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RESEARCH ARTICLE

DESIGN AND ANALYSIS OF COMPOSITE PISTON.

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Abstract

A piston is an integral part of an engine which reciprocates at very high speed thus producing combustion resulting in movement of the vehicle. The main purpose of a piston is to transfer power from gas in cylinder to crankshaft through connecting rod. Usually the piston is made of aluminium alloy to make it less weight and thermal conductivity. But the aluminium alloy piston has less strength and high coefficient of thermal expansion, thus making it not suitable for high temperature experience. Carbon-carbon fibre, a carbon reinforced matrix is used as an alternative for aluminium alloy piston so as to overcome the problems faced. SolidWorks was used to design the 3D model of engine piston. Structural and Thermal analysis was made in Ansys 15.0. After analysis, carbon- carbon composite was found to be better than Aluminium alloy in terms of thermal conductivity, thermal expansion and very minimal wear, high resistance, strength to weight ratio, high temperature performance.

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Introduction:-

In automobile industry, engine piston is the most vital part experiencing high mechanical and thermal stresses. Large temperature difference is created between piston crown and cooling galleries and it produces thermal stress in engine piston. A cycle of mechanical stresses take place with the development of piston acceleration and piston skirt side force that are superimposed on thermal stress. Hence, it has turned out to be essential to examine the thermal and mechanical stresses to enhance the quality and execution of the piston. Despite every one of the upgrades and progressions in the innovations there exists vast number of inadequate or damaged pistons.

Thermal and mechanical stress assumes a conspicuous part in the designing of piston. Large numbers of complex fatigue tests are conducted by piston manufacturers but this involves very high cost and time. For stresses, temperature gradient and deformation, finite element analysis is carried out to see the effect.

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Figure 1:- Engine Piston

Composite Material:-

A Composite material is a material produced using at least two constituent materials with essentially unique physical or chemical properties that, when consolidated, create a material with qualities not quite the same as the individual parts. The individual segments stay isolated and distnict inside the completed structure. Typical engineered composite materials include:

- Mortars, concrete
- Reinforced plastics, such as fiber-reinforced polymer
- Metal composites
- Ceramic composites (composite ceramic and metal matrices)

Characteristics of Composite Material:-

Getting the required level of sturdiness is conceivable by utilizing engine components made of materials with essentially incremental resistance to mechanical and thermal load. Composite materials explained in the second half of the twentieth century have been generally connected in a wide range of vehicles. The composite material is possible only because of certain selected properties such as:

- Higher tensile strength than the matrix (about 30% for cast and wrought aluminium alloys),
- Higher fatigue strength than the matrix material (20% by 15%Al_2O_3),
- Lower thermal expansion coefficient of composite than the matrix which allows to reduce
- Maintenance clearance between piston and cylinder liner,
- Possibilities of using solid lubricant in machine parts by applying porous composite materials,
- Particular topography of the composite surface after finishing of the machining process
- Improves oil absorption (about 25% in a drop test) compared to the surface of matrix material, which improves lubrication and reduces wear intensity, wear resistance which is several times higher than that of a matrix..

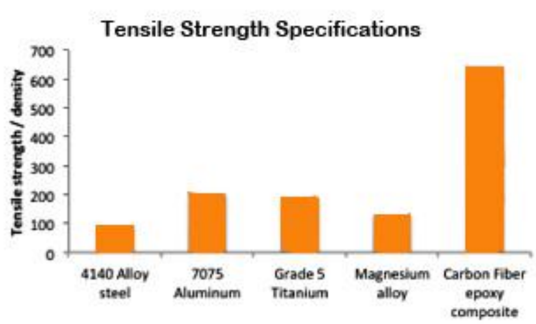

Figure 2:- Tensile strength of different materials

Carbon-Carbon Material:-

Carbon fibre-reinforced carbon (a.k.a. Carbon–Carbon, abbreviated C/C or Reinforced Carbon-Carbon, abbreviated RCC or Carbon-Fiber-Reinforced Carbon, abbreviated CFRC) is a composite material consisting of carbon fiber reinforcement in a matrix of graphite. Carbon–carbon is appropriate to auxiliary applications at high temperatures, or where thermal shock resistance as well as a low coefficient of thermal expansion is required. While it is less weak than numerous ceramics, it has poor impact resistance; Space Shuttle Columbia was annihilated amid atmospheric re-entry after one of its RCC boards was broken by the effect of a piece of foam insulation from the Space Shuttle External Tank. This disastrous disappointment was expected to a limited extent to unique transport outline prerequisites which did not consider the probability of such fierce effects.

Figure 3:- carbon carbon fiber

The Development Of Improvement Of Carbon-Carbon (C-C) Materials:-

There are important factors that determine to improve Carbon- Carbon (C-C) composite materials:

- The high thermal conductivity required should be perpendicular to the friction surface.
- The reason of the upgradation of Carbon- Carbon (C-C) material is that static coefficient of friction should remain in an increased position.
- An improvement in Carbon- Carbon (C-C) material would be by lowering the costs, and high specific strength of Carbon- Carbon (C-C) materials is a good example for improvement and enhancement.

A great prevention of failure.

Synthesis:-

Every carbon fiber is created from a polymer, for example, polyacrylonitrile (PAN), rayon, or oil pitch, known as a precursor. For manufactured polymers, for example, PAN or rayon, the antecedent is first spun into filament yarns, utilizing chemical and mechanical procedures to, at first adjust the polymer particles in an approach to improve the last physical properties of the finished carbon fiber. Antecedent compositions and mechanical procedures utilized amid spinning filament yarns may shift among makers. In the wake of drawing or turning, the polymer filament yarns are then heated to drive off non-carbon particles (carbonization), creating the last carbon fiber. The carbon fiber filament yarns might be additionally treated to enhance taking care of characteristics, at that point wounding on to bobbins. A typical technique for producing includes heating the spun PAN filament to around 300 °C in air, which breaks large portions of the hydrogen bonds and oxidation takes place in the material. The oxidized PAN is then put into a heater or furnace having an idle air of a gas, for example, argon, and heated to roughly 2000 °C, which graphitization of the material takes place, changing the molecular bond structure. At the point when heated in the right conditions, these chains bond side-to-side (step polymers), framing thin graphene sheets which in the end converge to shape a solitary, columnar fiber. The outcome is typically 93–95% carbon. Lower-quality fiber can be produced utilizing pitch or rayon as the antecedent rather than PAN.

Structure and Properties:-

Carbon fiber is regularly provided as a persistent tow wound onto a reel. The tow is a heap of thousands of constant individual carbon filament held together and secured by a organic covering, or size, for example, polyethylene oxide (PEO) or polyvinyl alcohol (PVA). The tow can be helpfully loosened up from the reel for utilization. Every carbon filament in the tow is a continuous cyilnder with a measurement of 5–10 micrometers and comprises only of carbon. The past years (e.g. T300, HTA and AS4) had diameters of 16–22 micrometers. Later strands (e.g. IM6 or IM600) have diameters across that are around 5 micrometers.

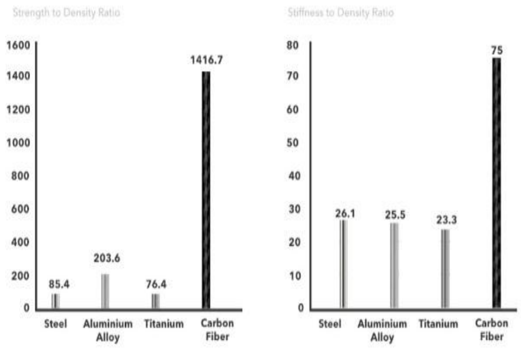

Figure 4:- Strength to Density Ratio & Stiffness to Density Ratio

Table 1:- Characteristic Comparison

PROPERTY	ALUMINIUM ALLOY	CARBON PISTON
Density g/cm3	2.70	1.80
Co-efficient of linear expansion l/k	21.10e-6	6.10e-6
Modulus of elasticity Gpa	80	11
Thermal conductivity W/mK	150	80
Maximum temperature C	380	460
Tensile strength Mpa	225	70

The atomic structure of carbon fiber is like that of graphite, comprising of sheets of carbon particles organized in a general hexagon, example (graphene sheets), the distinction standing out these sheets interlock. Graphite is a crystalline material in which the sheets are stacked parallel to each other in standard form. The intermolecular powers between the sheets are generally weak Van der Waals strengths, giving graphite its delicate and weak attributes.

Comparsion Between Aluminium Alloy And Carbon Carbon Material:-

Material	Density (g cm^{-3})	Tensile strength (GN m^{-2})	Young's modulus (GN m^{-2})	σ/ρ	E/ρ
*Composite**					
E glass	2.1	1.1	45	0.5	20
IM carbon	1.5	2.6	170	1.7	113
HM carbon	1.6	1.6	257	1.0	161
Aramid	1.4	1.4	75	1.0	50
Metals					
Steel	7.8	1.3	200	0.2	26
Aluminium	2.8	0.3	73	0.1	26
Titanium	4.0	0.4	100	0.1	25

Figure 5:- Comparison between Al alloy and Carbon-carbon material

Design And Optimization Of Carbon-Carbon (C-C) Friction Members:-

There are four major classifications of measurement or judgment for preferred fiber orientation within Carbon-Carbon (C-C) brake disc; it's determined by heat flow.

- Diffuses or discharges the heat away from friction surface and inside the brake disc.
- Heat can discharge radially.
- The slot machine must withstand shear force.
- The effectiveness of the drive slot could reduce to the minimum.

Design of Piston in SolidWorks:-

The piston is designed in SolidWorks as it is the platform for designing parts and many components accurately with the required dimensions. This software gives the idea of a part manufactured in reality as it serves like a prototype.

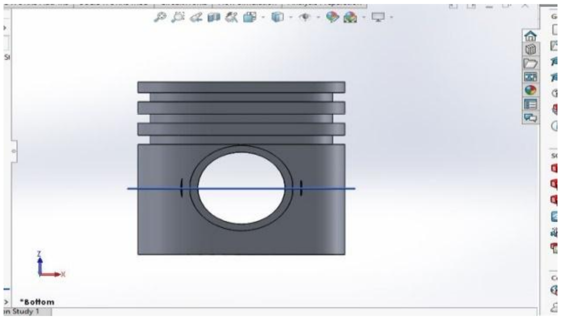

Figure 6:- Aluminium alloy piston design in SolidWorks

A piston was designed in SolidWorks 16.0 and the material assigned is Aluminium Alloy as to compare with the carbon-carbon composite piston.

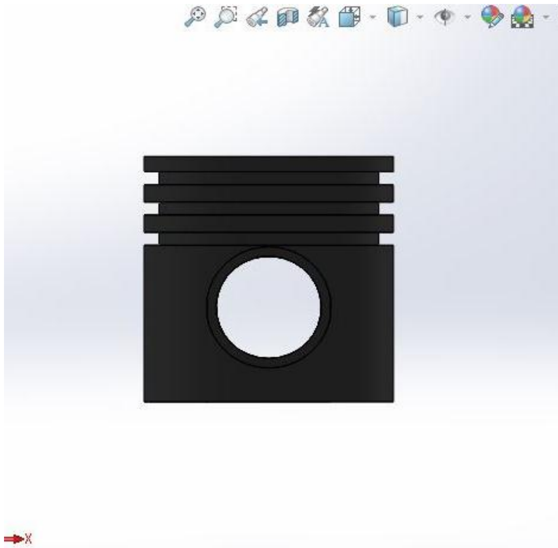

Figure 7:-Carbon-Carbon material piston design in SolidWorks

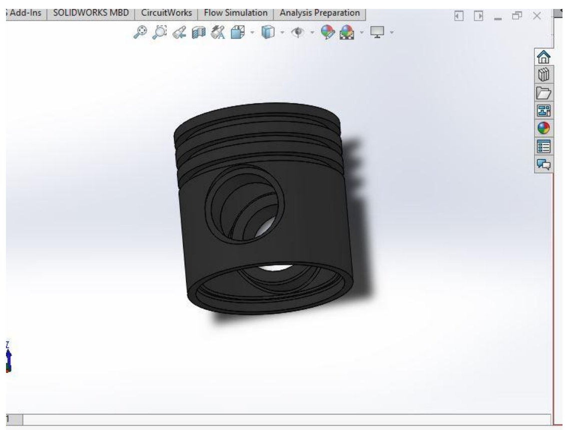

Figure 8:- Isometric view of piston

Analysis in Ansys 15.0:-

The analysis of piston is made in Ansys 15.0. The piston is designed in SolidWorks and the material Carbon-carbon composite is applied. The SolidWorks file is imported in Ansys for the analysis. Some unimportant factors, such as spot fillet, bevel edge, oil hole are neglected in the model to simplify the analysis. The three kinds of the stress fields, named as thermal stress field, mechanical stress field, thermal and mechanical coupling stress field, can be obtained by the imposition of the boundary conditions and loads on the FEA model.

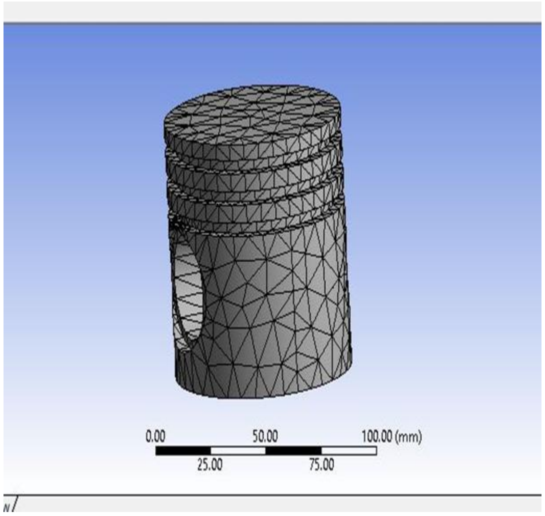

Figure 9:- Mesh generation Ansys 15.0

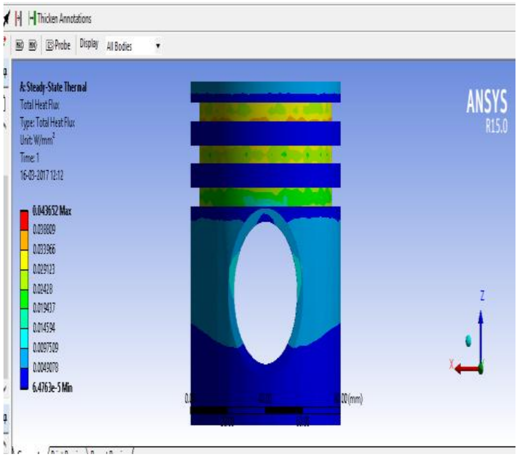

Figure 10:- Thermal Analysis of Carbon piston

Thermal boundary condition:-

In the thermal examination for model in ANSYS, the convection limit condition, as the surface load is incurred outward surface. The upper piece of the piston is having high temperature in view of direct contact with the gas. In this way, a temperature of 360 degrees is given to the upper surface of the piston.

Mechanical boundary condition:-

The most extreme hazardous pressure acts consistently on the piston head. The three freedom degrees of the cylinder stick are controlled to give the piston pin access a static condition. Coupling restrictions are forced on two points on the base of piston keeping in mind the end goal to dispose of the rotating of the piston around the piston pin. The surface-surface contact unit between the piston pin gap and the piston pin is set from default as "bonded" to 'no division' to give some dislodging amongst piston and piston pin during the movement. The above two boundary conditions are referred as displacement restraints.

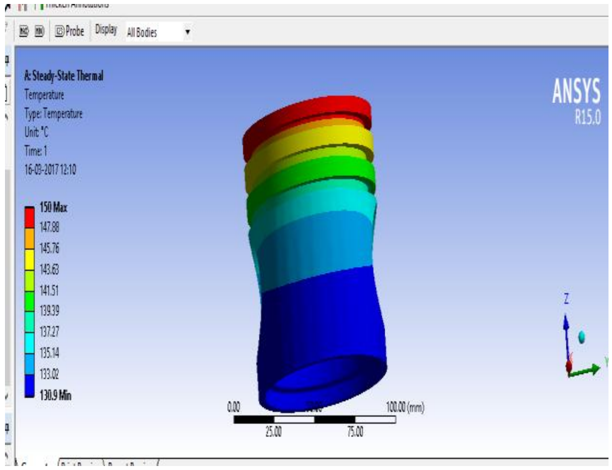

Figure 11:- Temperature difference in piston

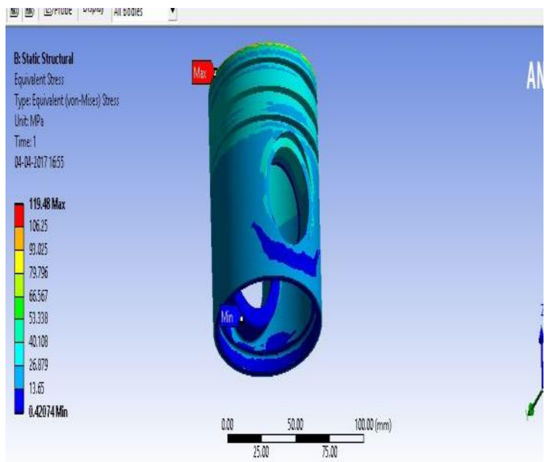

Figure 12:- Equivalent Stress Analysis of piston

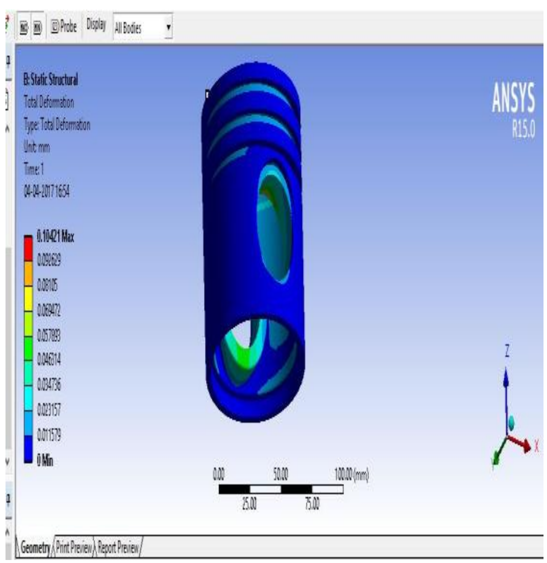

Figure 13:- Total Deformation of Piston

Conclusion:-

The piston is designed with Carbon-Carbon material as to improve the performance of the piston during reciprocating in engine cylinder. The Carbon- Carbon piston withstands heat higher than the Aluminium Alloy. Though the carbon piston is costlier than Aluminium piston, it gives better performance and high durability as it experiences very minimal wear and corrosion free material.

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