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DESIGN AND THERMAL ANALYSIS OF PISTON SUBJECTED TO DIFFERENT MATERIALS USING CAE TOOLS

A. Karunakar, Medari Karthik, P. Anil Kumar Goud, Sk. Murthi, Mr.T. Harish Babu
Dept. of Mechanical Engineering, SVITS, Mahbubnagar, Telangana, India.

Abstract: *An IC engine is one in which the combustion of fuel takes place inside the engine cylinder. IC engine uses either petrol or diesel as their fuel. In petrol engines (S.I engines) the correct proportion of air and petrol is mixed in the carburetor and fed to engine cylinder where it is ignited by means of a spark plug. The steps involved in a 4 stroke IC engine are suction stroke, compression stroke, and expansion stroke and exhaust stroke. One of the main components in an IC engine is the combustion chamber. The design of a combustion chamber has an important influence upon the engine performance and its knock and air swirl properties. Design of a combustion chamber involves the shape of the combustion chamber, location of the spark plug and the position of the inlet and exhaust valves. In this project, two different materials (Structural Steel and C35 Steel) are considered. Thermal Analysis is carried out on a piston using different materials. Performance parameters are calculated. Catia is parametric used for design and Ansys workbench used to perform thermal analysis of model piston.*

I- INTRODUCTION

A heat engine is a device which transforms the chemical energy of a fuel into thermal energy and uses this energy to produce mechanical work.

It is classified into two types

(a) External combustion engine

(b) Internal combustion engine

External combustion engine:

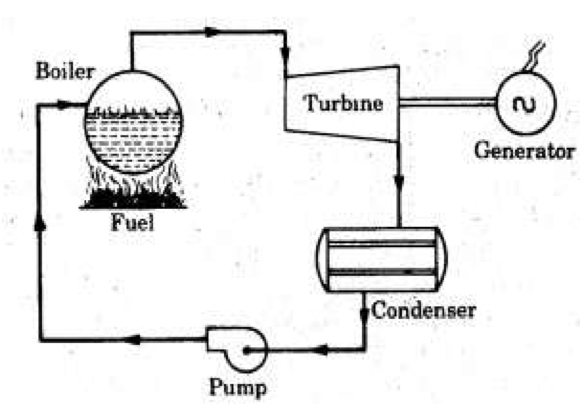

Fig: External combustion engine Cycle

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In this engine, the products of combustion of air and fuel transfer heat to a second fluid which is the working fluid of the cycle.

Internal combustion engine:

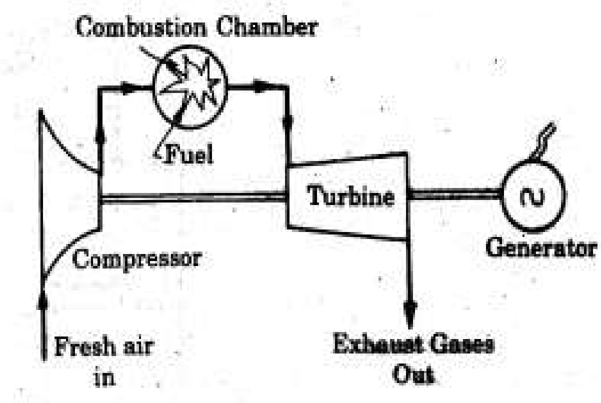

Fig: Internal combustion engine Cycle

An Internal Combustion Engine (IC Engine) is a type of combustion engine that converts chemical energy into thermal energy, to produce useful mechanical work. In an IC engine, combustion chamber is an integral part of the working fluid circuit.

The purpose of internal combustion engines is the production of mechanical power from the chemical energy contained in the fuel. In internal combustion engines, as distinct from external combustion engines, this energy is released by burning or oxidizing the fuel inside the engine. The fuel-air mixture before combustion and the burned products after combustion are the actual working fluids. The work transfers which provide the desired power output occur directly between these working fluids and the mechanical components of the engine. The internal combustion engines which are the subject of this book are spark-ignition engines (sometimes called Otto engines, or gasoline or petrol engines, though other fuels can be used) and compression-ignition or diesel engines. Because of their simplicity, ruggedness and high power weight ratio, these two types of engine have found wide application in transportation (land, sea, and air) and power generation. It is the fact that combustion takes place inside the work producing part of these engines that makes their design and operating characteristics fundamentally different from those of other types of engine.

II - LITERATURE SURVEY

Design And Analysis Of Aluminum Alloy Piston Using Cae Tools; Recent advancement of technology leads to complex decision in the Engineering field. Thus this paper entails the design and analysis of an IC engine piston using two different aluminum materials that are competitive in market. Piston plays a main role in energy

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conversation. Failure of piston due to various thermal and mechanical stresses is common and so expensive to replace. The specifications used for this work is related to four stroke single cylinder engine of Hero Karizma ZMR motorcycle. Design of the piston is carried out using SOLIDWORKS software, thermal and stress analysis is performed using Finite Element Analysis (FEA).The best aluminum alloy material is selected based on thermal and stress analysis results. The analysis results are used to optimize piston geometry of best aluminum alloy.

Design And Analysis Of The Piston By Using Five Different Materials; In the present work describes the stress distribution and thermal stresses of Five different materials for piston by using finite element method (FEM), testing of mechanical properties. The parameters used for the simulation are operating gas pressure, temperature and material properties of piston. The specifications used for this study of these pistons belong to four stroke single cylinder engine of Pulsar 220cc motorcycle. The results predict the maximum stress and critical region on the different materials piston using FEA.Design by using Catia v5 software and analysis by using Ansys software in Ansys 16.0 Static and thermal analysis is performed. The suitable material is selected based on results of structural and thermal analysis on these Al-sic graphite, A7075, A6082, A4032, AL-ghy 1250 materials

Optimization of Piston with Different Materials Using ANSYS; In the present work, optimization of IC engine's piston with different materials has been done on the model of the piston with actual specifications of a two wheeler vehicle. The modelling has been performed on CATIA V5R12 software and further analyses have been carried out on ANSYS thermal analysis workbench. The expected outcome from this project was to find the thermal load that is minimum temperature and maximum heat flux over the surface, and an attempt has been made to minimize the thermal load by optimizing the piston material to get some fruitful advantages. After analyses, it has been found the piston material AL 2024-T4 gives better temperature condition (239.29°C) but poor heat flux (0.39753 W/mm2) so this material is suggested for light or moderate vehicles where material AL 1100-O gives better heat flux (0.47726 W/mm2) but worst temperature condition (305.65°C) so this material is recommended for heavy vehicles.

Design And Static Thermal Analysis Of Piston Using Thermal Barrier Coating Materials Using FEM; Piston is considered to be one of the important parts of an internal combustion engine. It is a part which bears the pressure & temperature of the combustion of the gas inside the cylinder. • The project aims at to increase the performance of the engine by using the Thermal Barrier Coating (TBC). Now a days widely using Internal combustion engines High temperature produced in an I.C engine may contribute to high thermal stresses. • The literature survey shows that ideal piston consumes heat produced by burnt gases resulting in decrease of Engine overall Efficiency. The Aim of the project is UNICORN 150CC engine is considered and TBC material with 0.4mm thickness is coated on the piston crown. 3D modeling of the piston and crown surface design is done 3D designing using the catia software. • In this project taking 6 different Cases regular piston materials (Al-sic, TI64ALV, AL4032 and 2 TBC Materials (Mgzr03,Ni-cr-al). Finite Element analysis is used to calculate stresses, strains, deformations, temperature distributions and heat flux distribution on piston crown. Finally concluded the which material is the suitable for the Internal combustion engine based on the results.

III - OBJECTIVES AND METHODOLOGY

The objective of this project work is to successfully develop a design of the pistons for a IC Engine Combustion Chamber. The mechanism is to be have an important influence upon the engine performance and its knock and air swirl properties. The aim of this project is to provide study about the influence of knock and air swirl in the combustion chamber. This system is also supposed to enhance the comfort as the side force felt by the piston in a Combustion chamber taking a turn is comparatively better performance. Also in our purpose is to intensification of the swirl on the crown of the piston by three different configurations of models.

The methodology adopted to use standard and presently used components in design rather than to design all components from ground up. The advantage of this method is that, you do not have to spend ridiculous amount and time in testing the integrity of each part as they have already proved their worth in real world applications.

Initially the design was adopted from an already existing piston drawings and analysis were made to suite our purpose, this mechanism first devised was based on using power driven by combustion chamber. This mechanism was later dropped in testing phase due to following disadvantages.

1. It had a very large response time; this was not suitable for a combustion chamber approaching at a very high performance.
2. Wear and tear of piston and contact surface limits is too high to be satisfactorily used.
3. The system used for high torque and temperatures; this along with controls could shoot up the performance by using different materials.

Due to these disadvantages, the power screw design was dropped and a fully new design was defined. The design model also uses the same mechanism setup. The software to be used in design is Catia V5 and testing of design is Ansys.

Summary of capabilities

Like any software it is continually being developed to include new functionality. The details below aim to outline the scope of capabilities to give an overview rather than giving specific details on the individual functionality of the product.

Engineering Design

Catia Elements offers a range of tools to enable the generation of a complete digital representation of the product being designed. In addition to the general geometry tools there is also the ability to generate geometry of other integrated design disciplines such as industrial and standard pipe work and complete wiring definitions. Tools are also available to support collaborative development.

Analysis

Ansys Elements has numerous analysis tools available and covers thermal, static, dynamic and fatigue FEA analysis along with other tools all designed to help with the development of the product. These tools include human factors, manufacturing tolerance, mould flow and design optimization. The design optimization can be used at a geometry level to obtain the optimum design dimensions and in conjunction with the FEA analysis.

IV - WORKING MECHANISM

A piston is at the heart of a reciprocating engine. It consists of a moving cylinder of metal with piston rings to achieve an air-tight seal once it is installed within the engine cylinder. The piston is attached via a piston pin to a connecting rod, which in turn is connected to the crankshaft.

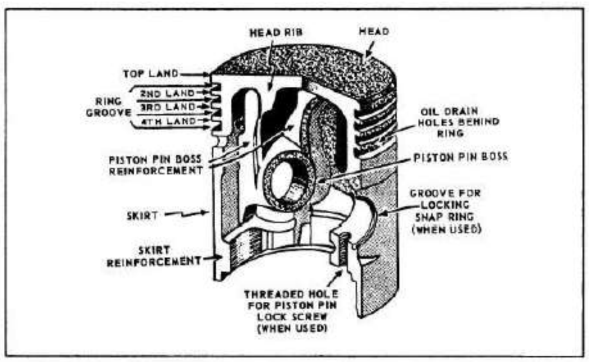

Fig: Cross-Section of Piston

In four-stroke (gasoline and diesel) car engines, the intake, compression, combustion and exhaust process takes place above the cylinder head, which forces the piston to move up and down (or in and out in a flat engine) within the cylinder, thereby causing the crankshaft to turn.

What is a piston made of?

Engine components need to be hardwearing for longevity and lightweight to improve efficiency.
As a result, pistons are usually made from an aluminium alloy but the piston rings (usually comprising, from top to bottom, a compression ring, a wiper ring and an oil ring) are made from cast iron or steel.

The oil ring wipes oil from the cylinder wall when the piston is moving but over time it and the other rings can wear, allowing oil from the crankcase to move into the combustion chamber.

Excessive oil consumption and white smoke from the exhaust tailpipes indicate piston ring wear.

Internal combustion engines can operate with a single cylinder - and therefore one piston (motorbikes and petrol lawnmowers) or as many as 12, but most automobiles have four or six. Radial engines, commonly used in propeller-driven planes, have an odd number of cylinders and pistons for a smoother operation.

Pistons also feature in external combustion engines, otherwise known as steam engines, where water is heated in a boiler and the resulting steam is used to propel a pair of pistons (typically) in external cylinders, which then drive the wheels. Rotary engines do not have cylinders or pistons.

2D Drawing of IC Engine Piston

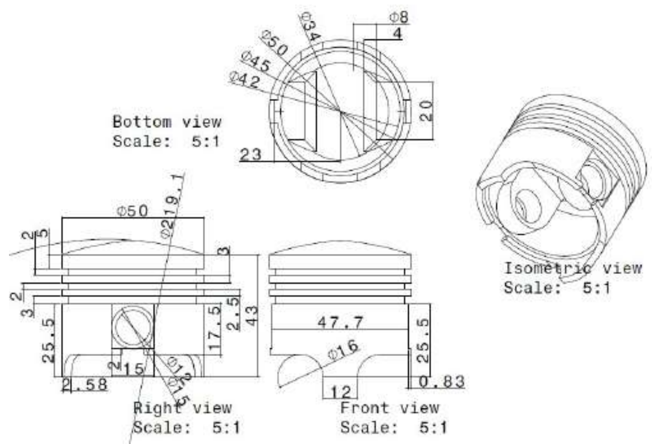

Fig: IC Engine Piston

V - DESIGN METHODLOGY OF 4 STROKE IC ENGINE PISTONS

Modeling 4 Stroke IC Engine Pistons in CATIA V5

These 4 Stroke IC Engine Pistons is designed using CATIA V5 software. This software used in automobile, aerospace, consumer goods, heavy engineering etc. it is very powerful software for designing complicated 3d models, applications of CATIA Version 5 like part design, assembly design.

The same CATIA V5 R20 3d model and 2d drawing model is shown below for reference. Dimensions are taken from. The design of 3d model is done in CATIA V5 software, and then to do test we are using below mentioned software's.

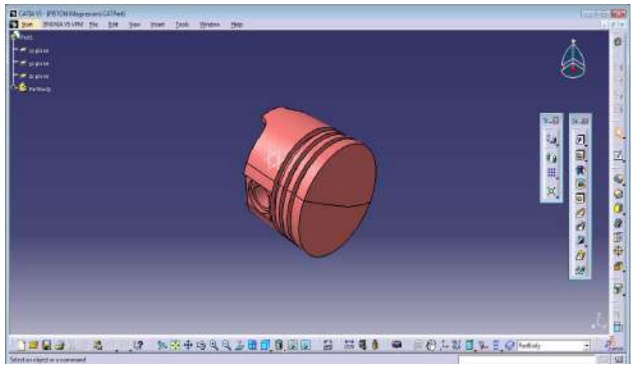

Fig: Model arrangement Piston – C35 Steel in CATIA-V5

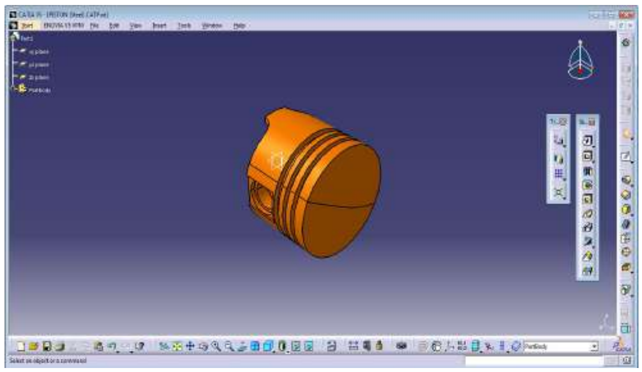

Fig: Model arrangement Piston – Structural Steel in CATIA-V5

VI - ANALYSIS OF 4 STROKE IC ENGINE PISTONS

6.1 Procedure for FE Analysis Using ANSYS:

The analysis of the different model pistons is done using ANSYS. For compete assembly is not required, is to carried out by applying moments at the location along which axis we need to mention. Fixing location is bottom legs.

6.2 Preprocessor

In this stage the following steps were executed:

- **Import file in ANSYS window**

File Menu > Import> STEP > Click ok for the popped up dialog box > Click

Browse" and choose the file saved from CATIAV5R20 > Click ok to import the file

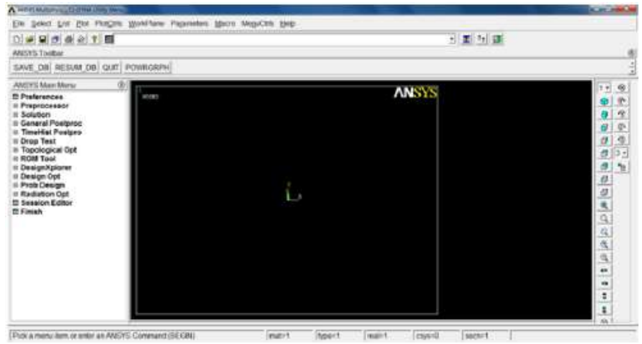

Fig.6.1: Import panel in Ansys.

VII - DISCUSSION ON ANALYSYS RESULT

Nodal Temperature Results for Piston:

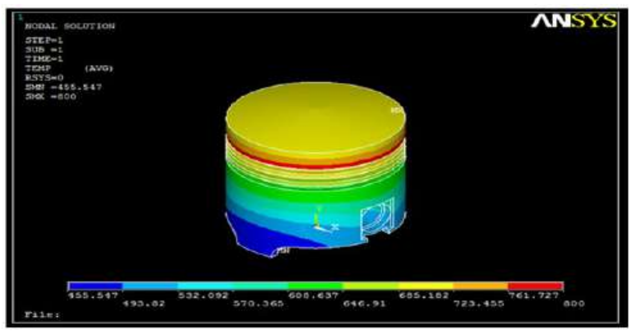

Fig: Nodal Temperature of Piston – C35 Steel

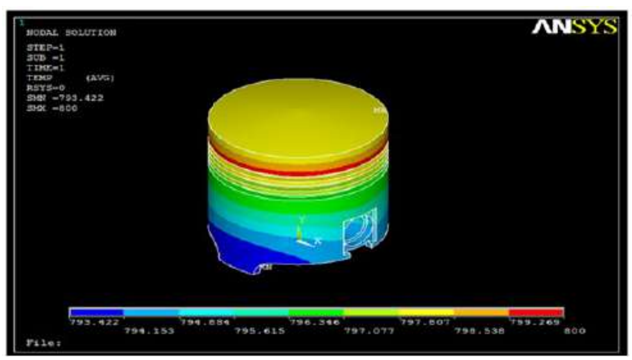

Fig: Nodal Temperature of Piston – Structural Steel

Thermal Gradient Results for Piston:

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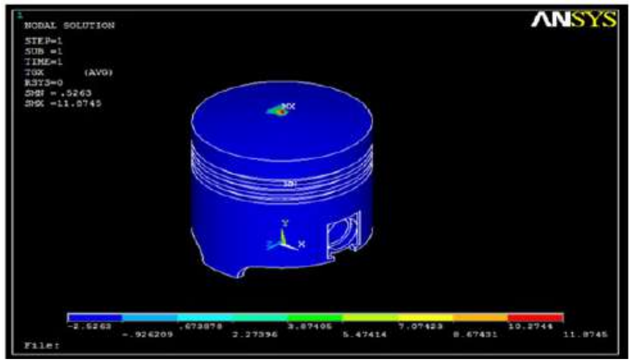

Fig: Thermal Gradient of Piston – C35 Steel

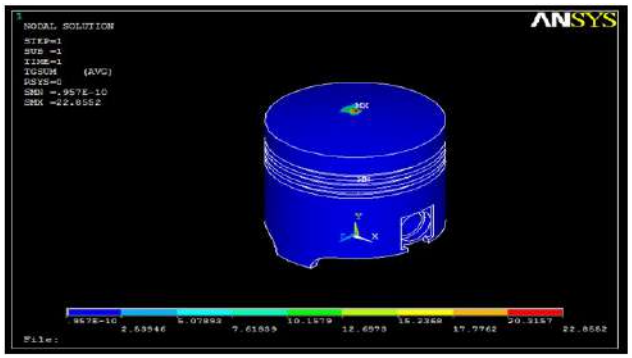

Fig: Thermal Gradient of Piston – Structural Steel

Thermal Flux Results for Piston:

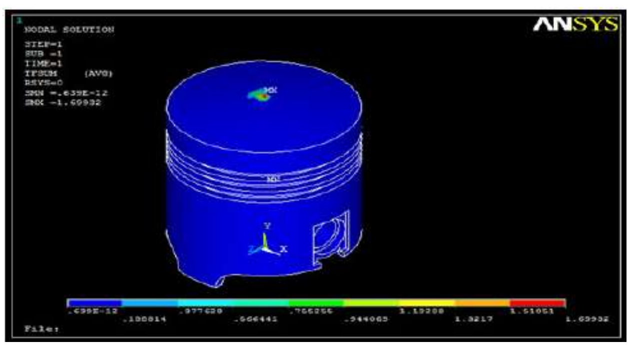

Fig: Thermal Flux of Piston – C35 Steel

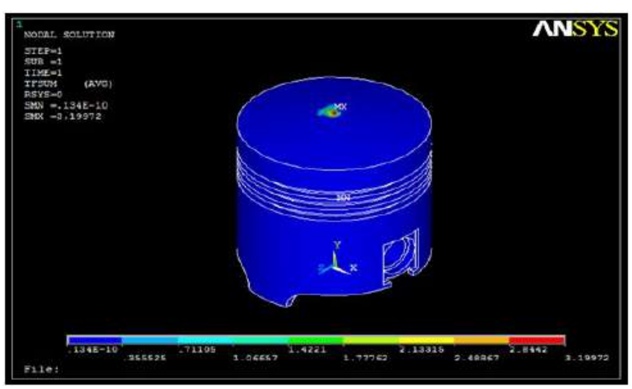

Fig: Thermal Flux of Piston – Structural Steel

Heat Flow Results for Piston:

Fig: Heat Flow of Piston – C35 Steel

Fig: Heat Flow of Piston – Structural Steel

VIII - CONCLUSION

It can be seen from the above result that, our objective to analyze the combustion chamber piston by using by the design of the piston with different materials has been successful.

As shown above figures the Nodal Temperature of the piston design is meshed and solved using Ansys. This is showing us that clearly each component in assembly. The maximum Thermal gradient is coming, this solution solving with the help of Ansys software. The maximum Thermal flux is coming, this solution solving with the help of Ansys software so that the maximum Thermal flux value is considered. So we can conclude our design parameters are approximately correct.

Table: Thermal Analysis Results

S.No	Description	C35 Steel	Structural Steel
01	Nodal Temperature (in °C)	4555.547	793.422
02	Thermal Gradient (in °C/mm)	11.8745	22.8552
03	Thermal Flux (in W/mm^2)	1.69932	3.19972
04	Heat Flow	0.03581	0.015681

Therefore, according to the above results we can state that C35 material is obtained better results compared to other Structural Steel as load applied on it. C35 Alloy Steel is a medium Carbon steel, one of the most widely used for machinery parts. Excellent forge ability. Special variants can be made available for cold drawing. Due to the carbon content preheating and post heating are required when welding. So we can conclude our design parameters are approximately correct.

The design of the piston models have intensificated the swirl and knocking on the crown of the piston in the combustion chamber by two different materials are done successfully and worked flawlessly in analysis as well. All these facts point to the completion of our objective in high esteem.

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