CRITIQUE OF ENGINE MATERIAL & COOLING SYSTEM

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ABSTRACT

As per scoop and development of materials many type of engine materials are available in market but some are as , cast iron and aluminum alloys have been the preferential materials used to manufacture most diesel and conventional gasoline-powered engine blocks. However, with a greater emphasis on increasing the efficiency of the engine via weight reduction, manufacturers have began to look for alternative alloys that are lighter than cast iron and aluminum alloys, while retaining the necessary strength to withstand the forces of an engine. As of late, new manufacturing processes have been developed that have engendered two new alloys suitable for use in an engine block, magnesium alloy AMC-SC1 and compacted graphite cast iron (CGI). In this paper, the functional requirements of the engine block, the processes used to manufacture the part, and the mechanical properties of the alloys will be discussed.

For The engine-cooling system (ECS has steadily improved as the power output and density of internal combustion (IC) engines gradually increases With greater emphasis placed on improving fuel economy and lowering emissions output from modern IC engines, engine downsizing and raising power density has been the favored option. Through this route, modern engines can attain similar power outputs to larger conventional engines with reduced frictional losses and mass. Most internal combustion engines are fluid cooled using either air (a gaseous fluid) or a liquid coolant run through a heat exchanger (radiator) cooled by air. In air cooling system, heat is carried away by the air flowing over and around the cylinder. Here fins are cast on the cylinder head and cylinder barrel which provide additional conductive and radiating surface. In water-cooling system of cooling engines, the cylinder walls and heads are provided with jacket through which the cooling liquid can circulate.

Keywords:

- **ECS-** Engine-cooling system
- **HIP-** Hot Isostatic Processing
- **CGI-** Graphite cast iron
- **AMC-SC1-** Magnesium alloy
- **YS-**Yielding stress
- **UTS-** Ultimate tensile stress
- **Cooling System:** A cooling system in an internal combustion engine that is used to maintain the various engine components at temperatures conductive to long life and proper functioning.
- **Air Cooling System:** In this system, heat is carried away by the air flowing over and around the cylinder.

- **Water Cooling System :** In this system, the cylinder walls and heads are provided with jacket through which the cooling liquid can circulate.

I. INTRODUCTION

We know that in case of Internal Combustion engines, combustion of air and fuel takes place inside the engine cylinder and hot gases are generated. The temperature of gases will be around 2300-2500°C. This is a very high temperature and may result into burning of oil film between the moving parts and may result into seizing or welding of the same. So, this temperature must be reduced to about 150-200°C at which the engine will work most efficiently. Too much cooling is also not desirable since it

reduces the thermal efficiency. So, the object of cooling system is to keep the engine running at its most efficient operating temperature. It is to be noted that the engine is quite inefficient when it is cold and hence the cooling system is designed in such a way that it prevents cooling when the engine is warming up and till it attains to maximum efficient operating temperature, then it starts cooling. It is also to be noted that:

(a) About 20-25% of total heat generated is used for producing brake power (useful work).

(b) Cooling system is designed to remove 30-35% of total heat.

(c) Remaining heat is lost in friction and carried away by exhaust gases.

In the 1930's (due to problems with durability), aluminum alloy use in engine blocks increased during the 1960's and 1970's as a way to increase fuel efficiency and performance. Together, these two metals were used exclusively to fabricate engine blocks. As of late, however, a new material process has made a magnesium alloy suitable for use in engines. The alloy, called AMC-SC1, weighs less than both cast iron and aluminum alloys and represents new possibilities in engine manufacturing. A new manufacturing process have made compacted graphite cast iron (CGI) a viable alternative to gray cast iron for the manufacture of diesel engine blocks. Like magnesium alloys, this material offers a higher strength and lower weight than gray cast iron.

II. BASIC STUDY OF ENGINE MATERIAL

2.1 Engine Materials and Properties

An engine is made up mainly of various metal alloys, so the material used in the engine and its components can be recycled. The most important structural materials in 4-stroke engines are **cast iron**, **alloy** and structural steels, and **aluminum** alloys.

The correct selection of a material for a particular application is a highly specialized field and usually requires consideration of a wide spectrum of requirements. In a race engine environment, the demands can be extreme, calling for various combinations of high strength and high fatigue resistance at high temperatures, and the minimum weight which will meet the stress and life requirements.

On the basis of some mechanical properties and terminologies materials are selected-

Stress is a normalized method for expressing the severity of loading applied to a material. It is expressed as the applied load divided by the area to which the load is applied. For example, if a 9,800 pound tension load was applied to a 1/2-inch diameter bar (0.196 square inch cross-sectional area = diameter x diameter x 0.7854) the tensile stress would be 50,000 pounds per square inch (psi) (stress = load / area = 9800 / 0.196).

The **Yield Stress** (YS) of a given material is the stress value required to permanently stretch a test specimen a specific amount (usually 2%).

The **Ultimate Tensile Stress** (c) of a given material is the stress value required to fracture the specimen (pull it apart into two pieces). The UTS and YS values are measured on a testing apparatus designed to gradually increase the load on a specimen until it fails, and measure the deflection as the load is applied.

Creep is the phenomenon in which a metal, when exposed to a high stress level over an extended time period (typically hundreds or even thousands of hours) will exhibit a quasi-permanent strain (deformation), which occurs at different rates depending on the length of exposure. High temperatures generally increase the rate of creep.

Fatigue is the term used to describe the breakage of a metal part that occurs when the part is subjected to a load which varies over time, even though the varying load is well below the YS of the material. Fatigue is covered in detail on a dedicated page on this site.

Notch Toughness is a measurement of a material's resistance to breakage from impact loading. If you hit a diamond with a hammer, it will shatter; If you hit the head of another hammer with a hammer and the hammer in your hand will spring back; If you hit the fender of your car with a hammer,

HRc - The hardness of a material as measured on the Rockwell "C" scale. (There are several other hardness scales: Rockwell A and B, Brinell, Vickers, Knoop, Shore, etc., having different uses and ranges. HRc is the most frequently used scale for steels; HRb is a common measurement for softer metals.) Since the strength versus hardness relationship is known for each material, this test is a simple way to verify the strength of a known material.

Work-Hardening is an increase in the strength and hardness of a metal resulting from plastic deformation at a temperature below the crystal-restructuring range.

Vacuum Induction Melting (VIM) is a primary-melt process for producing very high purity steels by melting the materials by induction heating inside a high-vacuum chamber.

Electro-Slag Remelting (ESR) is an open-air remelting process through a reactive slag which produces a clean steel with good crystallography.

Pressurized ESR (PESR) is an ESR remelt but the furnace is pressurized with 1-15 bar of nitrogen to prevent the formation of oxides, producing a cleaner steel than ESR.

Vacuum Arc Remelting (VAR) is a refining process in which steels are remelted inside a vacuum chamber to reduce the amount of dissolved gasses in the metal. Heating is by means of an electric arc between a consumable electrode and the ingot, and typically takes twice as long as ESR or PESR

Hot Isostatic Processing (HIP) is a method of essentially eliminating internal voids and microporosity in cast components and powder forgings. The components are put in an autoclave and heated to a temperature appropriate for the material and held for several hours while being subjected to a high pressure atmosphere of inert gas (as high as 200 bar)..

III. TYPES OF COOLING AND PROPERTIES

There are mainly two types of cooling systems :

(a) Air cooled system,

(b) Water cooled system

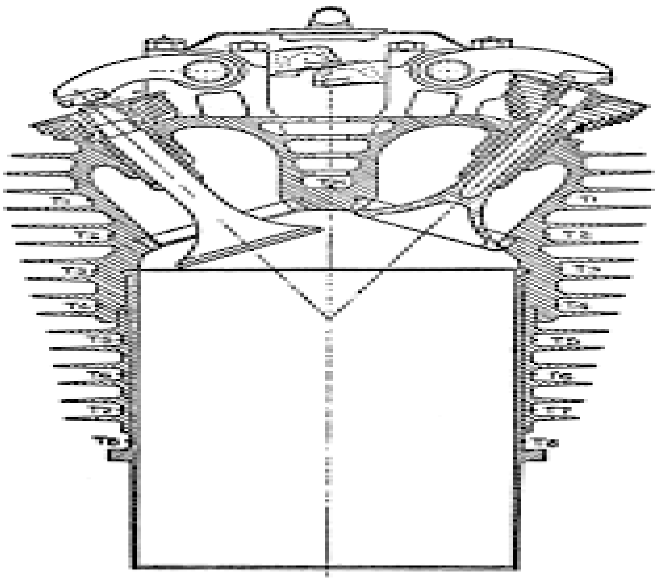
3.1 Air Cooled System

Air cooled system is generally used in small engines say up to 15-20 kW and in aero plane engines. In this system fins or extended surfaces are provided on the cylinder walls, cylinder head, etc. Heat generated due to combustion in the engine cylinder will be conducted to the fins and when the air flows over the fins, heat will be dissipated to air. The amount of heat dissipated to air depends upon:

(a) Amount of air flowing through the fins.

(b) Fin surface area.

(c) Thermal conductivity of metal used for fins.



3.2 Cylinder with Fins

<u>Advantages of Air Cooled System</u> –

Following are the advantages of air cooled system :

(a) Radiator/pump is absent hence the system is light.

(b) In case of water cooling system there are leakages, but in this case there are no leakages.

(c) Coolant and antifreeze solutions are not required.

(d) This system can be used in cold climates, where if water is used it may freeze.

<u>Disadvantages of Air Cooled System</u>-

(a) Comparatively it is less efficient.

(b) It is used in aero planes and motorcycle engines where the engines are exposed to air directly.

3.3 Water Cooling System

Types of Water Cooling System

There are two types of water cooling system:-

1) <u>Thermo Siphon System</u>

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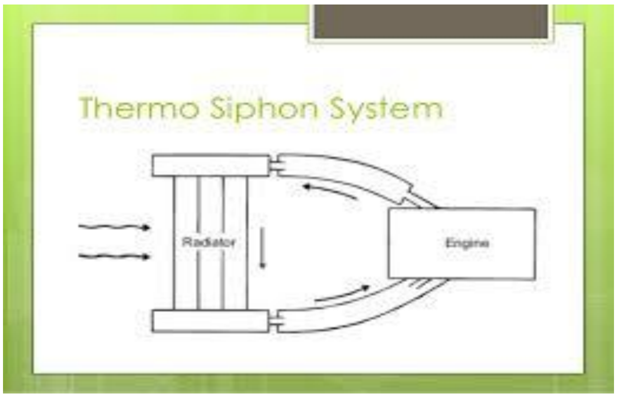
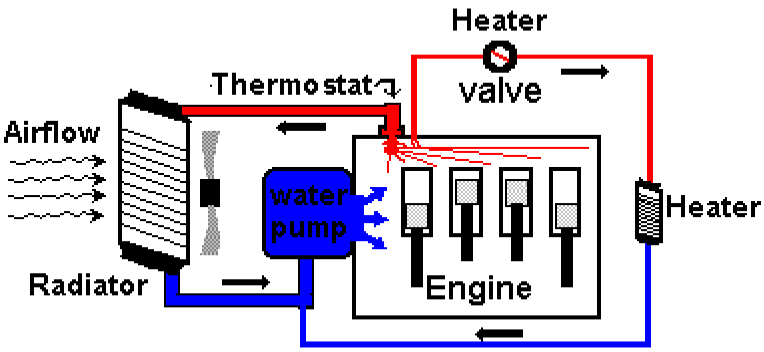
In this system the circulation of water is due to difference in temperature (i.e. difference in densities) of water. So in this system pump is not required but water is circulated because of density difference only.



Thermo Siphon System of Cooling

3.4 Pump Circulation System

In this system circulation of water is obtained by a pump. This pump is driven by means of engine output shaft through V-belts.



Pump Circulation System

IV. FEASIBILITY OF COOLING MATERIALS USE IN ENGINES

A **coolant** is a fluid which flows through or around a device to prevent its overheating, transferring the heat produced by the device to other devices that use or dissipate it. An ideal coolant has high thermal capacity, low viscosity, is low-cost, non-toxic, and chemically inert, neither causing nor promoting corrosion of the cooling system

The coolant can either keep its phase and stay liquid or gaseous, or can undergo a phase transition, with the latent heat adding to the cooling efficiency. The latter, when used to achieve low temperatures, is more commonly known as refrigerant..

4.1 Gases

Air is a common form of a coolant. Air cooling uses either convective airflow (passive cooling), or a forced circulation using fans

4.2 Liquids

The most common coolant is water. Its high heat capacity and low cost makes it a suitable heat-transfer medium. It is usually used with additives, like corrosion inhibitors and antifreeze.

Antifreeze, a solution of a suitable organic chemical (most often ethylene glycol, diethylene glycol, or propylene glycol) in water, is used when the water-based coolant has to withstand temperatures below 0 °C, or when its boiling point has to be raised. Betaine is a similar coolant, with the exception that it is made from pure plant juice, and is therefore not toxic or difficult to dispose of ecologically.

'The materials used in the radiator must be good heat conductors like brass or copper. Brass and copper are often used for tanks, combined with a copper core.

Modern vehicles often use plastic tanks combined with an aluminium core. This saves weight but still provides good heat transfer."

V. ENGINE MATERIALS AVAILABILITY

5.1 Aluminum Alloys

Aluminum is a lightweight, reasonably cheap metal widely used for packaging and transport. It has only been widely available and used for the last 60 years. Raw aluminum has low strength and high ductility (ideal for foil). Strength is increased by alloying, e.g. with Si, Mg, Cu, Zn, and heat treatment. Some alloys are cast, others are used for wrought products Aluminum is quite reactive, but protects itself very effectively with a thin oxide layer. The surface can be "anodised", to resist corrosion and to give decorative effects.

5.2 Cast iron

Cast irons were the forerunners to steels, being iron alloys of high carbon content (2-4%). The strength of iron-carbon alloys, particularly after heat treatment, has been exploited for thousands of years (since the "Iron Age"). Modern steels and ferrous alloys have mostly been developed since the Industrial Revolution. Cast irons are cheap, high carbon alloys of moderate strength and which can easily be cast to shape. Cast irons have a high density and a high Young's modulus. They tend to have poor toughness, but their strength and toughness can be improved by alloying and heat treatment. Cast irons rust easily, and must be protected by painting or other coatings.

5.3 Magnesium Alloy

Magnesium alloys are the lowest density metals, with good stiffness and strength relative to their weight. Pure magnesium is alloyed to improve its strength. It has a low melting point. Most alloys are cast, as it has poor formability. Magnesium is a reactive metal, which burns intensely. It therefore requires careful handling during casting.

VI. TECHNICAL PROPERTIES OF MATERIALS

In order for an engine block to meet the functional requirements listed above, the Engineering material(s) used to manufacture the product must possess high strength, modulus of elasticity, abrasion resistance, and corrosion resistance. High strength is a particular concern in diesel engines, since compression ratios are normally 17.0:1 or higher (compared to about 10.0:1) strength is a particular concern in diesel engines, since compression ratios are normally 17.0:1 or higher (compared to about 10.0:1 for conventional engines). The material should also have a low density, thermal expansion (to resist expanding under high operating temperatures), and thermal conductivity (to prevent failure under high temperatures). Good mach inability and cast ability of the metal alloy are also important factors in selecting the proper material, as the harder it is to machine the product, the higher the costs of manufacturing. In addition to the previously mentioned properties, the alloys must possess good vibration damping to absorb the shuddering of the moving parts.

VII. CONCLUSION

A set of novel design and operating features from alternate ECSs are identified and examined for their potential to improve engine protection, fuel efficiency, and emissions. Detailed investigation into these features has shown that they hold significant potential to extend the performance of modern engines even further. The integration of split cooling and precision cooling with controllable elements to run a cooler head and warmer block is singled out as the most promising concept to meet the expanding requirement on the performance of the ECS..

While aluminum and cast iron alloys have dominated the market for engine block materials for many years, new materials that were either once impossible or too expensive to consider have now become reality. Over the past couple of years, new machining processes and

material fabrication have increased the use of compacted graphite cast iron over gray cast iron as the material of choice to produce cylinder blocks for diesel- and regular petroleum-fueled vehicles. But perhaps the greatest innovation in engine block technology is the production of a magnesium alloy that is able to perform under the difficult conditions an engine is put through AMC-SC1 magnesium alloy will be able to increase fuel efficiency and power-to-weight ratios of automotive engines while decreasing emission levels. Though this may be a significant

impact for the internal combustion engine, it faces new challenges. Engines powered by fuel cells, hydrogen, and electricity are extremely efficient vehicles that have become viable within the last decade. As automobiles advance further into the 21st century, the role of the internal combustion engine may possibly diminish due to these new advances, despite the use of lighter alloys.

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