Thermal Analysis of Engine Cylinder Fins to Optimize the Shape to Improve the Heat Transfer Rate

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ABSTRACT: The Engine cylinder is one of the major automobile components, which is subjected to high temperature variations and thermal stresses. In order to cool the cylinder, fins are provided on the surface of the cylinder to increase the rate of heat transfer. By doing thermal analysis on the engine cylinder fins, it is helpful to know the heat dissipation inside the cylinder. We know that, by increasing the surface area we can increase the heat dissipation rate, so designing such a large complex engine is very difficult. The main aim is to analyze the thermal properties by varying the geometry of fins. The accurate thermal simulation could permit critical design parameters to be identified for improved life. Presently Material used for manufacturing cylinder fin body is Aluminum Alloy AA 6061 which has thermal conductivity of 160 – 170 W/mk. presently analysis is carried out for cylinder fins using this material.

Key words: FINs, HTR, AA6061, Simulation, material

I. INTRODUCTION

Internal combustion engine cooling uses either air or a liquid to remove the waste heat from an internal combustion engine. For small or special purpose engines, cooling using air from the atmosphere makes for a lightweight and relatively simple system. Watercraft can use water directly from the surrounding environment to cool their engines. For water-cooled engines on aircraft and surface vehicles, waste heat is transferred from a closed loop of water pumped through the engine to the surrounding atmosphere by a radiator. Water has a higher heat capacity than air, and can thus move heat more quickly away from the engine, but a radiator and pumping system add weight, complexity, and cost. Higher-power engines generate more waste heat, but can move more weight, meaning they are generally water-cooled. Radial engines allow air to flow around each cylinder directly, giving them an advantage for air cooling over straight engines, flat engines, and V engines. Rotary engines have a similar configuration, but the cylinders also continually rotate, creating an air flow even when the vehicle is stationary. Aircraft design more strongly favors lower weight and air-cooled designs. Rotary engines were popular on aircraft until the end of World War I, but had serious stability and efficiency problems. Radial engines were popular until the end of World War II, until gas turbine engines largely replaced them. Modern propeller-driven aircraft with internal-combustion engines are still largely air-cooled. Modern cars generally favor power over weight, and typically have water-cooled engines. Modern motorcycles are lighter than cars, and both cooling fluids are common. Heat engines generate mechanical power by extracting energy from heat flows, much as a water wheel extracts mechanical power from a flow of mass falling through a distance. Engines are inefficient, so more heat energy enters the engine than comes out as mechanical power; the difference is waste heat which must be removed. Internal combustion engines remove waste heat through cool intake air, hot exhaust gases, and explicit engine cooling Engines with higher efficiency have more energy leave as mechanical motion and less as waste heat. Some waste heat is essential: it guides heat through the engine, much as a water wheel works only if there is some exit velocity (energy) in the waste water to carry it away and make room for more water. Thus, all heat engines need cooling to operate. Cooling is also needed because high temperatures damage engine materials and lubricants. Cooling becomes more important when the climate becomes very hot. Internal-combustion engines burn fuel hotter than the melting temperature of engine materials, and hot enough to set fire to lubricants. Engine cooling removes energy fast enough to keep temperatures low so the engine can survive Some high-efficiency engines run without explicit cooling and with only incidental heat loss, a design called adiabatic. Such engines can achieve high efficiency but compromise power output, duty cycle, engine weight, durability, and emissions.

1.1 Generalization difficulties

It is difficult to make generalizations about air-cooled and liquid-cooled engines. Air-cooled diesel engines are chosen for reliability even in extreme heat, because air-cooling would be

simpler and more effective at coping with the extremes of temperatures during the depths of winter and height of

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summer, than water cooling systems, and are often used in situations where the engine runs unattended for months at a time.

Similarly, it is usually desirable to minimize the number of heat transfer stages in order to maximize the temperature difference at each stage. However, Detroit Diesel two-stroke cycle engines commonly used oil cooled by water, with the water in turn cooled by air.

The coolant used in many liquid-cooled engines must be renewed periodically, and can freeze at ordinary temperatures thus causing permanent engine damage. Air-cooled engines do not require coolant service, and do not suffer engine damage from freezing, two commonly cited advantages for air-cooled engines. However, coolant based on propylene glycol is liquid to −55 °C, colder than is encountered by many engines; shrinks slightly when it crystallizes, thus avoiding engine damage; and has a service life over 10,000 hours, essentially the lifetime of many engines.

It is usually more difficult to achieve either low emissions or low noise from an air-cooled engine, two more reasons most road vehicles use liquid-cooled engines. It is also often difficult to build large air-cooled engines, so nearly all air-cooled engines are under 500 kW (670 hp), whereas large liquid-cooled engines exceed 80 MW (107000 hp) (Wärtsilä-Sulzer RTA96-C 14-cylinder diesel).

1.2 Air-cooling

1.3 Liquid cooling

1.4 Transition from air cooling

1.5 Low heat rejection engines

A special class of experimental prototype internal combustion piston engines have been developed over several decades with the goal of improving efficiency by reducing heat loss. These engines are variously called adiabatic engines, due to better approximation of adiabatic expansion, low heat rejection engines, or high-temperature engine. They are generally diesel engines with combustion chamber parts lined with ceramic thermal barrier coatings. Some make use of titanium pistons and other titanium parts due to its low thermal conductivity and mass. Some designs are able to eliminate the use of a cooling system and associated parasitic losses altogether. Developing lubricants able to withstand the higher temperatures involved has been a major barrier to commercialization. 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

There are mainly two types of cooling systems:

(a) Air cooled system, and

(b) Water cooled system.

1.7 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

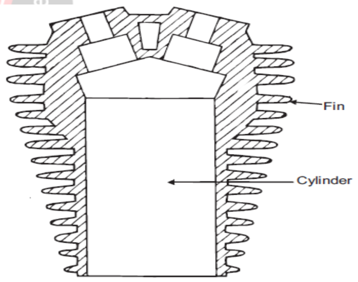

FIG 1.1 CYLINDER FINS

1.7.1 Advantages of Air-Cooled System

1.7.2 Disadvantages of Air-Cooled System

1.8 WATER COOLING SYSTEM

1.9 TYPES OF WATER-COOLING SYSTEM

1.9.1 Thermo Siphon System

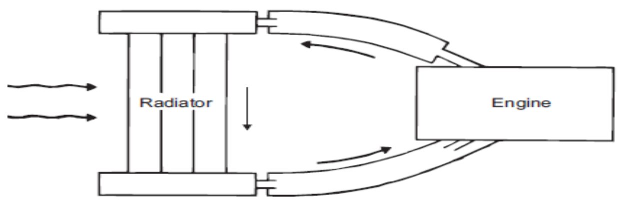

Fig 1.2 Thermo siphon system of cooling

1.9.2 Pump Circulation System

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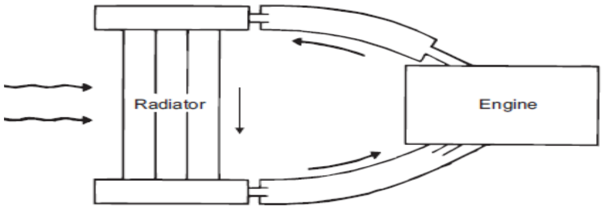

Fig 1.3 Pump circulation system

1.10 Components of Water-Cooling System

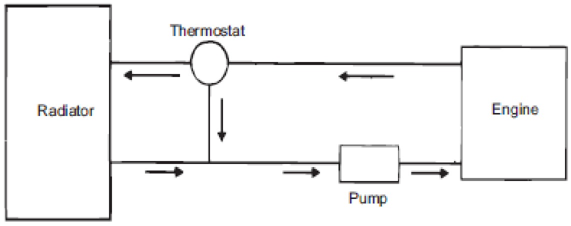

Fig 1.4 water cooling system using thermostat valve

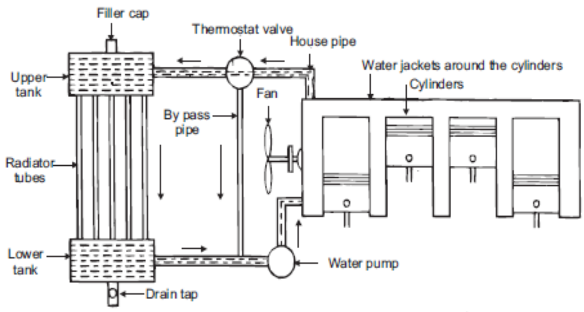

Fig 1.5 water cooling system of a 4-cylinder engine

Water cooling system mainly consists of:
(a) Radiator,
(b) Thermostat valve,
(c) Water pump,
(d) Fan,
(e) Water Jackets, and
(f) Antifreeze mixtures.

1.11 Types of fins:

Can be broadly classified into: -

* Fins of constant cross-section: rectangular or pin (spike) fins

* Fins of varying cross-section. Tapered fins.

Cullinan and Berggren (1959) analyzed space radiators with single or double active surface design, for obtaining temperature distribution as well as for maximizing the heat rejection per unit weight. Sparrow et al (1961) considered mutual interactions between fins but neglected the interaction of the fin with base. The geometry for the analysis was more than two fins arranged on a common base surface and the fin profile was rectangular. Solutions were obtained for angles of 45o,60o, 90o, 120o between two fins and for emissivity's 1,0.75 and 0.5. Temperature distributions, overall heat loss and local heat loss and the fin effectiveness were presented along with the conditions under which weight of the fins becomes a minimum. Sparrow et al (1961) studied heat transfer from fin tube radiator, including longitudinal heat conduction and radiant interchange between longitudinally non isothermal finite surfaces. The fins were considered to be infinitely long and the profile was rectangular. The study concluded that longitudinal conduction did not have any appreciable effect on the thermal performance of the system. Sparrow (1963) studied a plane –tube radiator in which there was considerable radiation interaction between the fin and base surfaces. The fins were of rectangular profile. Arbitrary radiation from external sources was also included. It was shown that the base heat loss comprises an important part of the total heat loss of the system. Karlekar and Chao (1963), presented an optimization procedure for achieving maximum dissipation from a longitudinal fin system of trapezoidal fins with mutual irradiation but no base interaction. The temperatures were obtained using the Newton-Raphson method. A new non-dimensional parameter based on the total heat dissipation from the fin system per unit axial length was proposed to characterize the total dissipating capacity of the fin system with mutual irradiation. Optimum fin number and their proportions were determined and charts of dissipation were presented. Schnarr (1975) studied radiation from an array of longitudinal fins of the triangular profile arranged around a cylinder of isothermal base. The fins were considered to be infinitely long and base interaction was also considered. The effects of external incident radiation were ignored. The results were useful in optimizing the design for minimum weight. Bejan (1979) studied the performance characteristics of annular finned radiators and duct type radiators. A novel feature of this study was consideration of variation of temperature along the length of the radiators. A thermodynamic optimization study of Nag and Mukherjee (1987) showed that the initial temperature difference between the fluid and wall considered as an important criterion for the design of thermal system. Chung and Zhang (1991) presented a new approach to minimize the weight of radiating straight fin array. The effect of base interaction was considered and the fins were infinitely long. In this study the fins were arranged symmetrically around the circular tube. The temperature of the tubes surface was considered to be uniform both longitudinally and circumferentially. Sridhar et al (1994) considered the effect of two dimensionality in radiating-conducting wedges. The base was considered to be isothermal and the fin profile was triangular. They analyzed a space radiator with six rectangular fins interacting with each other and with the environment. The study concluded that two dimensional effects were important only for low aspect ratio fins. Dinesh and Balaji (2001) numerically analyzed a horizontal circular duct with external longitudinal fins, trapezoidal in cross-section with turbulent flow for heat transfer by convection, radiation and entropy generation. The resulting two-

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dimensional fin equations were solved using second order finite difference scheme. The analysis takes into account the variation of base temperature along the duct. Sasikumar (2001) introduced a holistic approach to optimize fin systems over a rectangle duct considering the effect of thermal convection and radiation. A convicting radiating fin array, which stands vertically on a horizontal duct, was analyzed for entropy generation and total heat loss per unit mass. The flow was considered to be fully turbulent inside the duct and variation of fluid temperature along the duct was accounted for. Mohamed Najib Bouazizi et al (2001) aimed to quantify the effects of non-simplified situations on longitudinal fins efficiency. For this purpose, a more realistic model, which had been developed based on variable profile and temperature-dependent thermo physical properties in transient two-dimensional fin with internal non-uniform heat generation. An explicit exponential finite-difference method, conditionally stable, was extended in the study for the discretization of the governing equations. The numerical procedure consists in solving series of nodal temperature distribution according to the type of node, in order to reach the steady-state heat exchange. Then, the numerical simulation was used to present the sensitivity of some parameters on efficiency. Numerical results of interest were illustrated for a direct comparison with the traditional solutions. Extensive numerical experiments were conducted and showed that temperature-dependent heat transfer coefficient and generation lead to a significant reduction of fin-efficiency. The simultaneous effects of parameters for this non-linear problem were not negligible.

Modeling of cylinder fins in CATIA.

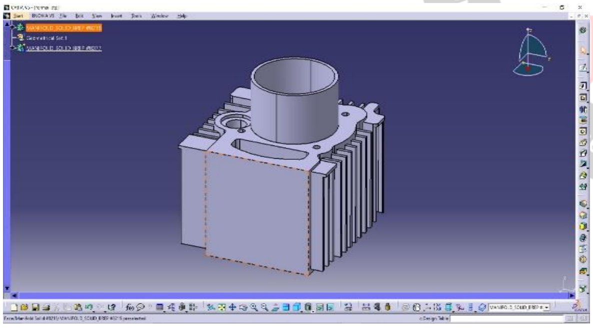

Fig 3.1: IC Engine fins with rectangular cross section

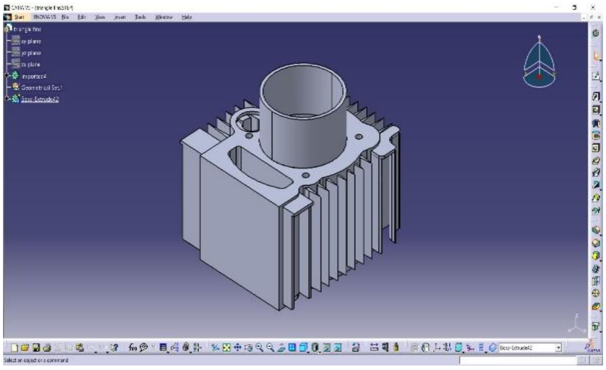

Fig 3.2: IC Engine fins with triangular cross section

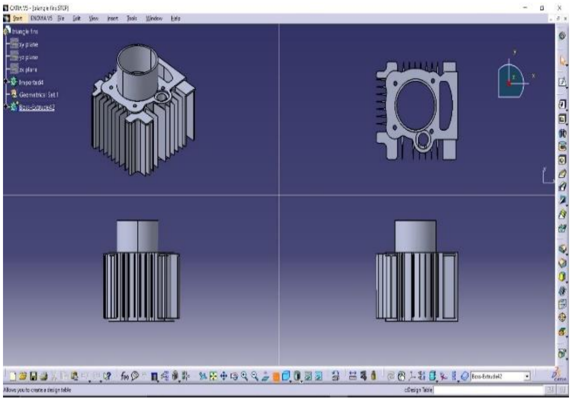

Fig 3.3: Multi view of IC Engine fins with triangular cross section

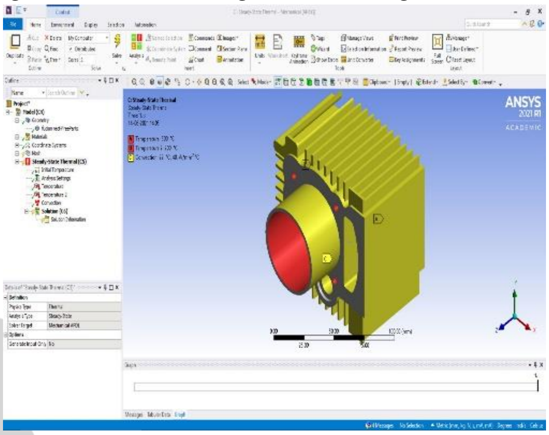

Fig 4.1: applying boundary conditions on the IC engine rectangular fins

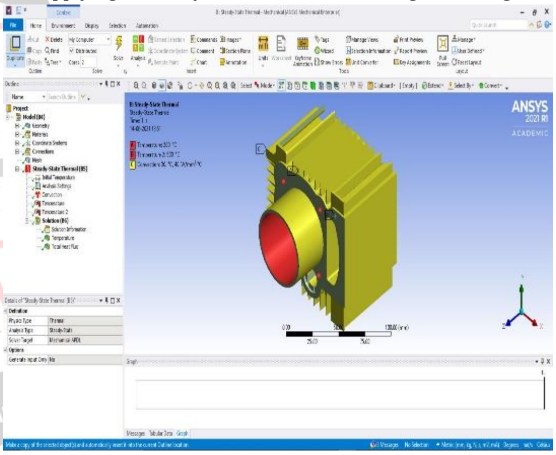

Fig 4.2: applying boundary conditions on the IC engine triangular fins

II. RESULTS

5.1 analysis of IC engine fins with rectangular cross section:

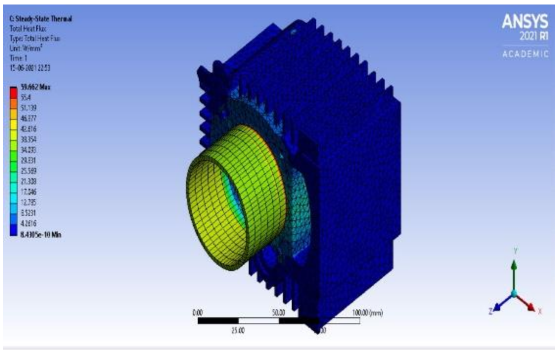

Fig 5.1: Total Heat flux of Rectangular Cross Section Fins

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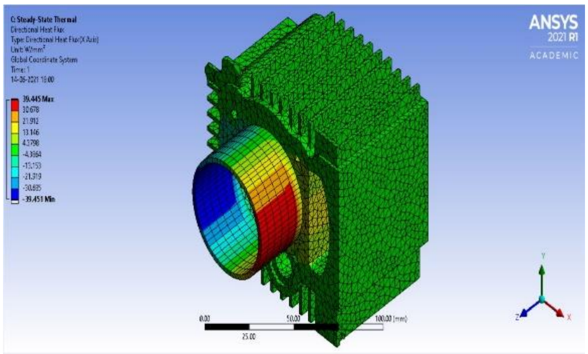

Fig 5.2: Directional Heat flux (X direction) of Rectangular Cross Section Fins

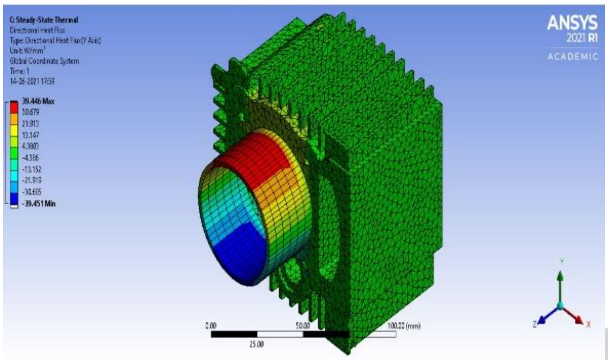

Fig 5.3: Directional Heat flux (Y direction) of Rectangular Cross Section Fins

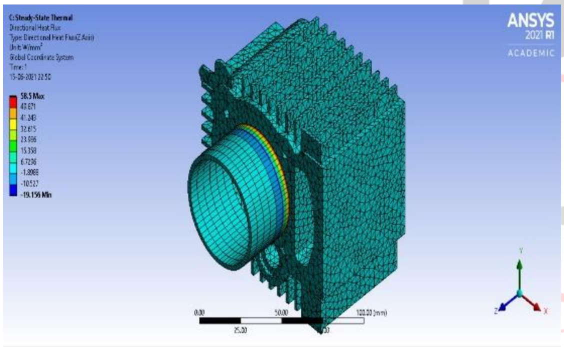

Fig 5.4: Directional Heat flux (Z direction) of Rectangular Cross Section Fins

5.2 analysis of IC engine fins with triangular cross section:

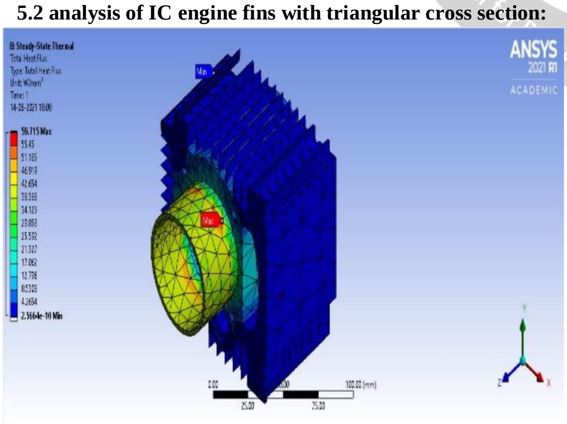

Fig 5.5: Total Heat flux of Triangular Cross Section Fins

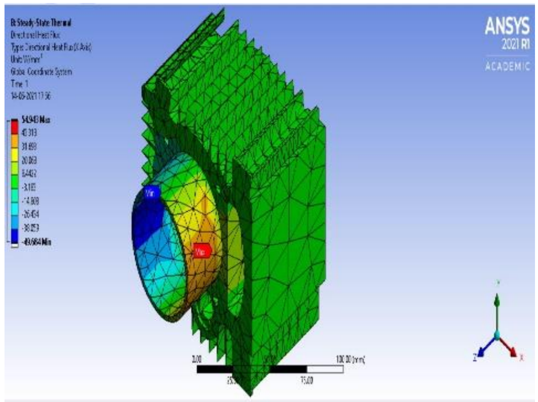

Fig 5.6: Directional Heat flux (X direction) of Triangular Cross Section Fins

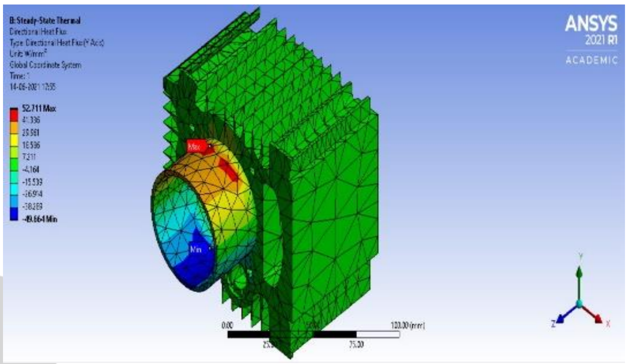

Fig 5.7: Directional Heat flux (Y direction) of Triangular Cross Section Fins

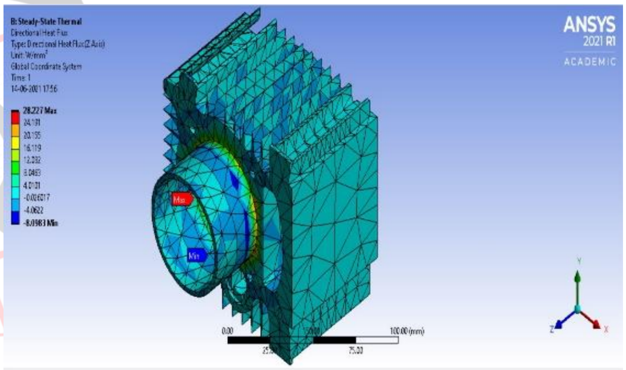

Fig 5.8: Directional Heat flux (Z direction) of Triangular Cross Section Fins

Direction of heat flow (w/mm2	**Rectangular cross section**	**Triangular cross section**
Total heat flux	59.662	59.715
X directional heat flow	39.445	54.943
Y directional heat flow	39.446	52.711
Z directional heat flow	58.5	28.227

III. CONCLUSION AND FUTURE SCOPE

In this paper, thermal behavior on engine fins is analyzed. The design of engine fins is generated by using CATIA V5 design software. thermal analysis is performed on the engine fin by using ANSYS.

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Study on different cross sections which are suitable for the improvement of engine fins are done. The best cross section has been suggested for engine fin by analysis on different cross sections (rectangular and triangular).

By comparing above results the triangular cross section is better than rectangular cross section. By comparing the heat flux values we concluded that triangular cross section has more heat dissipation when compared to rectangular cross section.

In this analysis, we concluded that using triangular fins is better, but rectangular fins are mostly used than triangular fins and also by using that, the weight of the fin body is also increases. By using triangular fins, the fin body weight is less, so more experiments are to be done to use triangular fins for the fin body in future.

IV. REFERENCES

[1] Heat Transfer in Process Engineering, by EDUARDO CAO

[2] Heat Exchanger Selection, Rating, and Thermal design (Second Edition) , by Sadik Kakac

[3] Computational Fluid Dynamics with applications, by John D. Anderson

[4] Fluid Mechanics, by S.K Som and Biswas

[5] Numerical study of heat transfer in a finned double pipe heat exchanger, Shiva Kumar, K. Vasudev Karanth, Krishna Murthy Dept of Mechanical Engg, MIT, Manipal, India (October 13 2014)

[6] A Review on Design & Analysis of Double Pipe Heat Exchanger N. R. Chaudhari, F. N. Adroja Mechanical Engineering Department, RK University, Rajkot, Gujarat, India

[7] Experimental Investigation of Heat Transfer in Double Heat Exchanger using Twisted dense wire mesh insert, Dr R. M. Saraiya, V.S. Fuskele.

[8] Optimum design of double pipe heat exchanger Prabhata K. Swamee , Nitin Aggarwal , Vijay Aggarwal

 DOI : 10.35291/2454-9150.2022.0249