of the piston with reduced material. The results obtained by this analysis shows that, by reducing the volume of the piston, thickness of barrel and width of other ring lands, Von mises stress is increased by and Deflection is increased after optimization. But all the parameters are with in design consideration.

V. V. Mukkawar et. al . (2015), describes the stress distribution of two different Al alloys by using CAE tools. The piston used for this analysis belongs to four stroke single cylinder engine of Bajaj Pulsar 220 cc motorcycle. He had concluded that deformation is low in AL-GHY 1250 piston as compare to conventional piston. Mass reduction is possible with this alloy. Factor of safety increased up to 27% at same working condition. He used Al-GHY 1250 and conventional material Al-2618 and results were compared, he found that Al-GHY 1250 is better than conventional alloy piston. Manjunatha T. R. et. al. (2013), under look specification for both high pressure and low-pressure stages and analysis is carried out during suction and compression stroke and identify area those are likely to fail due to maximum stress concentration. The material used foe the cylinder is cast-iron and for piston aluminum alloy for both low and high pressure. He concluded that the stress developed during suction and compression stroke is less than the allowable stress. So the design is safe.

Swati S. chougule et. al. (2013), focused on the main objective of this paper is to investigate and analyze the stress distribution of piston at actual engine condition during combustion process the parameters used for simulation is operating gas pressure and material properties of piston. She concluded that there is a scope for reduction in a scope for reduction in thickness of piston and therefore 0ptimization of piston is done with mass reduction by 24.319% than non-optimized piston. The static and dynamic analysis is carried out which are well below the permissible stress value.

The study of Lokesh Singh et. al(2015) is related to the material for the piston is aluminum silicon composites. The high temperature at piston head, due to direct contact with gas, thermal boundary conditions is applied and for maximum pressure mechanical boundary conditions are applied. After all these analyses all values obtained by the analysis is less than permissible value so the design is safe under applied loading condition.

Solid Works (stylized as **SOLIDWORKS**), is a solid modelling computer-aided design (CAD) and computer-aided engineering(CAE) software program that runs on Microsoft Windows. The Solid Works is produced by the Dassault Systems— a subsidiary of Dassault Systems, S. A. based in Vélizy, France— since 1997. Solid Works is currently used by over 2 million engineers and designers at more than 165,000 companies worldwide.

III. ANALYSIS RESULTS

3D printing simulation result for 450 W

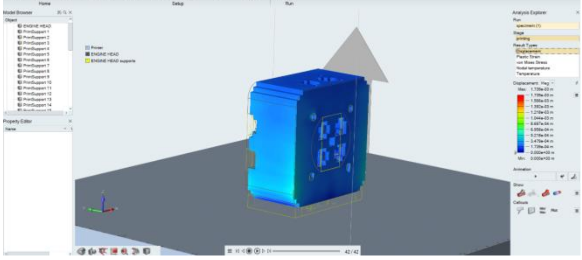

Fig 1: Displacement after printing process

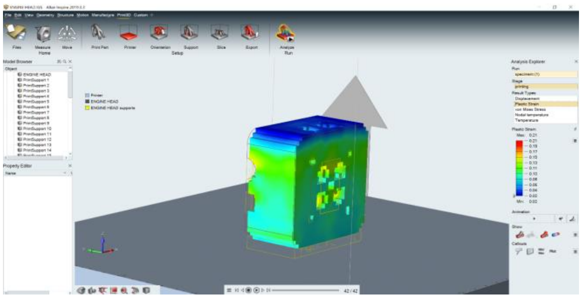

Fig 2: plastic strain after printing process

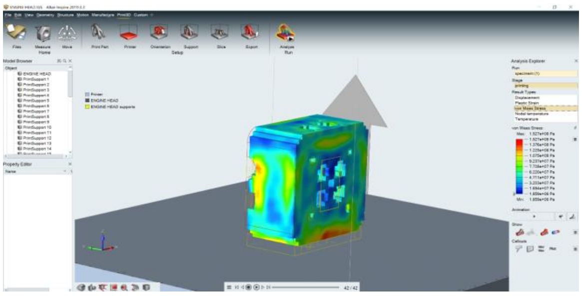

Fig 3: von mises stress after cooling process

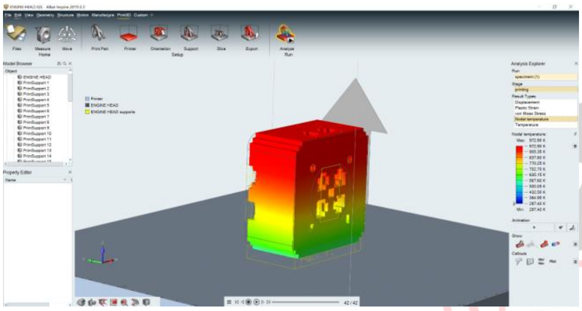

Fig 4: Nodal temperature distribution after cooling process

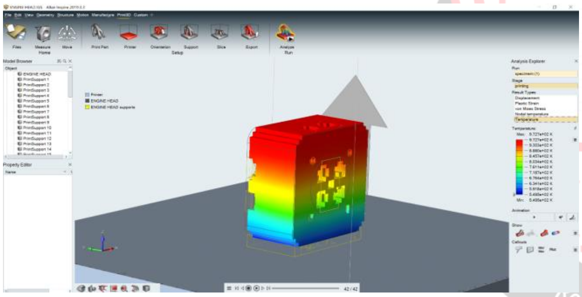

Fig 5: temperature distribution after printing process

3D printing simulation result for 500 W

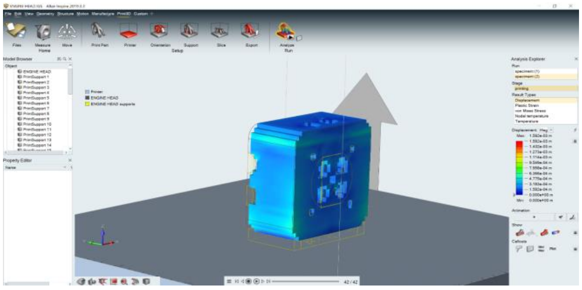

Fig 6: Displacement after printing process

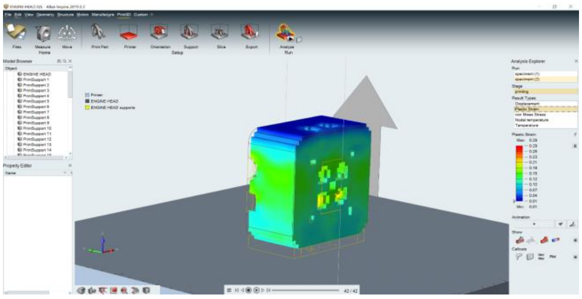

Fig 7: plastic strain after printing process

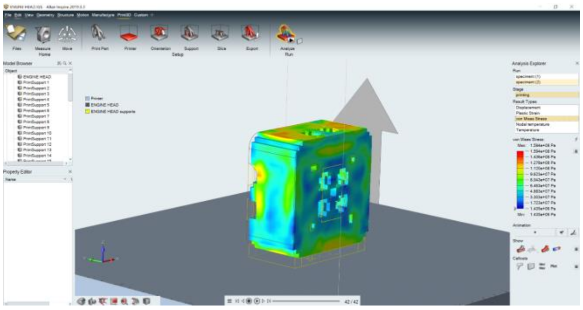

Fig 8: von mises stress after cooling process

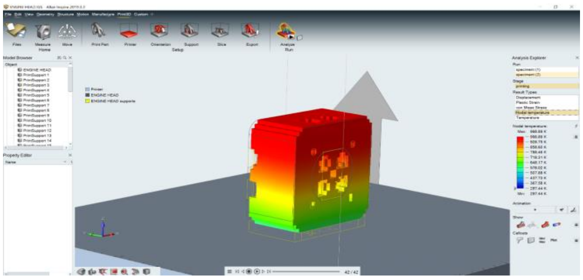

Fig 9: Nodal temperature distribution after cooling process

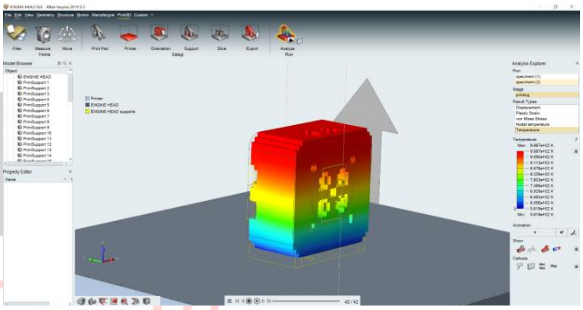

Fig 10: temperature distribution after printing process

3D printing simulation result for 550 W

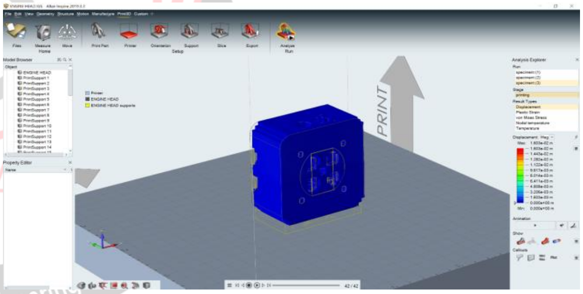

Fig 11: Displacement after printing process

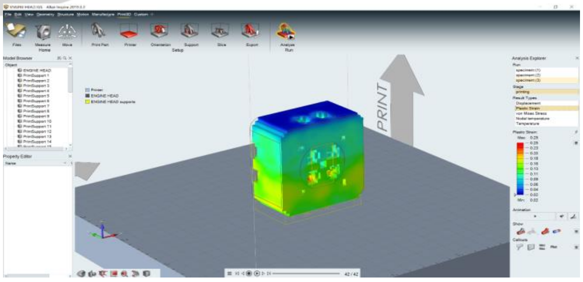

Fig 12: plastic strain after printing process

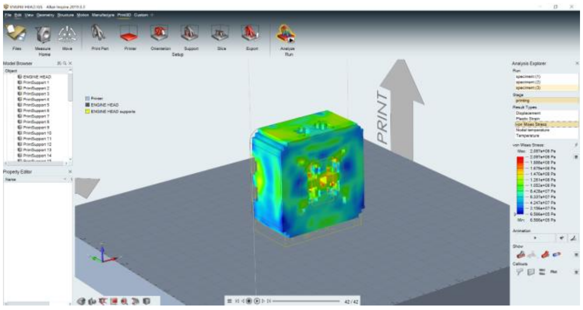

Fig 13: von mises stress after cooling process

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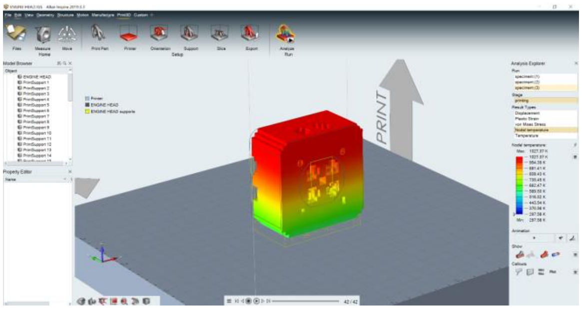

Fig 14: Nodal temperature distribution after cooling process

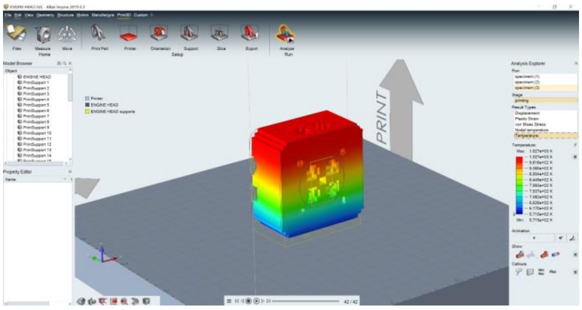

Fig 15: temperature distribution after printing process

IV. CONCLUSIONS

By performing the simulation of engine head for different laser powers 450 W, 500W, 550W we can conclude that

1. As the laser power increasing the displacement of the component increasing but at 500W we get the optimized displacement values.
2. Similarly, as the laser power increasing it unstable the melt pool and improper cooling rate and decreases the dimensional accuracy. Also, increase the surface roughness
3. As the laser power increasing von mises stresses also increasing in the final component.
4. As the stresses in the component increasing, it causes in increasing the residual stresses in the final component.
5. The nodal temperature in the final component increasing consciously which might be the reason for larger displacement. To avoid the nodal temperature, we need give more cooling time.
6. By conducting the simulations, we can conclude that engine head can be print with 450 W laser power where the optimized

In the future experimental investigations need to be performed to check the effect of laser power on the mechanical properties and dimensional accuracy

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