ANALYSIS AND DESIGN OF FOUR STROKE PISTON FOR DIESEL ENGINE

M.Govindraj[1], Mr.M.Ranjithkumar[2]

[1,2,]Assistant professor, Department of Mechanical Engineering,AEC,Salem

Abstract:

This study examines thermal analysis on a conventional piston composed of the aluminium alloy A2618. Second, a piston fabricated of Al-GHS1300 and coated with zirconium dust is subjected to a thermal study using the commercial code ANSYS. Examining and analysing the piston's thermal stress distribution during the combustion phase in an actual engine is the major goal. This paper examines the thermal behaviour of functionally graded coatings applied on zirconium- and aluminum-coated piston surfaces using the commercial code ANSYS. The goal of the research is to lessen the tension that builds up on the piston's upper portion, which includes the piston head, crown, skirt, and sleeve. The computer aided design V5 Catia software will be used to construct the structural model of a piston. Furthermore, the finite element analysis is carried out using ANSYS, a computer-aided simulation programme. For the investigation of piston input circumstances and the analytical process, a thorough literature search was done. A comparison analysis is done to determine the best content.

Keywords: **A2618, Al-GHS1300, Zirconium, Thermal analysis, Piston crown, Piston skirt, FEA, ANSYS etc.**

I. INTRODUCTION

The use of cars has risen dramatically in recent years as a result of the world's growing population. Within our budget, we expect good performance from automobile cal components such as pistons. To achieve this, R&D and inspection engineers must improve a variety of essential components in the shortest time possible for a new product. Here, we'll talk about one of the most important components: the piston. Each reciprocating I.C engine has a piston, which is one of the most essential components. Pistons are gas-tight piston rings that are mounted within the cylinder block as a moving part. A piston rod and connecting rod are used in an I.C engine to move the expanding gas force in the cylinder to the crankshaft. The piston generates cyclic gas pressure during compression, and the working conditions can lead to piston failures such as piston side wear, piston head or crown cranks, and piston overheating-seizure, among other things. As a result, analysing the stress distribution, temperature distribution, heat transfer, and mechanical load is critical in order to mitigate stress at various loads on the piston.

A. HISTORY OF IC ENGINES

1700s - Stream Engines (External Combustion Engines) 1860s - Lenoir Engine (η = 5 %) 1867s - Otto-Langen Engine (η = 11 %, 90 RPM max,) 1876s - Otto Four Stroke Spark

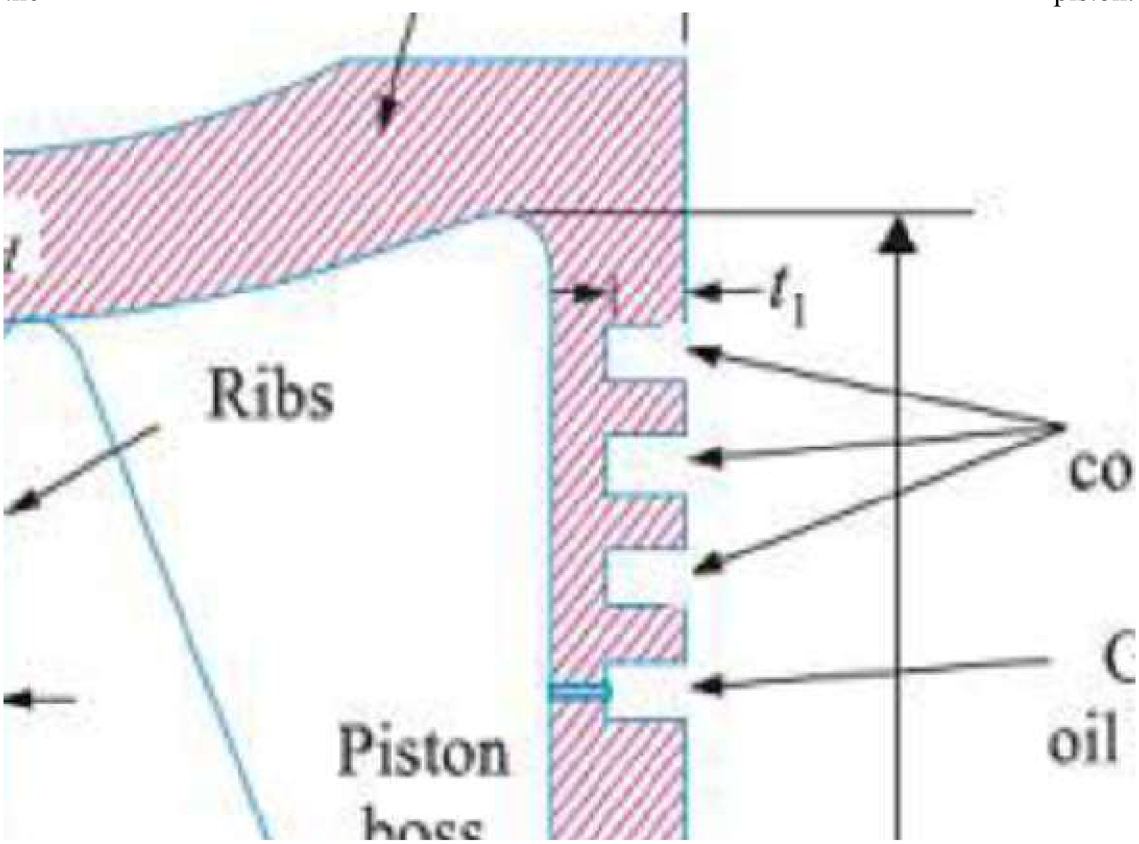
Ignition Engine (η = 14 %, 160 RPM max.) 1880s - Two Stroke Engine 1892s - Diesel Four Stroke Compression Ignition Engine 1957s - Wankel Rotary Engine **C. MATERIAL USED FOR PISTON** 1. Aluminum alloy A2618 2. Aluminum alloy GHS-1300 3. Zirconium **D. MATERIAL PROPERTIES Aluminium alloy A2618 & Al-GHS1300**

S. No	Parameters	Aluminum alloy A2618	Al- GHS1300
1	Poisson's Ratio (μ)	0.33	0.3
2	Young's Modulus(E) GPa	70-80	98
3	Thermal Conductivity(k) W/m°C	147	120
4	Density(ρ) Kg/m^3	2767.9981.25	2780
5	Permissible Bending stress(σ_t)Mpa	370	1220
6	Allowable Bending stress(σ_t)MPa	90	92
7	Ultimate Tensile Strength Mpa	440	1300

PROPERTIES	VALUES WITH UNIT
Atomic number	40
Atomic mass	91.22g/mol
Electro negativity	1.2
Density	6.49 g/cm^3
Melting point	1852◦C
Boiling point	4400◦C
Vander Waals radius	0.160nm
Ionic radius	0.08nm
Isotopes	11
Electronic shell	$4d^2$
Energy of first ionization	669kj/mol
Energy of second ionization	1346kj/mol
Energy of third ionization	2312kj/mol
Energy of fourth ionization	3256kj/mol
Discovered by	Martin klaproth in 1789

II. PISTON

Piston is one of the mechanical component, piston invented in a German scientist Nicholas August Otto in year 1866. Piston is considered to be one of the most important parts in a reciprocating engine, reciprocating pumps, gas compressors and pneumatic cylinders, among other similar mechanisms in which it helps to convert the chemical energy obtained by the combustion of fuel into useful power. The piston's purpose is to provide a means of conveying gas expansion to the crankshaft via the connecting rod. The piston is basically a cylindrical plug that goes up and down in the cylinder, serving as a movable end of the combustion chamber. It has piston rings to ensure a strong seal between the cylinder wall and the piston.



Piston components for I.C. engine F

Following are the main parts of piston 1) Piston Head or crown: It is flat, convex or concave depending on design of combustion chamber. It withstands pressure of gas in the cylinder. 2)

Piston rings: It is used to seal the cylinder in order to prevent leakage of gas past the piston. 3) Skirt: It acts as bearing for the side thrust of connecting rod on the walls of cylinder. 4) Piston pin: It is also called gudgeon pin or wrist pin. It is used to connect the piston to the connecting rod.

III. DESIGN

A. DESIGN CALCULATION

Let, IP = indicated power produced inside the cylinder (W) n = number of working stroke per minute = N/2 (for four stroke engine) N = engine speed (rpm) L = length of stroke (mm) A = cross-section area of cylinder (mm2) r = crank radius (mm) a = acceleration of the reciprocating part (m/s2) mp = mass of the piston (Kg) V = volume of the piston (mm3) D = cylinder bore (mm) Pmax = maximum gas pressure or explosion pressure (MPa) σt = allowable tensile strength (MPa) σut = ultimate tensile strength (MPa) F.O.S = Factor of Safety = 2.25 K = thermal conductivity (W/m K) Tc = temperature at the centre of the piston head (K) Te = temperature at the edge of the piston head (K) BP = brake power of the engine per cylinder (KW) m = mass of fuel used per brake power per second (Kg/KWs) b = radial width of ring (mm) Pw = allowable radial pressure on cylinder wall (N/mm2) = 0.025 MPaσp = permissible tensile strength for ring material (N/mm2) = 1110 N/mm2 h = axial thickness of piston ring (mm) h1 = width of top lands (mm) h2 = width of ring lands (mm) t1 = thickness of piston barrel at the top end (mm) t2 = thickness of piston barrel at the open end (mm) ls = length of skirt (mm) μ = coefficient of friction (0.01) l1 = length of piston pin in the bush of the small end of the connecting rod (mm) do = outer diameter of piston pin (mm) 1) THICKNESS OF PISTON HEAD (th) The piston thickness of piston head calculated using the following Grashoff's formula, th = D 316∗Pσt (in mm) Where P = 9 MN/m² = 9 N/mm² D = 140 mm σt = 469 N/mm² = 140 316∗9469 th = 8.397 mm 2) HEAT FLOW THROUGH THE PISTON HEAD (H) The heat flow through the piston head is calculated using the formula H = 12.56 * th * K * (Tc – Te) KJSec Where, K= 174.15W/mkTc = 969.75 °C Te = 23.366 °C = 12.56 * 8.397 * 174 * 946.384 H = 17367224.97 KJSec 3) RADIAL THICKNESS OF RING (t1) t1 = D 3 ∗PWσt (in mm) Where, D = 140 mm PW = 0.03 N/mm² σt= 90 MN/m² = 90 N/mm² = 140 3 ∗0.0390 t1 = 4 mm 4) AXIAL THICKNESS OF RING (t2) The thickness of the rings may be taken as t2 = 0.7t1 to t1 Let assume t2 = 4 mm Minimum axial thickness (t2) t2= D10 ∗ nr Where nr = number of rings = 3 = 14010 ∗ 3 t2= 4 mm

IV.SOLID TYPE PISTON:

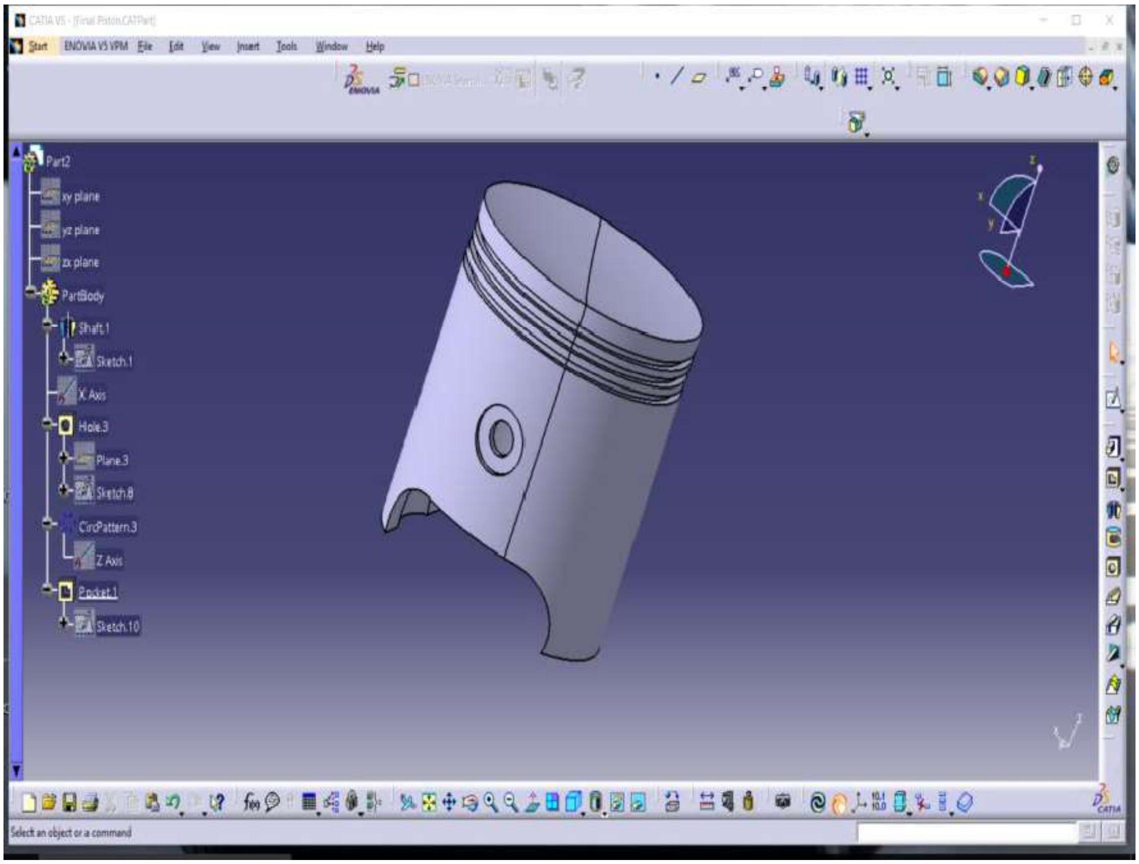


Fig.3 Catia Design without Zirconium Coating

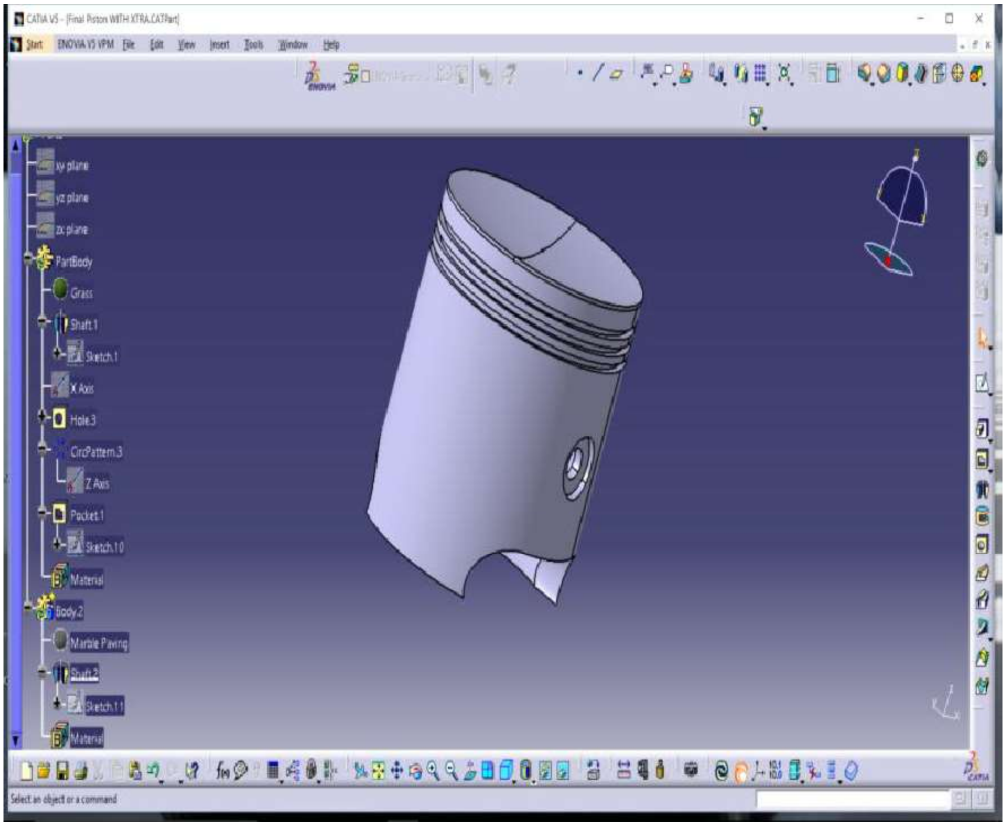


Fig.4 Piston Design With Zirconium Coating

VI. SIMULATED COMPARATIVE PERFORMANCES OF THREE ALLOYS

S.NO	PARAMETERS	CONVENTIONAL AL ALLOY A2618 MAX MIN	ZIRCONIUM &AL-GHY1250 MAX MIN
1	TEMPERATURE	2000 41.524	1726.8 24.371
2	TOTAL HEAT FLUX	8.1742e6 3999.7	1.5403e7 4750.6

A) THERMAL ANALYSIS

S.NO	PARAMETERS	CONVENTIONAL AL ALLOY A2618 MAX MIN	ZIRCONIUM &AL-GHY1250 MAX MIN
1	EQUIVALENT ELASTIC STRAIN	0.0042852 2.2943E-6	0.0012668 7.7769E-7
2	EQUIVALENT (VON-MISES) STRESS	5.0702E8 1.1717E5	9.4842E8 4.2034E5
3	MAXIMUM PRINCIPAL ELASTIC STRAIN	-4.223E-7 -0.0041101	-1.6433E-7 -0.00092604
4	MINIMUM PRINCIPAL STRESS	3.0783E7 -5.3262E8	7.2253E7 -8.3613E8
5	TOTAL DEFORMATION	0.00066709 1.4193E-8	0.00034151 4.4229E-8

CONCLUSION

It is concluded from the above study the piston is designed using Catia software and analyzing the piston using the ANSYS software, only few steps are needed to make drawing in three dimensions. The piston model is imported to ANSYS for analysis. Piston made of two different materials Al alloy A2618 & Al Alloy GHS1300 and Zirconium are analyzed. Their Thermal and Static analysis shows that the maximum stress intensity is obtained in Al alloy A2618, when compared to Al Alloy GHS1300 and Zirconium alloy piston. Maximum temperature is found at the centre of the top surface of the piston crown in Al alloy A2618. Depending on the thermal conductivity of the materials, heat transfer rate is found maximum in Al alloy piston. For the given loading conditions, Al Alloy GHS1300 and Zirconium alloy piston is found most suitable. But when the loading pattern changes, other materials may be considered. With the advancement in material science, very light weight materials with good thermal and mechanical properties can be used for fail safe design of the I.C Engine. This will reduce the fuel consumption and protect the environment. Finally, we concluded that Al Alloy GHS1300 and Zirconium alloy material is best one when compared to Al alloy A2618.

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