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Performance of Al-si-glass fiber composite piston in an IC Engine

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ABSTRACT
The piston is one of the major part of the automobile. The piston purpose is to transfer force from expanding gas in the cylinder to the crankshaft. The piston acts as the vital link between the generation of power inside the combustion chamber to its transfer to the crankshaft and converting to-and-fro motion into continuous rotary motion. The piston assembly is probably subjected to the widest range of mechanical and thermal stresses. Now a days we using aluminium material for the piston because it having low density, high thermal conductivity and high corrosive resistant when compare to cast iron. One of the major problem in aluminium piston is piston slap. It occurs due to high thermal expansion of the aluminium material so providing more gap between the cylinder and the piston. The thermal expansion coefficient of the aluminium is hardly two to three time higher than the cast iron material. For reducing the thermal expansion coefficient of the aluminium material by adding the composite material which having low thermal expansion coefficient without decreasing the hardness of the material. The glass fiber material having the
Coefficient of Expansion in inches of expansion per inch of material per degree Fahrenheit is “2.2”. The aluminium and the glass fiber melting point are nearly same so it can be easily mixed with each other. By adding the glass fiber to aluminium piston it will increase the thermal and mechanical property of the piston.

Indexing terms/Keywords

piston slap, thermal expansion coefficient, composite material, aluminium, glass fiber.

INTRODUCTION
The engine designers continue to be troubled by a phenomenon known as "piston slap." As a piston moves up and down inside its cylinder it also shifts from side to side, bumping first one side and then the other behavior that wastes fuel, wears out engines and makes an annoying bang. Excessive piston slap occurs when the clearance between the piston and the cylinder bore is too great. The piston to cylinder bore clearance becomes too great either through wear, mismatched pistons and cylinder bores at manufacturing or, a combination of both. In the cast iron piston coefficient of thermal expansion is very less when compare to aluminium piston but power loss is very high due weight of the piston. In cast iron 2.5 time density is greater than aluminium piston. The coefficient of thermal expansion for aluminium is about 2.5 times that of cast iron, therefore, a greater clearance must be provided between the piston and the cylinder wall (than with cast iron piston) in order to prevent seizing of the piston when engine runs continuously under heavy loads. In cold condition during the compression stroke the mixture (in the case of an Otto engine) or air (in the case of a Diesel engine) is compressed to the top of the cylinder by the piston at the time fresh fuel are escaped from the clearance to crankcase so it increase the HC emission due to greater clearance. And also the piston to cylinder bore clearance becomes too great either through wear, mismatched pistons and cylinder bores at manufacturing or, a combination of both. The audible noise associated with excessive piston slap is due to the perpendicular impact of the piston against the wall of the cylinder bore. Audible piston slap is typically loudest when the engine is first started up. The pistons then expand with heat reducing the piston to cylinder bore clearance thus, reducing the perpendicular impact of the piston against the cylinder wall and its resulting noise. In heavy load condition heat produced inside the combustion chamber is very high. If the temperature increases expansion of the aluminium piston also increase if it reach the cylinder wall diameter seizing of the piston may occur it will abnoarmally stop the vehicle and also damage the combustion chamber.
It decrease the life of the engine If we decrease the thermal expansion of the aluminium material by adding composite material will increase the efficiency of the engine and also increase the life of the engine. Composite material which adding it not decrease the strength and stiffness of the piston and also with stand the fatigue load due to gas pressure during the power stroke. Glass fiber is the one of the composite material having very low coefficient thermal expansion. Some time it called negative coefficient of thermal expansion because it has nearly zero thermal expansion. The melting point of the glass fiber and aluminium are nearly same so it can be easily added with the aluminium material. The tensile and compressive strength also higher than the aluminium so it can withstand the gas pressure.

MATERIALS USED IN PISTON

Aluminium alloy
Aluminium is remarkable for the metal's low density and its ability to resist corrosion due to the phenomenon of passivation. Structural components made from aluminium and its alloys are vital to the aerospace industry and are important in other areas of transportation and structural materials. The most useful compounds of aluminium, at least on a weight basis, are the oxides and sulfates. Aluminium is a relatively soft, lightweight, durable, ductile and malleable metal. Aluminium is a good thermal and electrical conductor, having 59% the conductivity of copper, both thermal and electrical, while having only 30% of copper's density. Aluminium is capable of being a superconductor, with a superconducting critical temperature of 1.2 Kelvin and a critical magnetic field of about 100 gauss. Corrosion resistance can be excellent due to a thin surface layer aluminium oxide that form when a metal is exposed to air effectively preventing further oxidation

Comparison between aluminium alloy and cast iron

The aluminium alloys used for pistons have high heat conductivity (nearly four times that of cast iron), therefore, these pistons ensure high rate of heat transfer and thus keeps down the maximum temperature difference between the center and edges of the piston head or crown. The coefficient of thermal expansion for aluminium is about 2.5 times that of cast iron, therefore, a greater clearance must be provided between the piston and the cylinder wall (than with cast iron piston) in order to prevent siezing of the piston when engine runs continuously under heavy loads

Silicon

Silicon is the eighth most common element in the universe by mass, but very rarely occurs as the pure free element in nature. It is most widely distributed in dusts, sands, planetoids, and planets as various forms of silicon dioxide (silica) or silicates. Over 90% of the Earth's crust is composed of silicate minerals, making silicon the second most abundant element in the Earth's crust (about 28% by mass) after oxygen. Silicon is a solid at room temperature, with relatively high melting and boiling points of 1414 and 3265 degrees Celsius respectively. Aluminum-silicon alloys are heavily used in the aluminum alloy casting industry, where silicon is the single most important additive to aluminum to improve its casting properties. Since cast aluminum is widely used in the automobile industry, this use of silicon is thus the single largest industrial use of "metallurgical grade" pure silicon.

Glass fiber

Glass fiber is a lightweight, extremely strong, and robust material. Although strength properties are somewhat lower than carbon fiber and it is less stiff, the material is typically far less brittle, and the raw materials are much less expensive. Its bulk strength and weight properties are also very favorable when compared to metals, and it can be easily formed using molding processes. Common uses of fiberglass include high performance aircraft (gliders), boats, automobiles, baths, hot tubs, water tanks, roofing, pipes, cladding, casts, surfboards and external door skins.

Material Properties of Glass fiber

- Low cost
- High production rates
- High strength
- High stiffness
- Relatively low density
- Resistant to heat
- Low thermal Conductivity
- Relatively insensitive to moisture
- Able to maintain strength properties over a wide range of conditions

AL-Si-Glass fiber composite piston
Comparing the aluminium and cast iron material

- The aluminium have high heat conductivity nearly four times greater than the cast iron
- Density of the aluminium is very less than the cast iron.so power loss will be very low.
- Thermal conductivity of the aluminium material is two to three time higher than cast iron
- But the coefficient of thermal expansion for aluminium is about 2.5 times greater than of cast iron so greater clearance must be provided between the piston and the cylinder

Need of AL-Si-Glass fiber composite piston

Due to greater clearance between the piston and the cylinder wall it will increase the wear of cylinder bores and also increase the hydro carbon emission due to fresh fuel escape from the crevice volume. Greater clearance between the piston and the cylinder wall given due to high thermal expansion coefficient of the aluminium material. Seizing of the piston occur when the piston diameter reach the cylinder wall diameter. In the aluminium material having the high thermal expansion of the material so the seizing of the piston may be occurs. Coefficient of thermal expansion is the most problem in the aluminium material, so decrease the coefficient of thermal expansion by adding the glass fiber. Glass fiber having very low thermal expansion coefficient and also having high compressive strength. Melting point of the glass fiber and aluminium material nearly same. So it can be easily added with the aluminium.

OBJECTIVE AND METHODOLOGY
Objective

The objective of the present work is to design and analyses of piston made of glass fiber mixed with aluminium and silicon to reduce the coefficient of thermal expansion. To reduce the piston slap occurrence and reduce the wear of the cylinder wall. The fracture toughness also needs to be above a certain minimum value. The selection of manufacturing process for which the constraints are shape, mass, quality and economics. In this project glass fiber is adding with existing piston material (aluminium and silicon). After analysis a comparison is made between existing material and aluminium Reinforced with glass fiber and silicon in terms of thermal properties, deformation and stresses.

METHODOLOGY

- Appropriate material aluminium and glass fiber has been selected.
- Die is prepared for exact size of the existing piston with allowance.
- Different compositions of piston are to be made.

- Both the aluminium and glass fiber are to be melted and poured into the die to fabricate the piston on appropriate compositions.
- After the fabrication work is done next the surface finishing process done on the piston.
- FEA analysis was carried out by considering two materials. The parameters like von misses stress, von misses strain and displacement were obtained from ANSYS software.
- By replacing existing piston by the composite piston in engine, the performance and emission characteristics are noted.
- From the Results obtained the reducing the thermal expansion of the aluminium piston can be found out.

PISTON DESIGN

Piston head or crown design =36mm
Thickness of RIBS= 12 to 18 mm

Number of rings = 4
Maximum thickness of barrel = 8.3 mm
Radial depth of the piston ring grooves (b) = 2.4 mm
Piston wall thickness towards the open end = 3 mm

MECHANICAL TESTING

Table :1 Tensile Test Result

Test Parameters	Al	Al with glass with fiber (15%)	Al with glass with fiber (20%)
Yield Strength (Mpa)	113.4	113.9	114.5
Ultimate Tensile Strength (Mpa)	160.7	161.3	161.8
% Elongation in 50mm GL	27	24.8	22.1

Table :2 Compression Test Result

Test Parameters	Al	Al with glass with fiber (15%)	Al with glass with fiber (20%)
Gage Thickness (mm)	10	10	10
Gage Width (mm)	50	50	50
Compressive Load (N)	16.2	15.4	13.9
Compression Strength(Mpa)	325	324.8	324.3

Table :3 Flexural Test Result

Test Parameters	Al	Al with glass with fiber (15%)	Al with glass with fiber (20%)
Flexural Load (N)	740	741	742
Flexural Strength (Mpa or N/mm2)	74.07	74.15	74.23

Table :4 Brinell Hardness Test Result

	Al	Al with glass with fiber (15%)	Al with glass with fiber (20%)
Observation in BHN (5mm/250kg)	72.3,70.1,68.2	70.8,69.2,65.9	68.7,66.8,64.5

CHARPY IMPACT TEST
Specimen Size (mm): 10 x 10 x 55

Notch Type: 'V'
Test Temperature: RT

Table :5 Charpy Impact test result

Test Parameters	Al	Al with glass with fiber (15%)	Al with glass with fiber (20%)
Absorbed Energy – Joules	2	2	2

THERMO MECHANICAL ANALYSIS (CTE)

Table :6 Thermo mechanical analysis

Measurement	**Sample 1**	**Sample 2**	**Sample 3**
Material of rod	**Aluminium**	**Al with glass with fiber (15%)**	**Al with glass with fiber (20%)**
Original length	50mm	50mm	50mm
Width of the rod	10mm	10mm	10mm
Measured α	26. x 10^{-6} / ^{O}C	22. x 10^{-6} / ^{O}C	19. x 10^{-6} / ^{O}C

CONSULSION

- Al-Si-glass fiber particle composite alloy pistons can run in an engine without seizing during the running-in period and they can withstand an endurance test of duration 20h without any apparent deterioration
- Specific fuel consumption is decreased up to 1 – 1.5%
- By adding the glass fiber to aluminium we can reduce the coefficient of thermal expansion.
- We can reduce the clearance between the piston ant the cylinder wall. So that fresh fuel charge escaping from the clearance can be reduced and it will decrease the specific fuel consumption.
- It also increase the life of the engine by preventing the seizing of the piston and reduce the wear formed by the piston slap

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