



DESIGN AND ANALYSIS OF A PISTON BY MATERIAL OPTIMIZATION

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ABSTRACT

In this project we are doing the material optimization of the piston and designed the 3D model of the piston by using pro-e software and the analysis taken by different materials and the analysis taken by the Ansys software. This project we are analyzing the pressure acting on the piston by the two materials. Presently the pistons are made by the material of AL-Mg-Si, this project we are testing the same load under with SILUMIN. Then the thermal analysis is done to determine the total heat flux in the existing piston for the given temperature conditions. The temperature acting on the surface of the piston is applied. The results were also used to determine the total heat flux for a particular material.

Keywords:

I. INTRODUCTION

The Piston is a 'heart' of an automobile engine.. The function of the piston is bearing the gas pressure and making the crankshaft rotation through the piston pin. Piston works in high temperature, high pressure, high speed and poor lubrication conditions. Piston contact with high temperature gas directly, the instantaneous temperature can be high. Because of the high temperature and the poor cooling condition, the temperature of the top of the piston can be reach certain level when the piston working in the engine. And the temperature distribution is uneven.

The top of the piston bears the gas pressure, in particular the work pressure. The investigations indicate that greatest stress appears on the upper end

of the piston and stress concentration is one of the mainly reason for failure.

In this study the piston is used in low idle and rated speed engine. In order to enhance the engine dynamic and economic, it is necessary for the piston to implement optimization. Based on the analysis of optimal result, the stress concentration on the upper end of piston has become evaluate, which provides a better reference for redesign of a piston. As one of the major moving parts in the power-transmitting assembly, the piston must be so designed that it can withstand the extreme heat and pressure of combustion. It also transmits heat to the cooling oil and some of the heat through the piston rings to the cylinder wall.

1.1 FUNCTIONS:

The functions which a piston is called to perform in an IC engine are;

- To transmit the force of explosion to the crankshaft.
- To form a seal so that the high pressure gases in the combustion chamber do not escape into the crankcase.
- To serve as a guide and a bearing for small end of the connecting rod. Apart from its capability to perform the above functions efficiently the pistons must have some other desirable characteristics.
- The design should be such that the seizure does not occur.
- It should offer sufficient resistance to corrosion due to some other products of combustion.



- It should have the shortest possible length so as to decrease overall engine size.

1.2 MATERIALS AND

CONSTRUCTIONAL FEATURES:

The top of the piston is called head or crown. Generally low cost low performance engines have flat head as shown. In some such pistons which come quite close to the valves, the head is provided valve relief. Pistons used in some high powered engines have a raised dome which is used to increase the compression ratio as well as to control combustion.

In some other engines the piston may be dished to form a desired shape of combustion chamber, jointly with cylinder head. In case of piston containing part of the combustion in its crown, compression ratio can be controlled very accurately but the disadvantage is that in this case much larger amount of heat has to be dissipated through the pistons and rings.

Towards the top of the piston of a few grooves are cut to house the piston rings. The bands left between the grooves are known as lands. These lands support the rings against the gas pressure and guide them so that they may flux freely in the radial direction. The supporting webs transmit the force of explosion directly from the crown to the piston pin bosses thereby relieving the groove portion of the large load and thus by preventing the deformation of the ring grooves.

The material used for pistons at one time was cast iron which has good wearing qualities. As the technology developed Aluminium alloy containing silicon replaced cast iron as piston material, because of two distinct advantages. Firstly it is as much as three times lighter than the cast iron which makes it is desirable from inertia point of view.

Secondly it possesses a higher thermal conductivity which causes it to run cool. But the aluminium alloy has its own advantages. It is not as strong as cast iron and hence thicker sections have to be used. As a result of which the weight of piston is increased. It is seen that an aluminium alloy piston in actual practice is only about 50 percent in weight as compared to its cast iron counterpart. Further aluminium alloy is relatively soft as a result of which fine particles in the lubricating oil become embedded in it. Aluminium alloy piston with fine particles embedded in it causes a sort of grinding or abrasion of the cylinder

walls thus shortening cylinder life. Another important drawback of using aluminium alloy pistons for cast iron cylinders is their unequal coefficient of expansion which causes engine slaps. Because if the cold clearance is kept just sufficient there is danger of seizure at operating temperatures and if cold clearance is kept large the engine knocks or slaps when cold. This difficulty has been overcome by different methods. Some of the functions are.

A. Use of vertical t slots;

vertical or t slots on the non linear side of the piston were earlier used quite commonly. These slots allow the piston skirt to expand without increase of diameter. However the mechanical strength is decreased on account of slot. Moreover with the slot the skirt tends to collapse inwards without elastic recovery. As a result the diameter is reduced permanently which increases the piston slap, instead of decreasing it. For these reasons fully split skirts in which the slot goes only about halfway up with blunting holes at the ends to avoid stress concentration have been used in pistons of some light duty engines. Heavy duty pistons never use any such slots.

B. Taper pistons:

The pistons are sometimes turned taper the crown side being smaller in diameter than the skirt end. As higher temperatures occur towards the crown than the side expands more than the skirt due to which the piston diameter becomes uniform under running conditions.

C. Cam ground pistons;

The pistons are cam ground such that they have elliptical section instead of the usual circular one. The minor diameter of the ellipse lies in the direction of the piston pin axis. Such pistons after expanding at operating temperatures become circular automatically the more expansion along minor axis being caused by the metal of piston bosses there. Generally tapered and ovality are combined in the same piston. The amount of ovality is kept maximum at the piston pin boss level and is reduced gradually towards the bottom of the skirt.

D. Special alloys;

special alloys having low coefficient of expansion or rather whose coefficient of expansion is nearly equal to that for cast iron have been used



in the manufacture of pistons without split or specially shaped skirts and giving no piston slap.

II. LITERATURE SURVEY

A few early gas engines had double-acting cylinders, but otherwise effectively all internal combustion engine pistons are single-acting. During World War II, the US submarine Pompano was fitted with a prototype of the infamously unreliable H.O.R. double-acting diesel engine. Although compact, for use in a cramped submarine, this design of engine was not repeated.

In International of science engineering and technology Mr. Vijayakumarpaluri briefly described about the material optimization of piston i.e. the aluminium alloy piston is optimized with the silumin piston. In this project deformation, stress and strain values of the aluminium alloy piston are compared with the silumin piston by using static analysis. [1]

In International journal of innovative research in science, engineering and technology S. Srikanth Reddy described about thermal analysis and design optimization of existing piston with the reduced dimensions of the piston. This project mainly carried out for reducing cost of the materials and the weight reduction of the engine.

III. STATIC STRUCTURAL ANALYSIS

A static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time-varying loads. A static analysis can, however, include steady inertia loads (such as gravity and rotational velocity), and time-varying loads that can be approximated as static equivalent loads (such as the static equivalent wind and seismic loads commonly defined in many building codes).

A. TRANSIENT THERMAL ANALYSIS

The ANSYS/Multiphysics, ANSYS/Mechanical, ANSYS/Thermal, and ANSYS/FLOTRAN products support transient thermal analysis. Transient thermal analysis determines temperatures and other thermal quantities that vary over time. Engineers commonly use temperatures that a transient thermal analysis calculates as input to structural analyses for thermal stress evaluations. Many heat transfer applications-heat treatment problems, nozzles, engine blocks,

pipng systems, pressure vessels, etc.-involve transient thermal analyses.

ALUMINIUM ALLOYS

Aluminium alloys typically have an elastic modulus of about 70 GPa, which is about one-third of the elastic modulus of most kinds of steel and steel alloys. Therefore, for a given load, a component or unit made of an aluminium alloy will experience a greater elastic deformation than a steel part of the identical size and shape. Though there are aluminium alloys with somewhat-higher tensile strengths than the commonly used kinds of steel, simply replacing a steel part with an aluminium alloy might lead to problems.

Table: 1 Mechanical and thermal properties for aluminum

AL-Mg-Si > Constants	
Structural	
Young's Modulus	2.3e+005 MPa
Poisson's Ratio	0.24
Density	2.707e-006 kg/mm ³
Thermal	
Thermal Conductivity	0.77 W/mm·°C
Specific Heat	892. J/kg·°C

SILUMIN

Silumin is the name that is used in some countries for alloys based on Al-Si system. Silumin is a series of lightweight, high-strength aluminium alloys with silicon content within range of 3-50%. Most of these alloys are casting ones, but also it would be produce by rapid solidification processes and powder metallurgy

Table: 2 Mechanical and thermal properties for Silumin

SILUMIN > Constants	
Structural	
Young's Modulus	3.17e+005 MPa
Poisson's Ratio	0.27
Density	2.659e-006 kg/mm ³
Thermal	
Thermal Conductivity	0.134 W/mm·°C
Specific Heat	867. J/kg·°C

IV. RESULTS AND DISCUSSIONS

(a) Aluminum alloy:

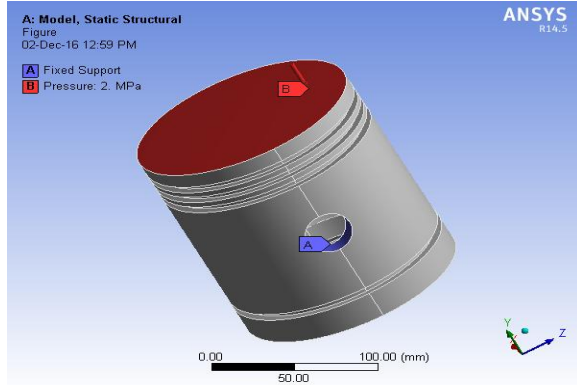


Fig: 1 Static Structural

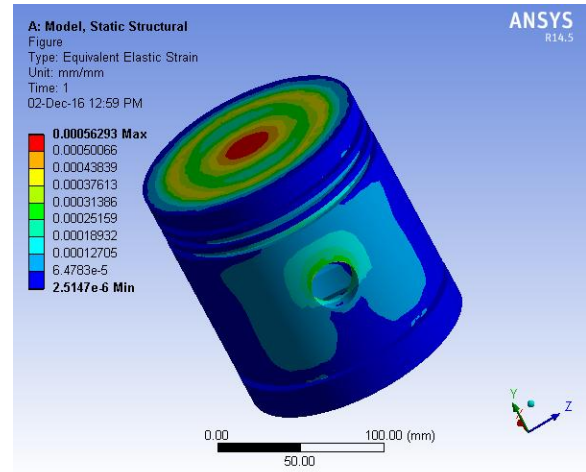


Fig:4: Equivalent elastic strain

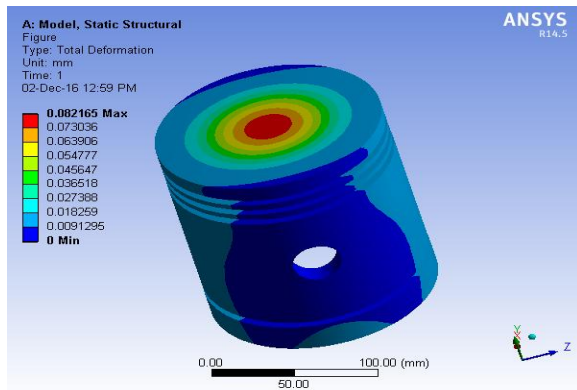


Fig:2 Total Deformation

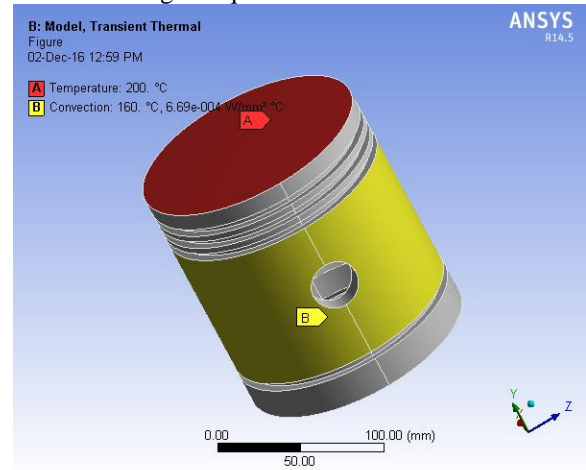


Fig:5: Transient Thermal

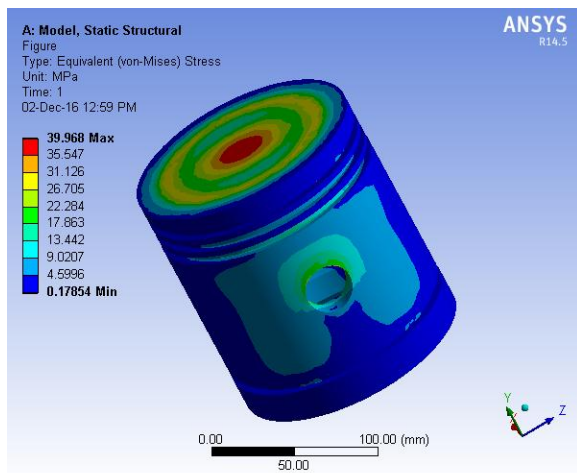


Fig:3: Equivalent stress

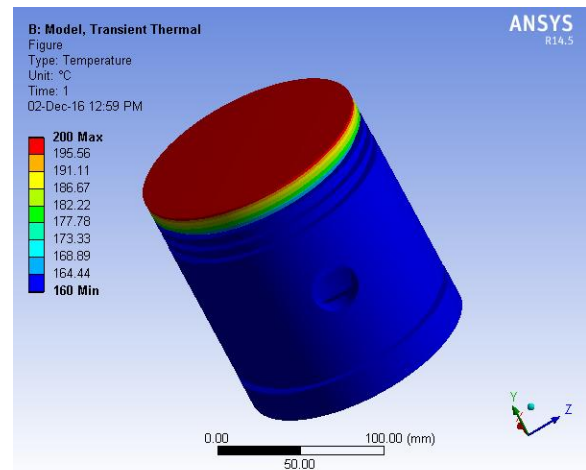


Fig:6: Temperature

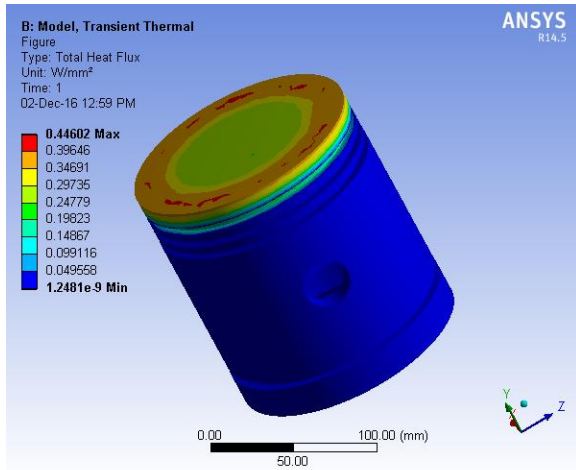


Fig.7: Total Heat Flux+

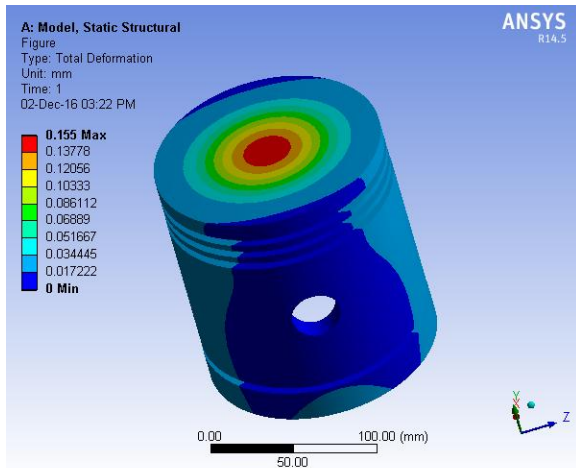


Fig.8: Total Deformation

V. COMPARISION TABLE FOR EXISTING DESIGN

	Total Deformaion (mm)	Max strain (mm/mm)	Max stress (MPa)
Aluminium	0.08217	5.63e-4	39.968
silumin	0.01887	1.20e-4	39.214

FOR OPTIMIZED DESIGN

	Total Deformaion (mm)	Max strain (mm/mm)	Max stress (MPa)
Aluminium	0.13325	7.48e-4	52.52
Silumin	0.03059	1.79e-4	50.18

VI. CONCLUSION

From the above analysis, the weight reduction has been achieved by both design and material optimization. The weight reduction that is been achieved by 26.59 %. From this analysis, the optimized design silumin piston has low deformation and equivalent strain values compared to existing design aluminium alloy piston deformation and equivalent strain values. So the optimized design silumin piston can be used to reduce the cost of the material and the weight of the engine can be minimized to improve the efficiency. So we conclude that the best material for piston is silumin as it has low values of deformation.

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