ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Design and Structural Analysis of Composite Piston

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Abstract :

The project mainly deals with the design, analysis of piston. A piston is a component of reciprocating engines, reciprocating compressors and pneumatic cylinders among other similar mechanisms. In an engine, its purpose is to transfer force from expanding gas in the cylinder to the crankshaft via a piston rod/and or connecting rod. Here the piston is designed, analyzed and the manufacturing processes have been studied. Piston temperature has considerable influence on efficiency, emission, performance of the SI engine. Purpose of the investigation is the measurement of piston transient temperature at several points on the piston, from cold start to steady condition and comparison with the results of finite element analysis.

In this project the piston is modeled and assembled with the help of CATIA software and component is meshed and analysis is done in ANSYS software and the thermal and static behavior is studied and the results are tabulated. The various stresses acting on the piston under various loading conditions has been studied. In the present thesis work has been taken up on the following aspects to cover the research gaps and to present the results based on the systematic studies.

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INTRODUCTION:

The report traces the mechanism of operation of ICE and its different kinds based on the operation mechanism, specially the two stroke and four stroke engines. It also involves the thermodynamics relations that govern the processes of these engines, highlighting two main important cycles, which are: Otto Cycle and Diesel cycles.

Thus, it uses both cycles to introduce the second categorization of ICE based on the thermodynamic relations, introducing Gasoline engines and Diesel engines.

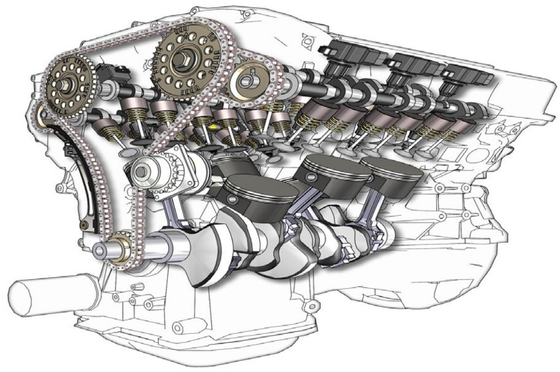
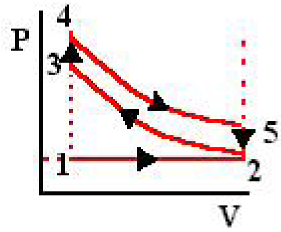


Fig.: Combustion Engine

There are two main cycles based on which we can categorize internal combustion engines, which are Ottocycle and Dieselcycle.

OTTO CYCLE:

Otto cycle is the typical cycle for most of the cars internal combustion engines that work using gasoline as a fuel. Otto cycle is exactly the same one that was described for the four-stroke engine. It consists of the same four major steps: Intake, compression, ignition and exhaust.



SPARK IGNITION ENGINE:

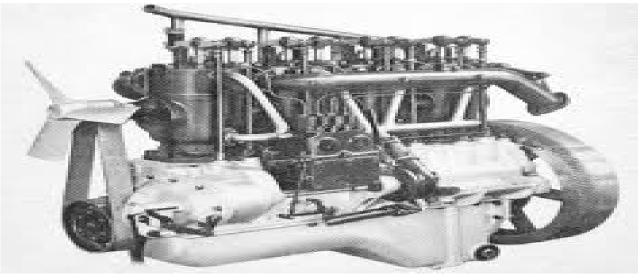


Fig:1.5 Spark Ignition Engine

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The Spark Ignition (SI) engines work on the principle of cycle of operations invented by Nicolas A. Otto in the year 1876.In a gasoline engine the compression ratio (which controls the compression temperature) is limited by the air-fuel mixture entering the cylinders. The lower ignition temperature of gasoline will cause it to ignite (burn) at a compression ratio of less than 10:1. The average car has a 7:1 compression ratio.

LITERATURE REVIEW INTRODUCTION

This work concentrates on processing and machining of bimetallic pistons. This chapter gives an insight for the thorough understanding of the state-of-art in

1.Bimetallic pistons
2.Heat treatment
3.Machining of bimetallic pistons and mach inability studies.

The work addresses the requirement of a piston industry. It emphasizes on the productivity improvement of the bimetallic pistons. Due to its industry relevant nature, the literature available for this topic is scarce. Albeit, some limited literature is available; most are patented.

LITERATURE SURVEY:

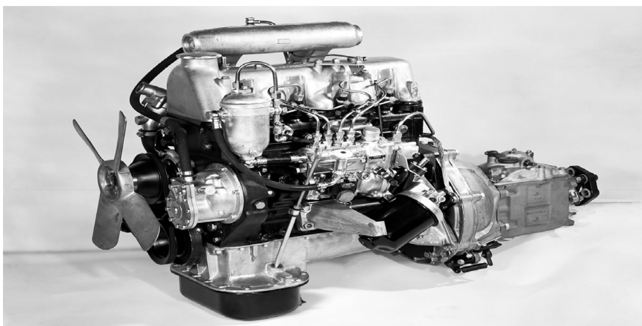
The cast iron pistons were superseded by aluminum alloy piston around the year 1920 (Sarkar 1975). Cole G.S. and Sherman A.M.(1995) explained that a considerable interest had been grown in replacing cast iron and steel in automotive component like piston with light weight aluminum alloy casting to improve the performance and efficiency. Haque M.M and Young J.M. (2001) referred the low expansion group of aluminum–silicon alloy as piston alloy, since this group of alloy provides the best overall balance of properties. Near eutectic aluminum silicon piston alloy exhibit complex fatigue behavior due to their multi component microstructure (Moffat et al 2005)

A ceramic insert is adapted on the head portion of the piston and connected to the same by mechanical locking. The ceramic insert is provided with pores at least on the portion engaging the piston head. The pores have sizes which enable them to be filled with the light alloy during the manufacture of the piston by the squeeze casting method (Mahrus 1988).

Piston can be formed in two parts. The main part is formed by gravity die casting from aluminum or aluminum alloy and a second part of the piston is formed by a squeeze casting process to produce a material which is stronger and more resistant than the gravity die cast aluminum or aluminum alloy. The two parts are then electron beam welded together to form the complete piston. The squeeze cast portion may be reinforced with whiskers or fibers to further improve its properties. This method of construction has the benefit that only a smaller portion of piston is formed by the more expensive and time-consuming squeeze casting process. This is the benefit in large diesel pistons (Avezou 1987). David. J (1985) worked on the provision of a wear resistant insert for pistons of light weight alloys. The insert comprises an annular ring of wear resistant material which has a cylindrical peripheral edge. The annular ring has at least one projection or A ceramic insert is adapted on the head portion of the piston and connected to the same by mechanical locking. The ceramic insert is provided with pores at least on the portion engaging the piston head. The pores have sizes which enable them to be filled with the light alloy during the manufacture of the piston by the squeeze casting method (Mahrus 1988).

INTRODUCTION TO COMPRESSION IGNITION ENGINE:

The concept behind compression ignition involves using the latent heat built up by highly compressing air inside a combustion chamber as the means for igniting fuel. The process involves compressing a charge of air inside the combustion chamber to a ratio of approximately 21:1 (compared to about 9:1 for a spark). This high level of compression builds tremendous heat and pressure inside the combustion chamber just as fuel is primed for delivery. An injection nozzle plumbed into the combustion chamber sprays a mist of precisely metered fuel into the hot compressed air where upon it bursts into a controlled explosion that turns the rotating mass inside the engine.



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Diesel engines are not self-speed-limiting because the air (oxygen) entering the engine is always the maximum amount. Therefore, the engine speed is limited solely by the amount of fuel injected into the engine cylinders. Therefore, the engine always has sufficient oxygen to burn and the engine will attempt to accelerate to meet the new fuel injection rate. Because of this, a manual fuel control is not possible because these engines, in an unloaded condition, can accelerate at a rate of more than 2000 rps. Diesel engines require a speed limiter, commonly called the governor, to control the amount of fuel being injected into the engine.In the case of CI engines the value of compression ratio is higher; hence these engines have the potential to achieve higher thermal efficiency.CI engines are heavier and the fuel is burned heterogeneously, hence producing lower speeds.In the case of CI engines the value of compression ratio is higher; hence these engines have the potential to achieve higher thermal efficiency.

MAIN COMPONENTS OF COMPRESSION IGNITION ENGINE:

CYLINDER BLOCK:

In the bore of cylinder the fresh charge of air-fuel mixture is ignited, compressed by piston and expanded to give power to piston.

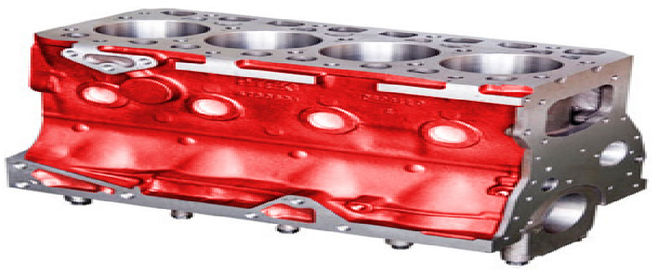

Fig: cylinder block

* CYLINDER HEAD:

It carries inlet and valve. Fresh charge is admitted through inlet valve and burnt gases are exhausted from exhaust valve. In case of engine, a spark plug and in case of diesel engine, a injector is also mounted on cylinder head.

Fig: Cylinder head

PISTON:

During suction stroke, it sucks the fresh charge of air-fuel mixture through inlet valve and compresses during the compression stroke inside the cylinder. This way piston receives power from the expanding gases after ignition in cylinder. Also forces the burnt exhaust gases out of the cylinder through exhaust valve.

DESCRIPTION OF THE PISTON:

A piston is a component of reciprocating engines, reciprocating pumps, gas compressors and pneumatic cylinders, among other similar mechanisms. It is the moving component that is contained by a cylinder and is made gas-tight by piston rings. In an engine, its purpose is to transfer force from expanding gas in the cylinder to the crankshaft via a piston rod and/or connecting rod. In a pump, the function is reversed and force is transferred from the crankshaft to the piston for the purpose of compressing or ejecting the fluid in the cylinder. In some engines, the piston also acts as a valve by covering and uncovering ports in the cylinder wall.Credit for inventing history's first piston engine goes to French physicist Denis Papen, who published his design for a piston steam engine in 1690. The basic design evolved by the early eighteenth century: Thomas Newcomen of England and James Watt of Scotland improved uponPapen's innovation by adding a boiler and steam condenser to the cylinder.

A piston is a cylindrical engine component that slides back and forth in the cylinder bore by forces produced during the combustion process. The piston acts as a movable end of the combustion chamber. The stationary end of the combustion chamber is the cylinder head. Pistons are commonly made of a cast aluminum alloy for excellent and lightweight thermal conductivity. Thermal conductivity is the ability of a material to conduct and transfer heat. Aluminum expands when heated and proper clearance must be provided to maintain free piston movement in the cylinder bore. Insufficient clearance can cause the piston to seize in the cylinder. Excessive clearance can cause a loss of compression and an increase in piston noise. In general, a piston is a sliding plug that fits closely inside the bore of a cylinder.Its purpose is either to change the volume enclosed by the cylinder, or to exert a force on a fluid inside the cylinder.

PISTON RINGS:

A piston ring is a split ring that fits into a groove on the outer diameter of a piston in a reciprocating engine such as an internal combustion engine or steam engine.
The three main functions of piston rings in reciprocating engines are:

1.Sealing the combustion/expansion chamber.
2.Supporting heat transfer from the piston to the cylinder wall.
3.Regulating engine oil consumption.
The gap in the piston ring compresses to a few thousandths of an inch when inside the cylinder bore.

A) LAND:

That part of the piston above the top ring or between ring grooves. The lands confine and support the piston rings in their grooves.

B) HEAT DAM:

A narrow groove cut in the top land of some pistons to reduce heat flow to the top ring groove. This groove fills with carbon during engine operation and reduces heat flow to the top ring.

C)COMPRESSION DISTANCE (or HEIGH T):

The distance from the center of the pin hole to the top of the piston. Where grooves are machined.

D) RING BELT:

That area between the top of the piston and the pin hole for the installation of piston rings.

E) PISTON HEAD:

The top piston surface against which the combustion gases exert pressure. The piston head may be flat, concave, convex or of irregular shape.

F) PISTON PINS (Wrist pins or gudgeon pins):

Connections between the upper end of the connecting rod and the piston. Pins may be held in one of three ways:

1. Anchored in the piston with the bushing in the upper end of the connecting rod oscillating on the pin.
2. Clamped in the rod with the pin oscillating in the piston.
3. Full floating in both connecting rod and piston with lock rings or other devices preventing the pin from contacting the cylinder wall.

G) SKIRT:

That part of the piston located between the first ring groove above the pin hole, and the bottom (open end) of the piston. The skirt forms a bearing area in contact with the cylinder wall.

INTRODUCTION TO CATIA:

CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Assault Systems. Written in the C++ programming language, CATIA is the cornerstone of the Assault Systems product lifecycle management software suite.CATIA competes in the CAD/CAM/CAE market with Siemens NX, Pro/E, Autodesk Inventor, and Solid Edge as well as many others.

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Material Type	Vonmises Stresses (MPa)	Deformation (mm)	Nodal Temp (ºC)	Thermal Flux (W/mm²)	Thermal Gradient (ºC)
Alluminium 2024 Alloy	12072	0.633974	400	0.04825	0.26807
Copper Alloy	19531	0.657864	400	0.04962	0.84524
Stainless Steel Alloy	3170	0.617445	400	0.04107	1.226

Table : Details of CATIA

HISTORY OF CATIA:

CATIA started as an in-house development in 1977 by French aircraft manufacturer Avions Marcel Dassault, at that time customer of the CADAM CAD software to develop Dassault's Mirage fighter jet, then was adopted in the aerospace, automotive, shipbuilding, and other industries.Initially named CATI (Conception Assisted Tridimensionnelle Interactive - French for Interactive Aided Three-dimensional Design) - it was renamed CATIA in 1981, when Dassault created a subsidiary to develop and sell the software, and signed a non-exclusive distribution agreement with IBM.

In 1984, the Boeing Company chose CATIA as its main 3D CAD tool, becoming its largest customer.In 1988, CATIA version 3 was ported from mainframe computers to UNIX.In 1990,

General Dynamics Electric Boat Corp chose CATIA as its main 3D CAD tool, to design the U.S. Navy's Virginia class submarine.In 1992, CADAM was purchased from IBM and the next year CATIA CADAM V4 was published. In 1996, it was ported from one to four UNIX operating systems, including IBM AIX, Silicon Graphics IRIX, Sun Microsystems SunOS and Hewlett-Packard HP-UX.

In 1998, an entirely rewritten version of CATIA, CATIA V5 was released, with support for UNIX, Windows NT and Windows XP since 2001.In 2008, Dassault announced and released CATIA V6. While the server can run on Microsoft Windows, Linux or AIX, client support for any operating system other than Microsoft Windows is dropped.

Release History

Name/Version	Latest Build Number	Original Release Date	Latest Release Date
CATIA v4	R25	1993	January 2007
CATIA v5	R20	1998	February 2010
CATIA v6	R2012	29/05/2008	May 2011

Table versions of CATIA

SCOPE OF APPLICATION:

Commonly referred to as 3D Product Lifecycle Management software suite, CATIA supports multiple stages of product development (CAx), from conceptualization, design (CAD), manufacturing (CAM), and engineering (CAE). CATIA facilitates collaborative engineering across disciplines, including surfacing & shape design, mechanical engineering, equipment and systems engineering.

Surfacing & Shape Design:

CATIA provides a suite of surfacing, reverse engineering, and visualization solutions to create, modify, and validate complex innovative shapes. From subdivision, styling, and Class A surfaces to mechanical functional surfaces.

Mechanical Engineering:

CATIA enables the creation of 3D parts, from 3D sketches, sheet metal, composites, and molded, forged or tooling parts up to the definition of mechanical assemblies. It provides tools to complete product definition, including functional tolerances, as well as kinematics definition.

Equipment Design:

CATIA facilitates the design of electronic, electrical as well as distributed systems such as fluid and HVAC systems, all the way to the production of documentation for manufacturing.

Systems Engineering:

CATIA offers a solution to model complex and intelligent products through the systems engineering approach. It covers the requirements definition, the systems architecture, the behavior modeling and the virtual product or embedded software generation.

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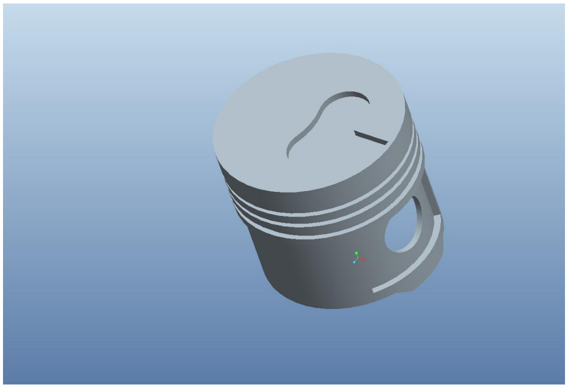
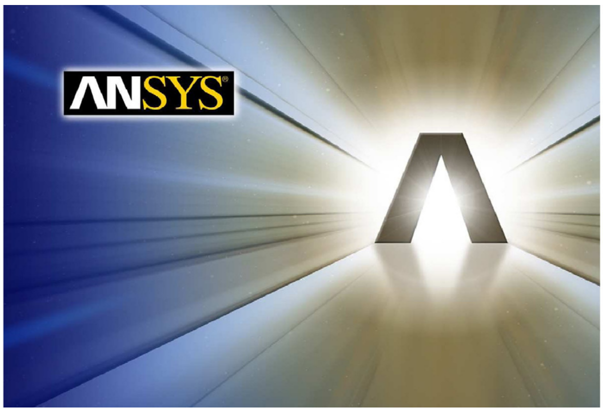
CATIA can be customized via application programming interfaces (API). CATIA V5 & V6 can be adapted using Visual Basic and C++ programming languages via CAA (Component Application Architecture); a component object model (COM)-like interface.Although later versions of CATIA V4 implemented NURBS, V4 principally used piecewise polynomial surface. CATIA V4 uses a non-manifold solid engine.Catia V5 features a parametric solid/surface-based package which uses NURBS as the core surface representation and has several workbenches that provide KBE support.V5 can work with other applications, including Enova, Smarteam, and various CAE Analysis applications.

Model of Piston:



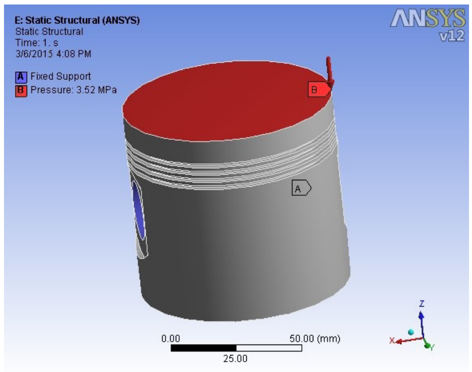
INTRODUCTION TO ANSYS:



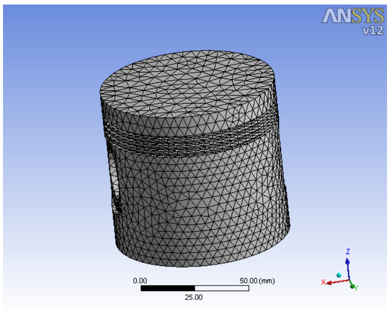
ANSYS is commercial finite-element analysis software with the capability to analyze a wide range of different problems. ANSYS runs under a variety of environments, including IRIX, Solaris, and Windows NT. Like any finite-element software, ANSYS solves governing differential equations by breaking the problem into small elements. The governing equations of elasticity, fluid flow, heat transfer, and electro-magnetism can all be solved by the Finite element method in ANSYS.

ANSYS can solve transient problems as well as nonlinear problems. This document will focus on the basics of ANSYS using primarily structural examples.ANSYS is available on all MEnet Sun and SGI machines. It is available on the Linux machines by remote-login only. On the right side, rumor has it that ANSYS is looking into a Linux port. Currently, MEnet uses the Research/Faculty version of ANSYS 12.1. The Research/Faculty license level permits larger, more complex models than does the current level running on the IT Labs machines. This document is meant to be a starting point. The material covered here is by no means comprehensive. In fact, we will only scratch the surface of ANSYS's capabilities. Given that, I will try to cover most of what I know about ANSYS and some tricks I have learned while using it. The document will begin with two simple examples, taking the user through all of the steps of creating a model, meshing, adding boundary conditions, solving, and, finally, looking at the results. The remainders of this document will over tips and tricks for each of the steps.

IMPORTING THE PRO-E MODEL & FIXING THE SUPPORT IN ANSYS:



MESHING MODEL OF PISTON:



RESULT:

Table 2 Static analysis for piston material 2(aluminum-5045) stress developed by the pressure of 3.45 Mpa

s.no	Stress	Values in Mpa
1	Normal stress in x-direction	97.574
2	Normal stress in y-direction	93.113
3	Normal stress in z-direction	63.517
4	Shear stress in x-direction	31.81
5	Shear stress in y-direction	38.548
6	Shear stress in z-direction	42.325
7	Equivalent Stress	209.02

CONCLUSION:

Background :

Physically, chemically and mechanically aluminium is a metal like steel, brass, copper, zinc, lead or titanium. It can be melted, cast, formed and machined much like these metals and it conducts electric current. In fact often the same equipment and fabrication methods are used as for steel.

Light Weight :

Aluminium is a very light metal with a specific weight of 2.7 g/cm3, about a third that of steel. For example, the use of aluminium in vehicles reduces dead-weight and energy consumption while increasing load capacity. Its strength can be adapted to the application required by modifying the composition of its alloys.

Corrosion Resistance :

Aluminium naturally generates a protective oxide coating and is highly corrosion resistant. Different types of surface treatment such as anodising, painting or lacquering can further improve this property. It is particularly useful for applications where protection and conservation are required.

Electrical and Thermal Conductivity :

Aluminium is an excellent heat and electricity conductor and in relation to its weight is almost twice as good a conductor as copper. This has made aluminium the most commonly used material in major power transmission lines.

Ductility :

Aluminium is ductile and has a low melting point and density. In a molten condition it can be processed in a number of ways. Its ductility allows products of aluminium to be basically formed close to the end of the product's design. The electrical and thermal conductivity of aluminum can be improved by the addition of trace amounts of boron to eliminate the undesirable effects of chromium, titanium, vanadium, and zirconium. Aluminium Boron master alloys provide a convenient mechanism for making the desired boron addition. Boron has also been acknowledged as an effective grain refiner for silicon aluminum alloys .

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