OPTIMIZATION OF ENGINE CYLINDER FINS OF VARYING GEOMETRY AND MATERIAL

DECLARATION

We hereby declare that the project work entitled the "Optimization of engine cylinder fins of varying geometry & material" is an original work done by us and not submitted earlier for the award of degree or diploma in any other universities.

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OPTIMIZATION OF ENGINE CYLINDER

FINS OF

VARYING GEOMETRY AND MATERIAL

1. 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 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.

The principle implemented in this project is to increase the heat dissipation rate by using the invisible working fluid, nothing but air. 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 purpose of using these cooling fins is to cool the engine cylinder by air.

The main aim of the project is to analyze the thermal properties by varying geometry, material, distance between the fins and thickness of cylinder fins. Parametric models of cylinder with fins have been developed to predict the transient thermal behavior. The models are created by varying the geometry circular and also by varying thickness of the fins for both geometries. The 3D modeling software used is Pro/Engineer.

Thermal analysis is done on the cylinder fins to determine variation temperature distribution over time. The analysis is done using ANSYS. Thermal analysis determines temperatures and other thermal quantities. The accurate thermal simulation could permit critical design parameters to be identified for improved life.

Presently Material used for manufacturing cylinder fin body is Cast Iron. In this thesis, using materials Copper and Aluminum alloy 6082 are also analyzed. Thermal analysis is done using all the three materials by changing geometries, distance between the fins and thickness of the fins for the actual model of the cylinder fin body.

2. INTRODUCTION TO COOLING SYSTEM

The internal combustion engine is an engine in which the combustion of a fuel (normally a fossil fuel) occurs with an oxidizer (usually air) in a combustion chamber. In an internal combustion engine, the expansion of the high-temperature and -pressure gases produced by combustion applies direct force to some component of the engine, such as pistons, turbine blades, or a nozzle. This force moves the component over a distance, generating useful mechanical energy.

2.1 NECESSITY OF COOLING SYSTEM IN IC ENGINES

All the heat produced by the combustion of fuel in the engine cylinders is not converted into useful power at the crankshaft. A typical distribution for the fuel energy is given below:

Useful work at the crank shaft	=	25 per cent
Loss to the cylinders walls	=	30 per cent
Loss in exhaust gases	=	35 per cent
Loss in friction	=	10 per cent

It is seen that the quantity of heat given to the cylinder walls is considerable and if this heat is not removed from the cylinders it would result in the preignition of the charge. In addition, the lubricant would also burn away, thereby causing the seizing of the piston. Excess heating will also damage the cylinder material.

Keeping the above factors in view, it is observed that suitable means must be provided to dissipate the excess heat from the cylinder walls, so as to maintain the temperature below certain limits.

However, cooling beyond optimum limits is not desirable, because it decreases the overall efficiency due to the following reasons:

1. Thermal efficiency is decreased due to more loss of heat to the cylinder walls.
2. The vaporization of fuel is less; this results in fall of combustion efficiency.
3. Low temperatures increase the viscosity of lubrication and hence more piston friction is encountered, thus decreasing the mechanical efficiency.

Though more cooling improves the volumetric efficiency, yet the factors mentioned above result in the decrease of overall efficiency.

Thus it may be observed that only sufficient cooling is desirable and any deviation from the optimum limits will result in the deterioration of the engine performance.

2.2 METHODS OF COOLING

Various methods used for cooling of automobile engines are:

1. Air Cooling 2.Water cooling

2.2.1 AIR-COOLING

Cars and trucks using direct air cooling (without an intermediate liquid) were built over a long period beginning with the advent of mass produced passenger cars and ending with a small and generally unrecognized technical change. Before World War II, water cooled cars and trucks routinely overheated while climbing mountain roads, creating geysers of boiling cooling water. This was considered normal, and at the time, most noted mountain roads had auto repair shops to minister to overheating engines.

ACS (Auto Club Suisse) maintains historical monuments to that era on the Susten Pass where two radiator refill stations remain (See a picture here). These have instructions on a cast metal plaque and a spherical bottom watering can hanging next to a water spigot. The spherical bottom was intended to keep it from being set down and, therefore, be useless around the house, in spite of which it was stolen, as the picture shows.

During that period, European firms such as Magirus-Deutz built air-cooled diesel trucks, Porsche built air-cooled farm tractors, and Volkswagen became famous with air-cooled passenger cars. In the USA, Franklin built air-cooled engines. The Czechoslovakia based company Tatra is known for their big size air cooled V8 car engines,Tatra engineer Julius Mackerle published a book on it. Air cooled engines are better adapted to extremely cold and hot environmental weather temperatures, you can see air cooled engines starting and running in freezing conditions that stuck water cooled engines and continue working when water cooled ones start producing steam jets.

2.2.2 LIQUID COOLING

Today, most engines are liquid-cooled.

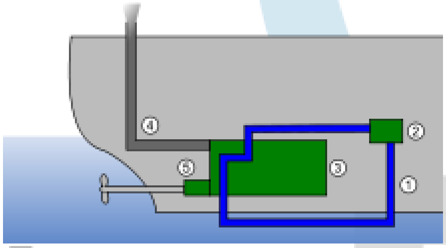

figure 2.1
A fully closed IC engine cooling system

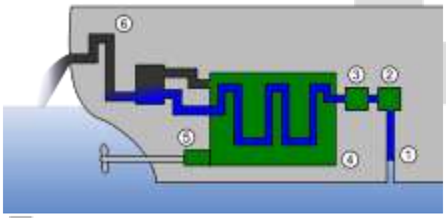

figure 2.2
Open IC engine cooling system

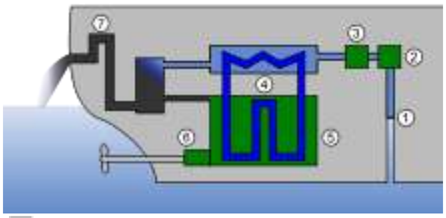

figure 2.3
Semiclosed IC engine cooling system

Liquid cooling is also employed in maritime vehicles (vessels, ...). For vessels, the seawater itself is mostly used for cooling. In some cases, chemical coolants are also employed (in closed systems) or they are mixed with seawater cooling.

2.3 TRANSITION AWAY FROM AIR COOLING

The change of air cooling to liquid cooling occurred at the start of World War II when the US military needed reliable vehicles. The subject of boiling engines was addressed, researched, and a solution found. Previous radiators and engine blocks were properly designed and survived durability tests, but used water pumps with a leaky graphite-lubricated "rope" seal (gland) on the pump shaft. The seal was inherited from steam engines, where water loss is accepted, since steam engines already expend large volumes of water. Because the pump seal leaked mainly when the pump was running and the engine was hot, the water loss evaporated inconspicuously, leaving at best a small rusty trace when the engine stopped and cooled, thereby not revealing significant water loss. Automobile radiators (or heat exchangers) have an outlet that feeds cooled water to the engine and the engine has an outlet that feeds heated water to the top of the radiator. Water circulation is aided by a rotary pump that has only a slight effect, having to work over such a wide range of speeds that its impeller has only a minimal effect as a pump. While running, the leaking pump seal drained cooling water to a level where the pump could no longer return water to the top of the radiator, so water circulation ceased and water in the engine boiled. However, since water loss led to overheat and further water loss from boil-over, the original water loss was hidden.

After isolating the pump problem, cars and trucks built for the war effort (no civilian cars were built during that time) were equipped with carbon-seal water pumps that did not leak and caused no more geysers. Meanwhile, air cooling advanced in memory of boiling engines... even though boil-over was no longer a common problem. Air-cooled engines became popular throughout Europe. After the war, Volkswagen advertised in the USA as not boiling over, even though new water-cooled cars no longer boiled over, but these cars sold well, and without question. But as air quality awareness rose in the 1960s, and laws governing exhaust emissions were passed, unleaded gas replaced leaded gas and leaner fuel mixtures became the norm. These reductions in the cooling effects of both the lead and the formerly rich fuel mixture, led to overheating in the air-cooled engines. Valve failures and other engine damage was the result. Volkswagen responded by abandoning their (flat) horizontally opposed air-cooled engines, while Subaru took a different course and chose liquid-cooling for their (flat) engines.

Today practically no air-cooled automotive engines are built, air cooling being fraught with manufacturing expense and maintenance problems. Motorcycles had an additional problem in that a water leak presented a greater threat to reliability, their engines having small cooling water volume, so they were loath to change; today most larger motorcycles are water cooled with many relying on convection circulation with no pump.

3. AIM OF THE PROJECT

The main aim of the project is to design cylinder with fins for Passion Plus 100cc engine, by changing the geometry, distance between the fins and thickness of the fins and to analyze the thermal properties of the fins. Analyzation is also done by varying the materials of fins. Present used material for cylinder fin body is Cast Iron.

Our aim is to change the material for fin body by analyzing the fin body with other materials and also by changing the geometry distance between the fins and thickness of the fins.

Geometry of fins – Original model and Modified Model

For Original Model **-** Thickness of fins – 2mm and Distance between the fins – 7.5mm

For modified model **-** Thickness of fins – 1.5mm and Distance between the fins for combustion side 9.65mm and for opp side 4.23 mm

Materials – Cast Iron, Copper and Aluminum alloy 6082

3.1 STEPS INVOLVED IN THE PROJECT

1. MODELING
2. THERMAL ANALYSIS

For modeling of the fin body, we have used Pro/Engineer, which is a parametric 3D modeling software. For analysis we have used ANSYS, which is a FEA software.

4. LITERATURE SURVEY

4.1 COOLING SYSTEM OF IC ENGINES

4.1.1Overview

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. 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 accidental heat loss, a design called adiabatic. For example, 10,000 mile-per-gallon "cars" for the Shell economy challenge are insulated, both to transfer as much energy as possible from hot gases to mechanical motion, and to reduce reheat losses when restarting. Such engines can achieve high efficiency but compromise power output, duty cycle, engine weight, durability, and emissions.

4.2 BASIC PRINCIPLES

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. Marine engines and some stationary engines have ready access to a large volume of water at a suitable temperature. The water may be used directly to cool the engine, but often has sediment, which can clog coolant passages, or chemicals, such as salt, that can chemically damage the engine. Thus, engine coolant may be run through a heat exchanger that is cooled by the body of water.

Most liquid-cooled engines use a mixture of water and chemicals such as antifreeze and rust inhibitors. The industry term for the antifreeze mixture is *engine coolant*. Some antifreezes use no water at all, instead using a liquid with different properties, such as propylene glycol or a combination of propylene glycol and ethylene glycol. Most "air-cooled" engines use some liquid oil cooling, to maintain acceptable temperatures for both critical engine parts and the oil itself. Most "liquid-cooled" engines use some air cooling, with the intake stroke of air cooling the combustion chamber. An exception is Wankel engines, where some parts of the combustion chamber are never cooled by intake, requiring extra effort for successful operation.

There are many demands on a cooling system. One key requirement is that an engine fails if just one part overheats. Therefore, it is vital that the cooling system keep *all* parts at suitably low temperatures. Liquid-cooled engines are able to vary the size of their passageways through the engine block so that coolant flow may be tailored to the needs of each area. Locations with either high peak temperatures (narrow islands around the combustion chamber) or high heat flow (around exhaust ports) may require generous cooling. This reduces the occurrence of hot spots, which are more difficult to avoid with air cooling. Air cooled engines may also vary their cooling capacity by using more closely-spaced cooling fins in that area, but this can make their manufacture difficult and expensive.

Only the fixed parts of the engine, such as the block and head, are cooled directly by the main coolant system. Moving parts such as the pistons, and to a lesser extent the crank and rods, must rely on the lubrication oil as a coolant, or to a very limited amount of conduction into the block and thence the main coolant. High performance engines frequently have additional oil, beyond the amount needed for lubrication, sprayed upwards onto the bottom of the piston just for extra cooling. Air-cooled motorcycles often rely heavily on oil-cooling in addition to air-cooling of the cylinder barrels.

Liquid-cooled engines usually have a circulation pump. The first engines relied on thermo-syphon cooling alone, where hot coolant left the top of the engine block and passed to the radiator, where it was cooled before returning to the bottom of the engine. Circulation was powered by convection alone.

Other demands include cost, weight, reliability, and durability of the cooling system itself.

Conductive heat transfer is proportional to the temperature difference between materials. If engine metal is at 250 °C and the air is at 20°C, then there is a 230°C temperature difference for cooling. An air-cooled engine uses all of this difference. In contrast, a liquid-cooled engine might dump heat from the engine to a liquid, heating the liquid to 135°C (Water's standard boiling point of

100°C can be exceeded as the cooling system is both pressurised, and uses a mixture with antifreeze) which is then cooled with 20°C air. In each step, the liquid-cooled engine has half the temperature difference and so at first appears to need twice the cooling area.

However, properties of the coolant (water, oil, or air) also affect cooling. As example, comparing water and oil as coolants, one gram of oil can absorb about 55% of the heat for the same rise in temperature (called the specific heat capacity). Oil has about 90% the density of water, so a given volume of oil can absorb only about 50% of the energy of the same volume of water. The thermal conductivity of water is about 4 times that of oil, which can aid heat transfer. The viscosity of oil can be ten times greater than water, increasing the energy required to pump oil for cooling, and reducing the net power output of the engine.

Comparing air and water, air has vastly lower heat capacity per gram and per volume (4000) and less than a tenth the conductivity, but also much lower viscosity (about 200 times lower: 17.4×10^{-6} Pa·s for air vs 8.94×10^{-4} Pa·s for water). Continuing the calculation from two paragraphs above, air cooling needs ten times of the surface area, therefore the fins, and air needs 2000 times the flow velocity and thus a recirculating air fan needs ten times the power of a recirculating water pump. Moving heat from the cylinder to a large surface area for air cooling can present problems such as difficulties manufacturing the shapes needed for good heat transfer and the space needed for free flow of a large volume of air. Water boils at about the same temperature desired for engine cooling. This has the advantage that it absorbs a great deal of energy with very little rise in temperature (called heat of vaporization), which is good for keeping things cool, especially for passing one stream of coolant over several hot objects and achieving uniform temperature. In contrast, passing air over several hot objects in series warms the air at each step, so the first may be over-cooled and the last under-cooled. However, once water boils, it is an insulator, leading to a sudden loss of cooling where steam bubbles form (for more, see heat transfer). Unfortunately, steam may return to water as it mixes with other coolant, so an engine temperature gauge can indicate an acceptable temperature even though local temperatures are high enough that damage is being done.

An engine needs different temperatures. The inlet including the compressor of a turbo and in the inlet trumpets and the inlet valves need to be as cold as possible. A countercurrent heat exchange with forced cooling air does the job. The cylinder-walls should not heat up the air before compression, but also not cool down the gas at the combustion. A compromise is a wall temperature of 90°C. The viscosity of the oil is optimized for just this temperature. Any cooling of the exhaust and the turbine of the turbocharger reduces the amount of power available to the turbine, so the exhaust system is often insulated between engine and turbocharger to keep the exhaust gases as hot as possible.

The temperature of the cooling air may range from well below freezing to 50°C. Further, while engines in long-haul boat or rail service may operate at a steady load, road vehicles often see widely-varying and quickly-varying load. Thus, the cooling system is designed to vary cooling so the engine is neither too hot nor too cold. Cooling system regulation includes adjustable baffles in the air flow (sometimes called 'shutters' and commonly run by a pneumatic 'shutterstat); a fan which operates either independently of the engine, such as an electric fan, or which has an adjustable clutch; a thermostatic valve or just 'thermostat' that can block the coolant flow when too cool. In addition, the motor, coolant, and heat exchanger have some heat capacity which smooths out temperature increase in short sprints. Some engine controls shut down an engine or limit it to half throttle if it overheats. Modern electronic engine controls adjust cooling based on throttle to anticipate a temperature rise, and limit engine power output to compensate for finite cooling.

Finally, other concerns may dominate cooling system design. As example, air is a relatively poor coolant, but air cooling systems are simple, and failure rates typically rise as the square of the number of failure points. Also, cooling capacity is reduced only slightly by small air coolant leaks. Where reliability is of utmost importance, as in aircraft, it may be a good trade-off to give up efficiency, durability (interval between engine rebuilds), and quietness in order to achieve slightly higher reliability — the consequences of a broken airplane engine are so severe, even a slight increase in reliability is worth giving up other good properties to achieve it.

Air cooled and liquid-cooled engines are both used commonly. Each principle has advantages and disadvantages, and particular applications may favor one over the other. For example, most cars and trucks use liquid-cooled engines, while many small airplane and low-cost engines are air-cooled.

4.3 AIR COOLED ENGINES

Air-cooled engines rely on the circulation of air directly over hot parts of the engine to cool them.

4.3.1 INTRODUCTION

Most modern internal combustion engines are cooled by a closed circuit carrying liquid coolant through channels in the engine block, where the coolant absorbs heat, to a heat exchanger or radiator where the coolant releases heat into the air. Thus, while they are *ultimately* cooled by air, because of the liquid-coolant circuit they are known as *water-cooled*. In contrast, heat generated by an air-cooled engine is released directly into the air. Typically this is facilitated with metal fins covering the outside of the cylinders which increase the surface area that air can act on.

In all combustion engines, a great percentage of the heat generated (around 44%) escapes through the exhaust, not through either a liquid cooling system nor through the metal fins of an air-cooled engine (12%). About 8% of the heat energy finds its way into the oil, which although primarily meant for lubrication, also plays a role in heat dissipation via a cooler.

4.3.2.1 Road vehicles

Many motorcycles use air cooling for the sake of reducing weight and complexity. Few current production automobiles have air-cooled engines (such as Tatra 815), but historically it was common for many high-volume vehicles. Examples of past air-cooled road vehicles, in roughly chronological order, include:

- Franklin (1902-1934)
- GM "copper-cooled" models of Chevrolet, Olds, and Oakland (1921-1923) (very few built)[1]
- Tatra 11 (1923-1927) and subsequent models
- Tatra T77 (1934-1938)
- Tatra T87 (1936-1950)
- Tatra T97 (1936-1939)
- Tatra T600 Tatraplan (1946-1952)
- Tatra T603 (1955-1975)
- Tatra T613 (1974-1996)
- Tatra T700 (1996-1999)
- Fiat 126 (1972-2000)
- Porsche 356 (1948-1965)
- VW-Porsche 914 (1969-1976)
- Porsche 911 (1964-1998)
- The Volkswagen Beetle, Type 2, SP2, Karmann Ghia, and Type 3 all utilized the same air cooled engine (1938-2003) with various displacements. Volkswagen Type 2 (T3) (1979–1982).
- Volkswagen Type 4 (1968-1974)
- Chevrolet Corvair (1960-1969)
- Citroën 2CV (1948-1990) (Featured a high pressure oil cooling system, and used a fan that was both axial and radial).
- Citroën GS and GSA
- Honda 1300 (1969-1973)
- The East German Trabant (1957-1991)
- NSU Prinz
- Tatra (company) all wheel drive military trucks.

4.3.2.2Aviation

Most aviation piston engines are air-cooled, including most of the engines currently (2005) manufactured by Lycoming and Continental and used by major manufacturers of light aircraft Cirrus, Cessna and so on. Notable exceptions have included the Allison V-1710 and Rolls-Royce series of (most well known, the Merlin V-1650) liquid-cooled V12 engines which powered P-51 Mustangs, Avro Lancasters, Hawker Hurricanes and Spitfires.

Other engine manufactures using air-cooled engine technology are ULPower and Jabiru, more active in the Light-Sport Aircraft (LSA) and ultralight aircraft market. Rotax uses a combination of air-cooled cylinders and liquid cooled cylinder heads.

4.3.2.3 Diesel engines

Some small diesel engines, e.g. those made by Deutz AG and Lister Petter are air-cooled. Probably the only big Euro 5 truck air cooled engine (V8 320 kW power 2100 Nm torque one) is being produced by Tatra.

4.3.2.3.1 AIR COOLING SYSTEM

The basic principle involved in this method is to have current of air flowing continuously over the heated metal surface from where the heat is to be removed. The heat dissipated depends upon following factors:

a) Surface area of metal into contact with air.
b) Mass flow rate of air.
c) Temperature difference between the heated surface and air.
d) Conductivity of metal.

Thus for an effective cooling the surface area of the metal which is in contact with the air should be increased. This is done by using fins over the cylinder barrels. These fins are either cast as an integral part of the cylinder or separate finned barrels are inserted over the cylinder barrels. These fins are either cast as an integral part of the cylinder or separate finned barrels are inserted over the cylinder barrel. Sometimes, particularly in the case of aero engines, the fins are machined from the forged cylinder blanks.

To increase the contact area still further, baffles are used sometimes.

Use of copper and steel alloys has also been made to improve heat transfer because of their better thermal conductivity.

4.3.2.3.2 ADVANTAGES

1. Air cooled engines are lighter because of the absence of the radiator**,** the cooling jackets and the coolant.

2. They can be operated in extreme climates, where the water may freeze.

3. In certain areas where there is scarcity of cooling water, the air cooled engine is an advantage.

4. Maintenance is easier because the problem of leakage is not there.

5. Air cooled engines get warmed up earlier than the water cooled engines.

4.3.2.3.3 DISADVANTAGES

1. It is not easy to maintain even cooling all around the cylinder, so that the distortion of the cylinders takes place. This defect has been remedied sometimes by using fins parallel to the cylinder axis. This is also helpful where a number of cylinders in a row are to be cooled. However, this increases the overall engine length.

2. As the coefficient of heat transfer for air is less than that for water, there is less efficient cooling in this case and as a result the highest useful compression ratio is lesser in the case of air cooled engines than in the water cooled ones.

3. The fan used is very bulky and absorbs a considerable portion of the engine power (about 5%) to drive it.

4. Air cooled engines are more noisy, because of the absence of cooling water which acts as sound insulator.

5. Some engine components may become inaccessible easily due to the guiding baffles and cooling, which makes the maintenance difficult.

6. The cooling fins around the cylinders may vibrate under certain conditions due to which noise level would be considerably enhanced.

4.4 DIFFERENCE BETWEEN AIR COOLED ENGINES AND WATER COOLED ENGINES

Air cooling uses airflow directed at fins on the cylinders and heads is the cooling medium: heat is transferred directly to the air. The air comes either by natural convection (e.g., a motorcycle) or by forced air (e.g., air-cooled VW or Porsche engine.)

Water cooled engines circulate coolant around the heads + cylinders though a surrounding water jacket, and use a separate high-efficiency radiator for the final heat exchange to the air. (Marine engines are a bit different - they use the surrounding water instead, either directly or through a water-to-water heat exchanger.)

Air-cooled engines are simpler, lighter and easier to maintain as they don't have the 'wet' cooling system elements. They excel in cold climates where coolant freezing can be a problem. However, air cooling is less efficient due to the low heat capacity of air so these engines suffer from hot spots which reduces power, increases emissions and shortens their life.

Air-cooled engines are also considerably noisier - both from the engine directly and also from the air blower cooling fan if used.

Water-cooled engines take advantage of water's high heat capacity to efficiently carry away the heat. So they offer the best control over temperature allowing for more aggressive / efficient tuning and optimal head design. While they have increased near-term maintenance costs (coolant, water pump, hoses, etc.) they make up for it in a longer-lived engine core (longer time between overhaul.)

Water-cooled engines are also quieter due to the insulating properties of the water jacket and the lessened airflow requirement.

Water cooling also permits more flexibility in engine architecture and installation since there isn't a need to duct cooling air directly to the cylinders.

4.5 GENERALIZATION DIFFICULTIES

It is difficult to make generalizations about air-cooled and liquid-cooled engines. Air-cooled Volkswagen kombis are known for rapid wear in normal use and sometimes sudden failure when driven in hot weather. Alternatively, air-cooled Deutz diesel engines are known for reliability even in extreme heat, 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 2-stroke cycle engines commonly use 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).

5. INTRODUCTION TO CAD

Throughout the history of our industrial society, many inventions have been patented and whole new technologies have evolved. Perhaps the single development that has impacted manufacturing more quickly and significantly than any previous technology is the digital computer. Computers are being used increasingly for both design and detailing of engineering components in the drawing office. Computer-aided design(CAD) is defined as the application of computers and graphics software to aid or enhance the product design from conceptualization to documentation. CAD is most commonly associated with the use of an interactive computer graphics system, referred to as a CAD system. Computer-aided design systems are powerful tools and in the mechanical design and geometric modeling of products and components. There are several good reasons for using a CAD system to support the engineering design function:

- To increase the productivity
- To improve the quality of the design
- To uniform design standards
- To create a manufacturing data base
- To eliminate inaccuracies caused by hand-copying of drawings and inconsistency between
- Drawings

5.1 CAD/CAM Software

Software allows the human user to turn a hardware configuration into a powerful design and manufacturing system. CAD/CAM software falls into two broad categories,2-D and 3-D, based on the number of dimensions are called 2-D representations of 3-D objects is inherently confusing. Equally problem has been the inability of manufacturing personnel to properly read and interpret complicated 2-D representations of objects. 3-D software permits the parts to be viewed with the 3-D planes-height, width, and depth-visible. The trend in CAD/CAM is toward 3-D representation of graphic images. Such representation approximates the actual shape and appearance of the object to be produced; therefore, they are easier to read and understand.

5.2 Applications of CAD/CAM

The emergence of CAD/CAM has had a major impact on manufacturing, by standardizing product development and by reducing design effort, tryout, and prototype work; it has made possible significantly reduced costs and improved productivity.

AutoCAD is a computer-aided drafting and design system implemenented on a personal computer. It supports a large number of devices. Device drivers come with the system and include most of the digitizers, printer/plotters, video display boards, and plotters available on the market.

AutoCAD supports 2-D drafting and 3-D wire-frame models. The system is designed as a single-user CAD package. The drawing elements are lines, polylines ofany width, arcs, circles, faces, and solids. There are many ways to define a drawing element. For example, a circle canbe defined by center and its radius, three points, and two end points of its diameter. The system alwaysprompts the user for all options.

Of course, the prompt can be turned off by advanced users. Annotation and dimensioning are also supported. Text and dimension symbols can be placed on anywhere on the drawing, at any angle, and at any size. A variety of fonts and styles are also availble.

Some typical applications of CAD/CAM are as follows:

Programming for NC, CNC, and industrial robots;
Design of dies and molds for casting, in which, for example, shrinkage
allowances are preprogrammed;
Design of tools and fixtures and EDM electrodes;
Quality control and inspection----for instance, coordinate-measuring
machines programmed on a CAD/CAM workstation;
Process planning and scheduling.

6. INTRODUCTION TO PRO/ENGINEER

Pro/ENGINEER, PTC's parametric, integrated **3D CAD/CAM/CAE solution**, is used by discrete manufacturers for mechanical engineering, design and manufacturing.

Created by Dr. Samuel P. Geisberg in the mid-1980s, Pro/ENGINEER was the industry's first successful parametric, 3D CAD modeling system. The parametric modeling approach uses parameters, dimensions, features, and relationships to capture intended product behavior and create a recipe which enables design automation and the optimization of design and product development processes.

This powerful and rich design approach is used by companies whose product strategy is family-based or platform-driven, where a prescriptive design strategy is critical to the success of the design process by embedding engineering constraints and relationships to quickly optimize the design, or where the resulting geometry may be complex or based upon equations. Pro/ENGINEER provides a complete set of design, analysis and manufacturing capabilities on one, integral, scalable platform. These capabilities, include Solid Modeling, Surfacing, Rendering, Data Interoperability, Routed Systems Design, Simulation, Tolerance Analysis, and NC and Tooling Design.

Companies use Pro/ENGINEER to create a complete 3D digital model of their products.The models consist of 2D and 3D solid model data which can also be used downstream in finite element analysis, rapid prototyping, tooling design, and CNC manufacturing. All data is associative and interchangeable between the CAD, CAE and CAM modules without conversion. A product and its entire bill of materials(BOM) can be modeled accurately with fully associative engineering drawings, and revision control information. The associativity in Pro/ENGINEER enables users to make changes in the design at any time during the product development process and automatically update downstream deliverables. This capability enables concurrent engineering — design, analysis and manufacturing engineers working in parallel — and streamlines product development processes.

Pro/ENGINEER is an integral part of a broader product development system developed by PTC. It seamlessly connects to PTC’s other solutions including Windchill, ProductView, Mathcad and Arbortext.

6.1 DIFFERENT MODULES IN PRO/ENGINEER

- PART DESIGN
- ASSEMBLY
- DRAWING
- SHEETMETAL
- MANUFACTURING

MODELS OF CYLINDER FIN BODY

6.1 ORGINAL FIN BODY

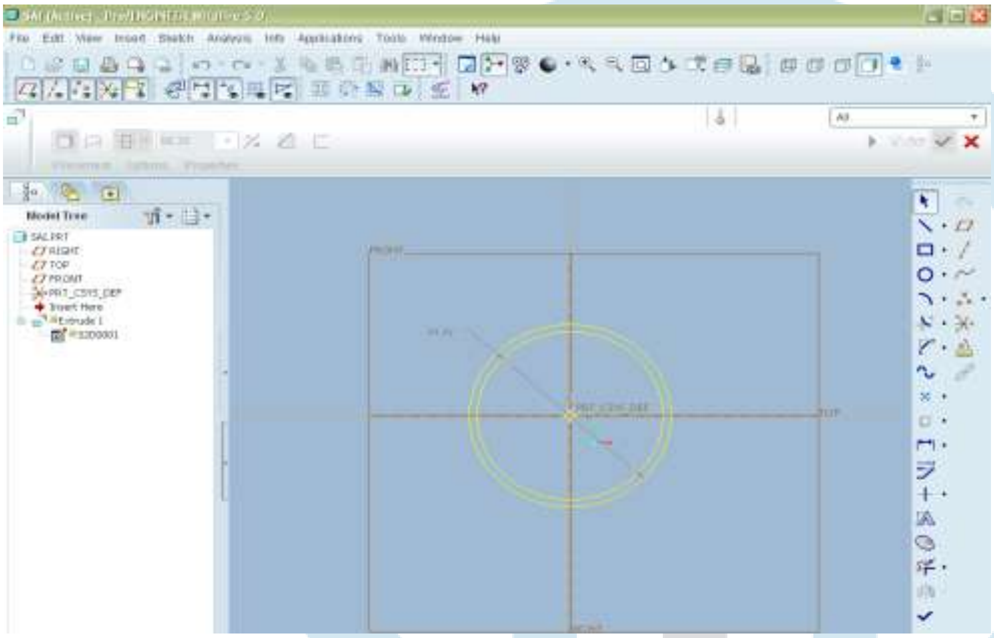

Figure 6.1.1 : 2D model-1

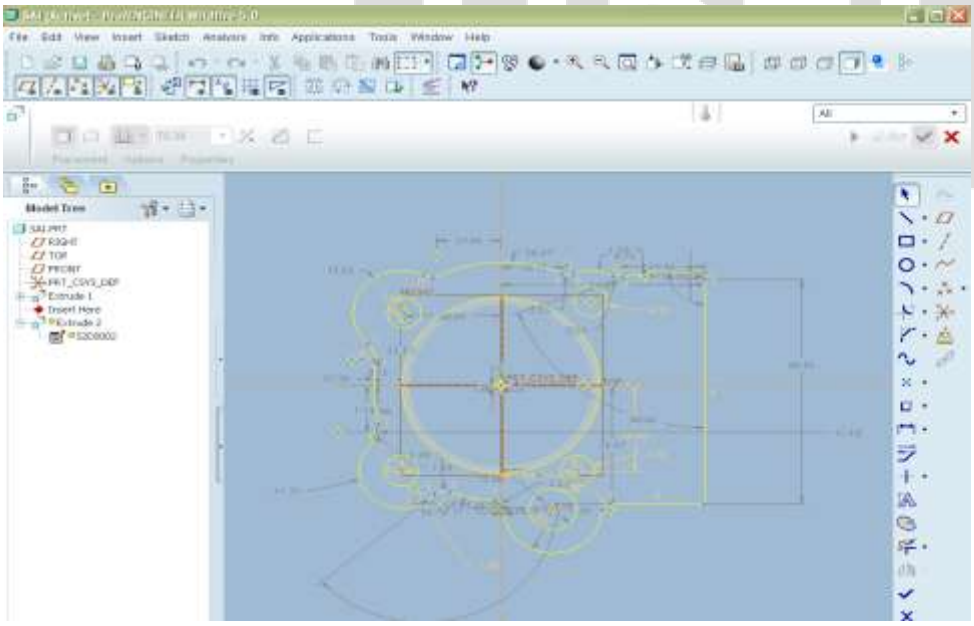

Figure 6.1.2 : 2D model 2

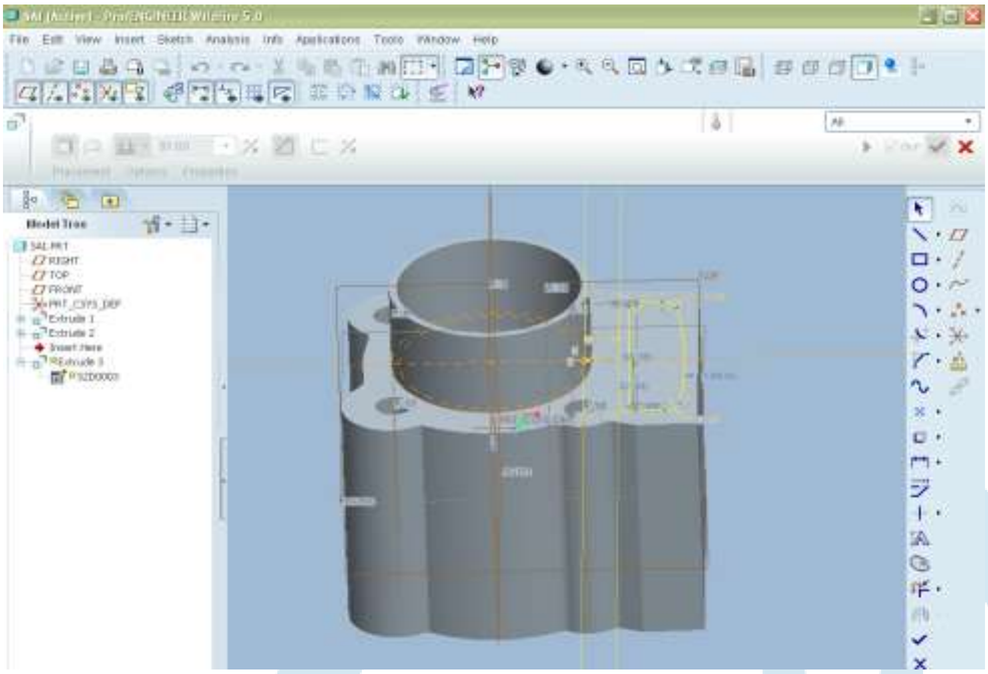

Figure 6.1.3 : 3D model 1

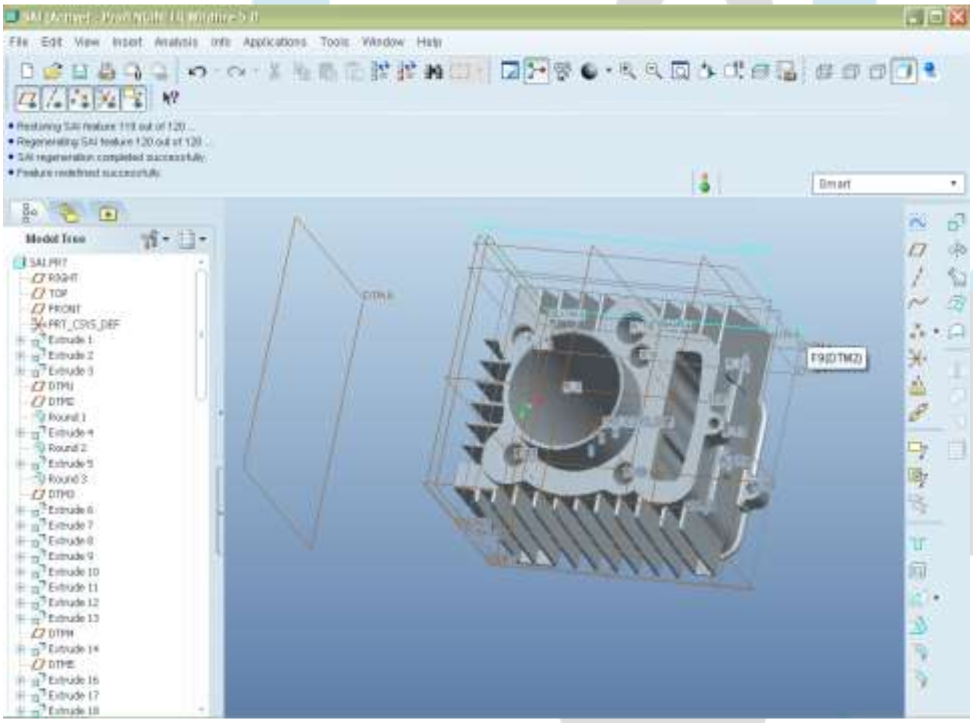

Figure 6.1.4 : 3D model 2

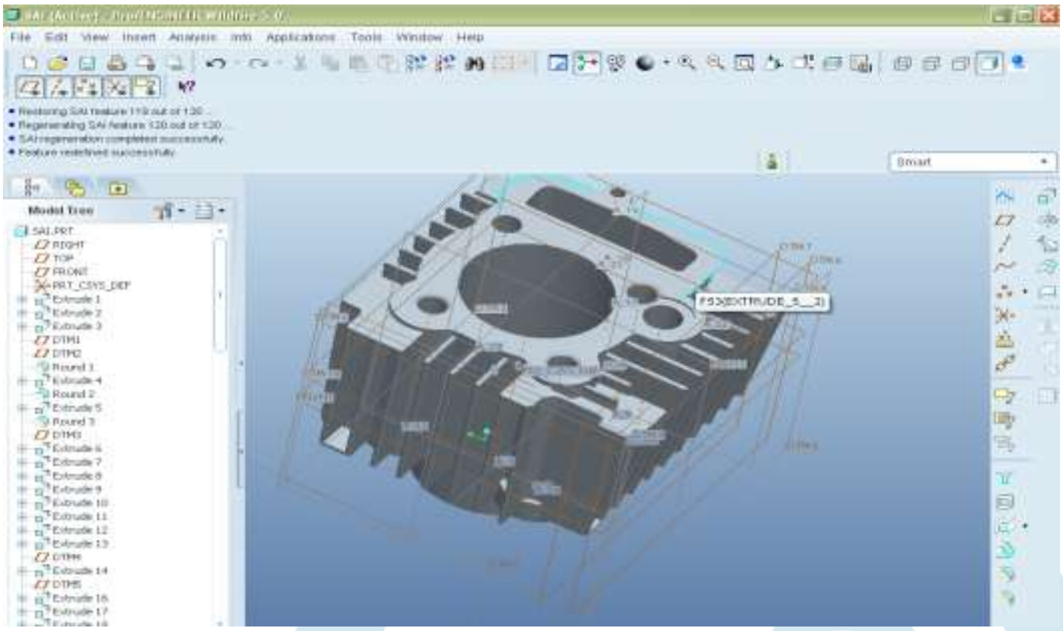

Figure 6.1.5 : 3D model 3

2D DRAFTING IMAGE

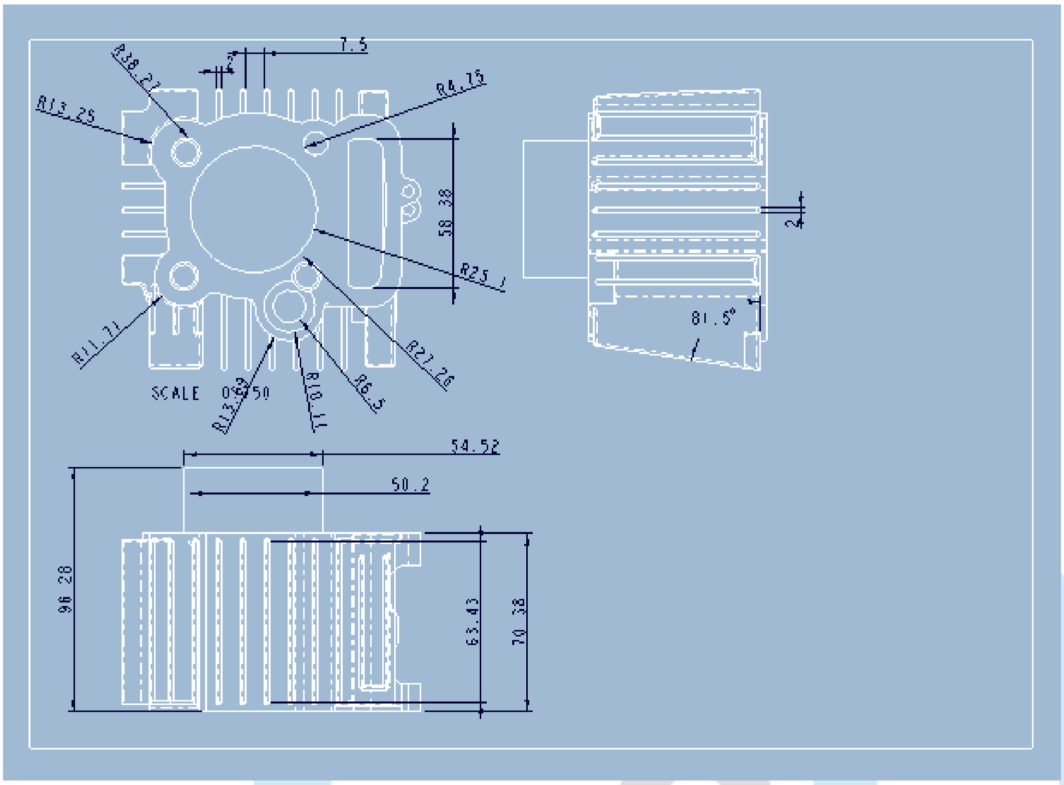

Figure 6.1.6 : Drafting model

6.2 MODIFIED MODEL

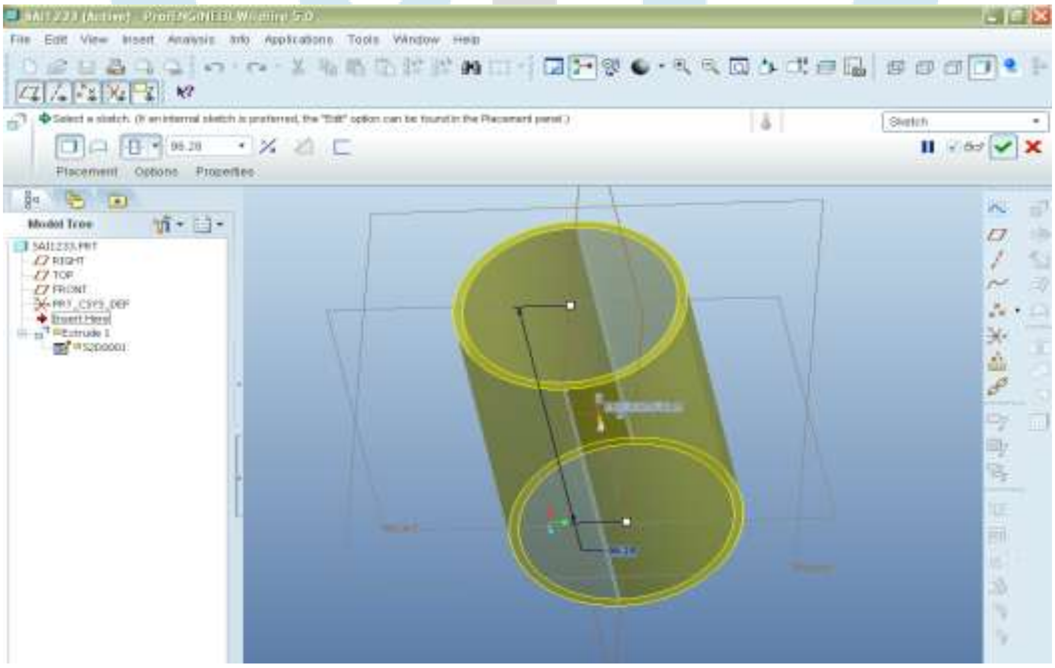

Figure 6.2.1 : Modified model 1

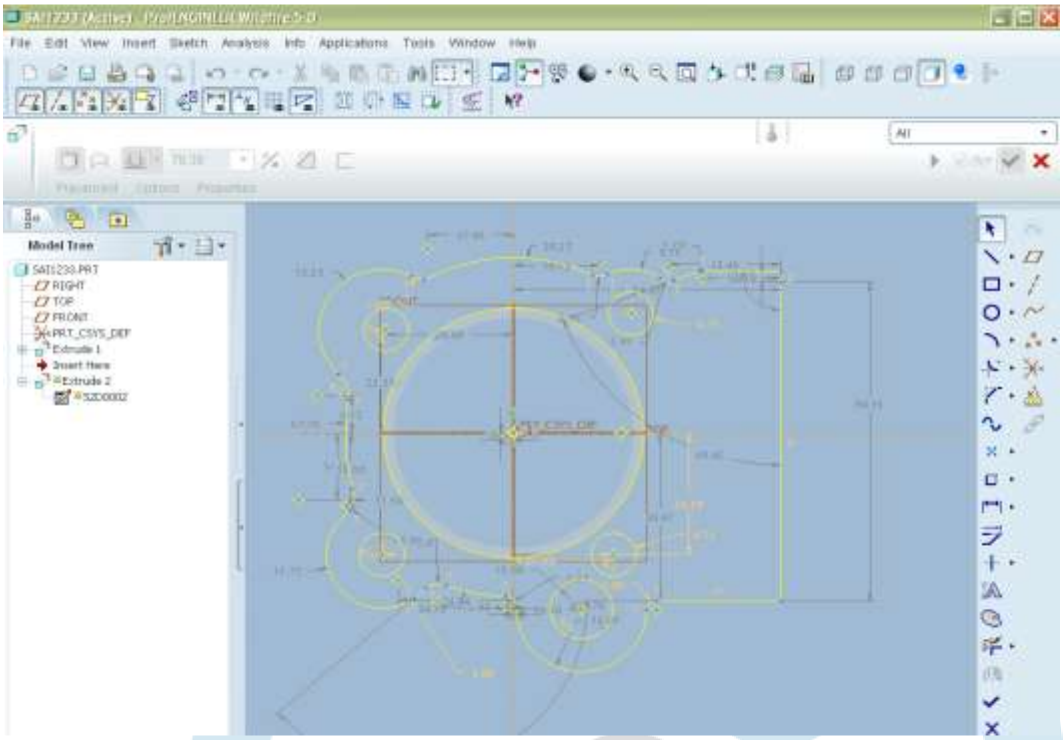

Figure 6.2.2 : Modified 2D model 2

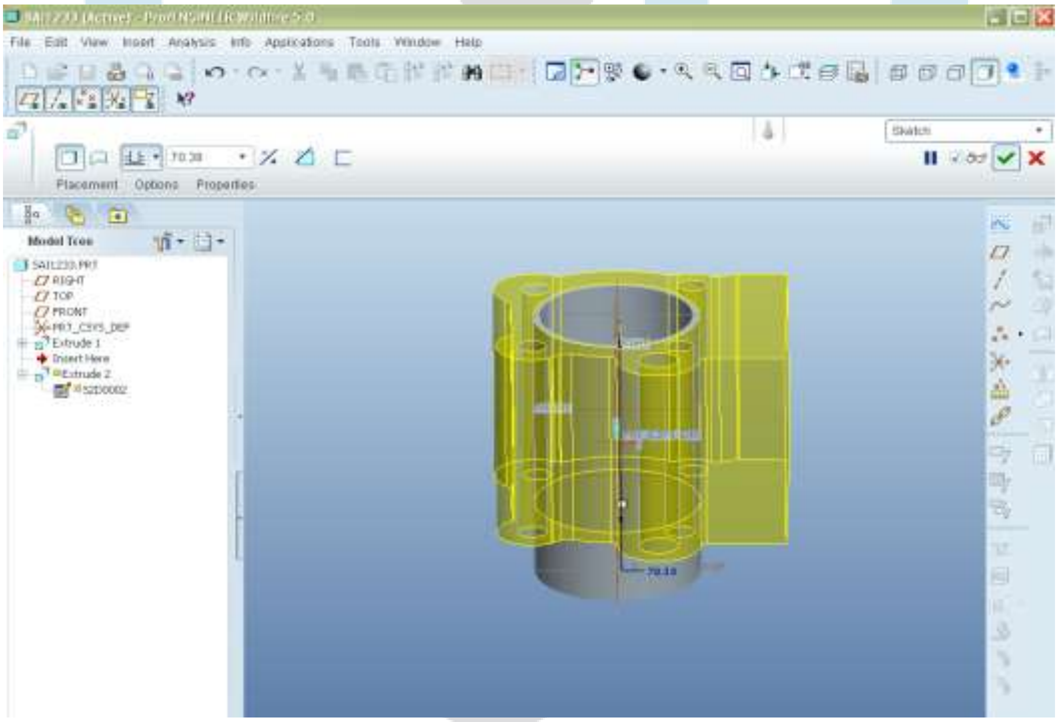

Figure 6.2.3 : Modified 3D model 1

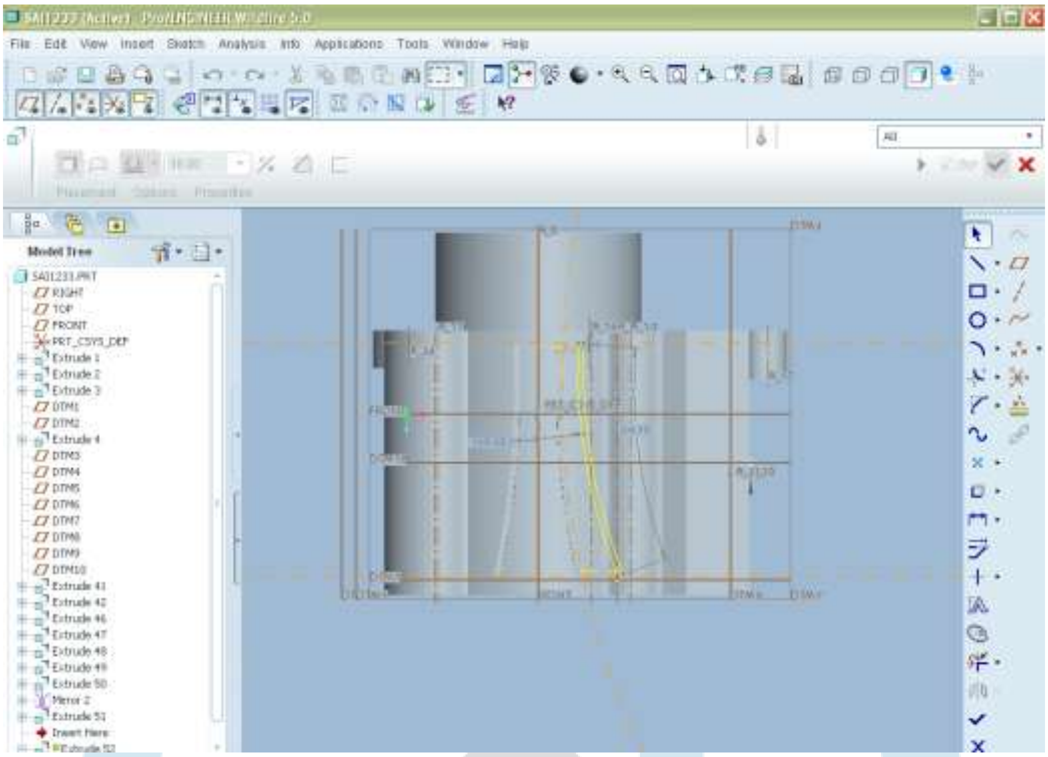

Figure 6.2.4 : Modified 3D model 2

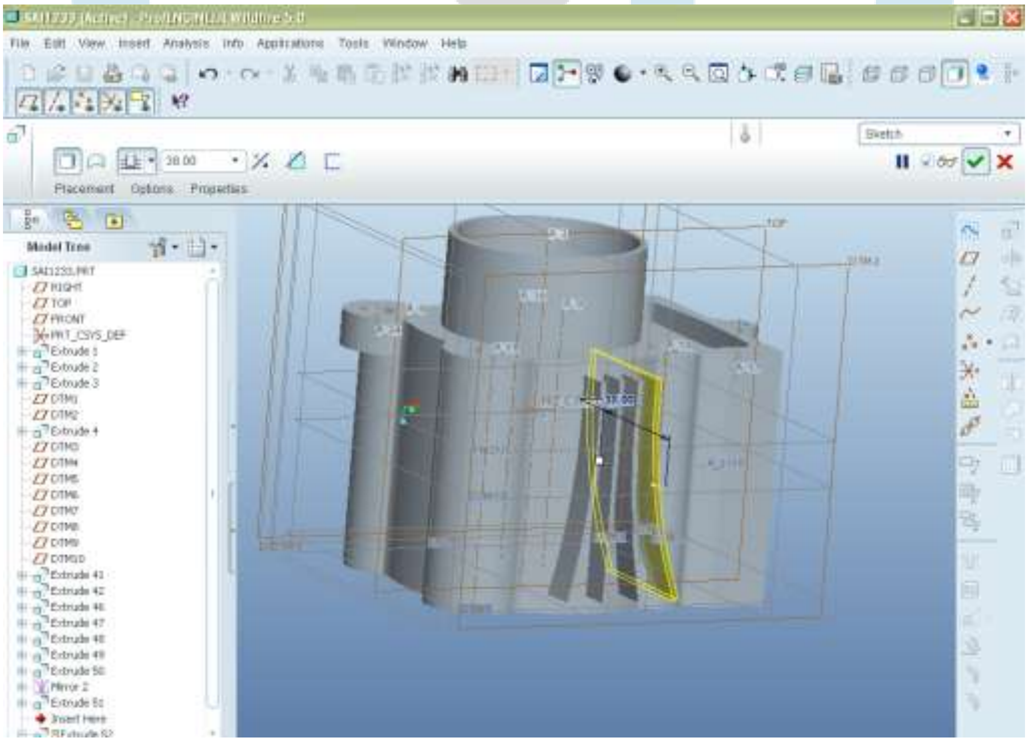

Figure 6.2.5 : Modified 2D model 3

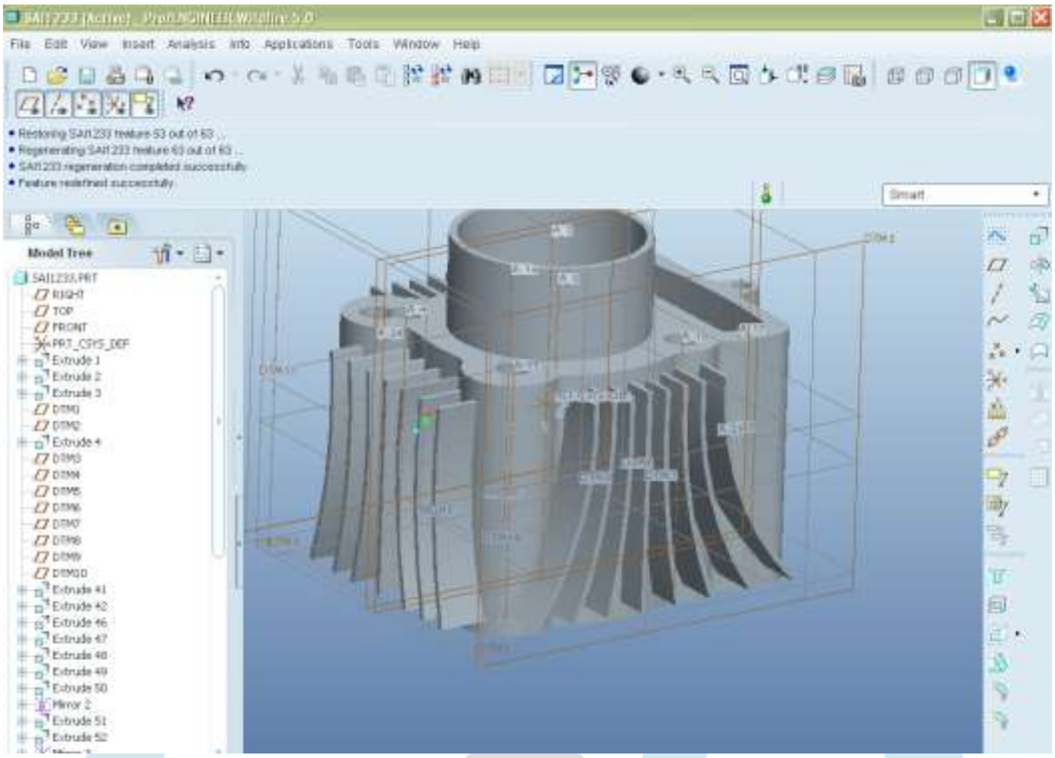

Figure 6.2.6: Modified 2D model 4

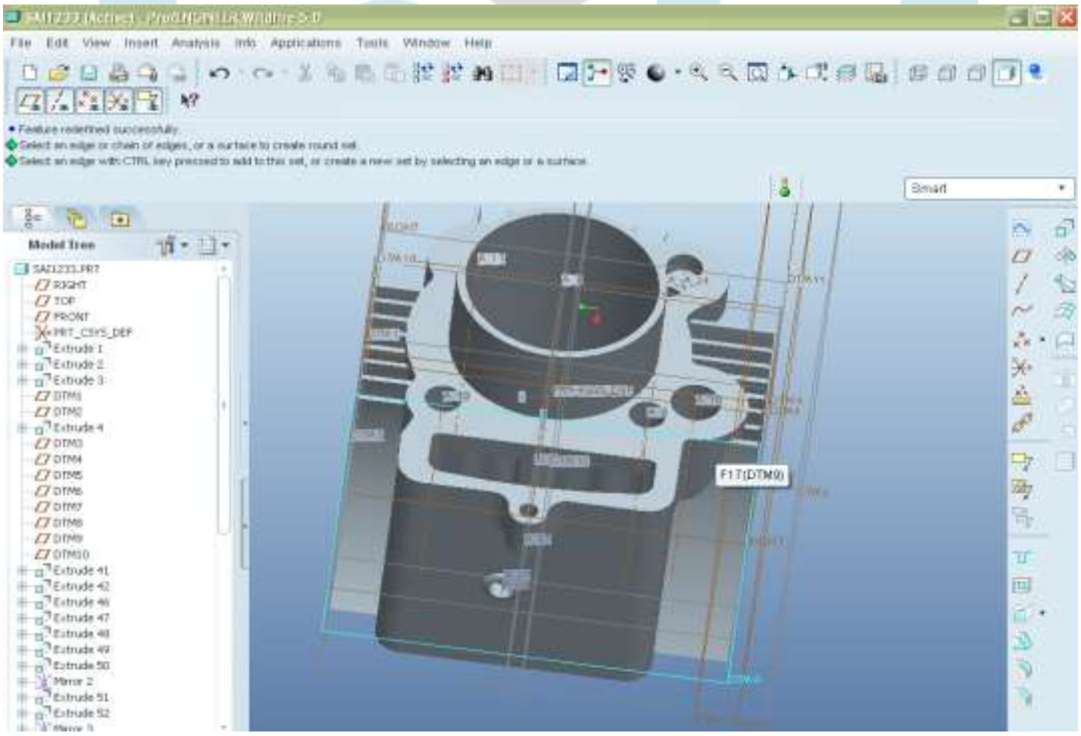

Figure 6.2.7 : Modified 2D model 5

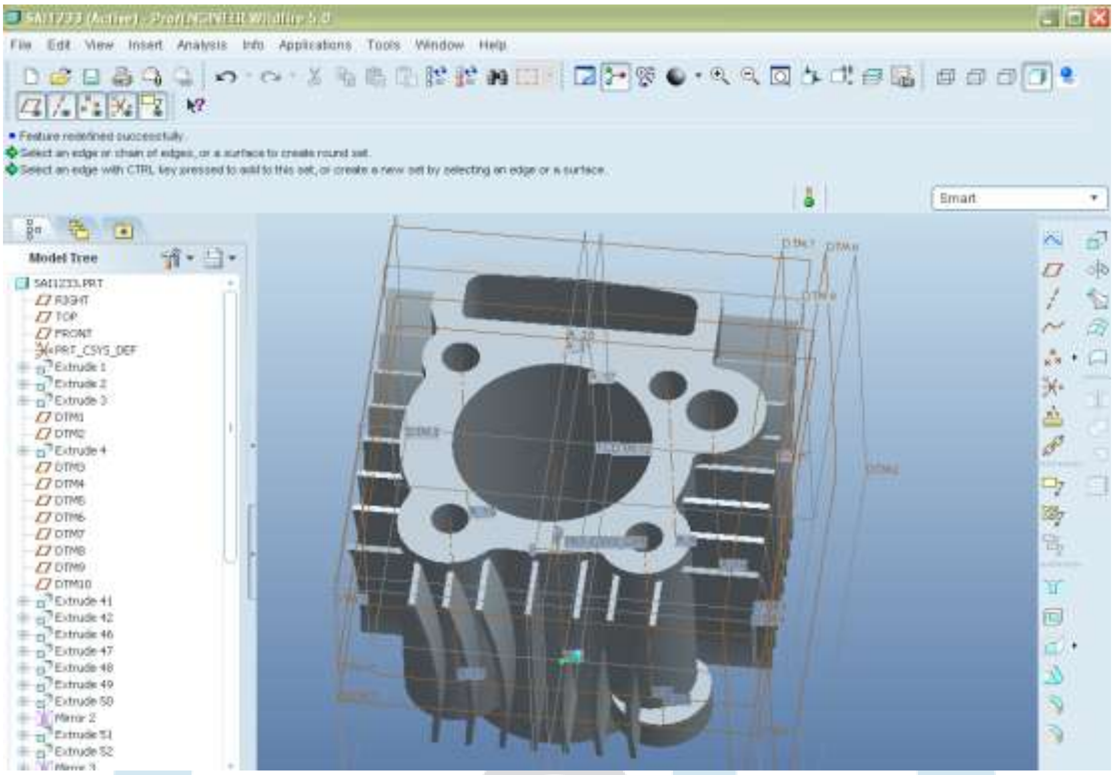

Figure 6.2.8 : Modified 2D model 6

2D DRAFTING IMAGE

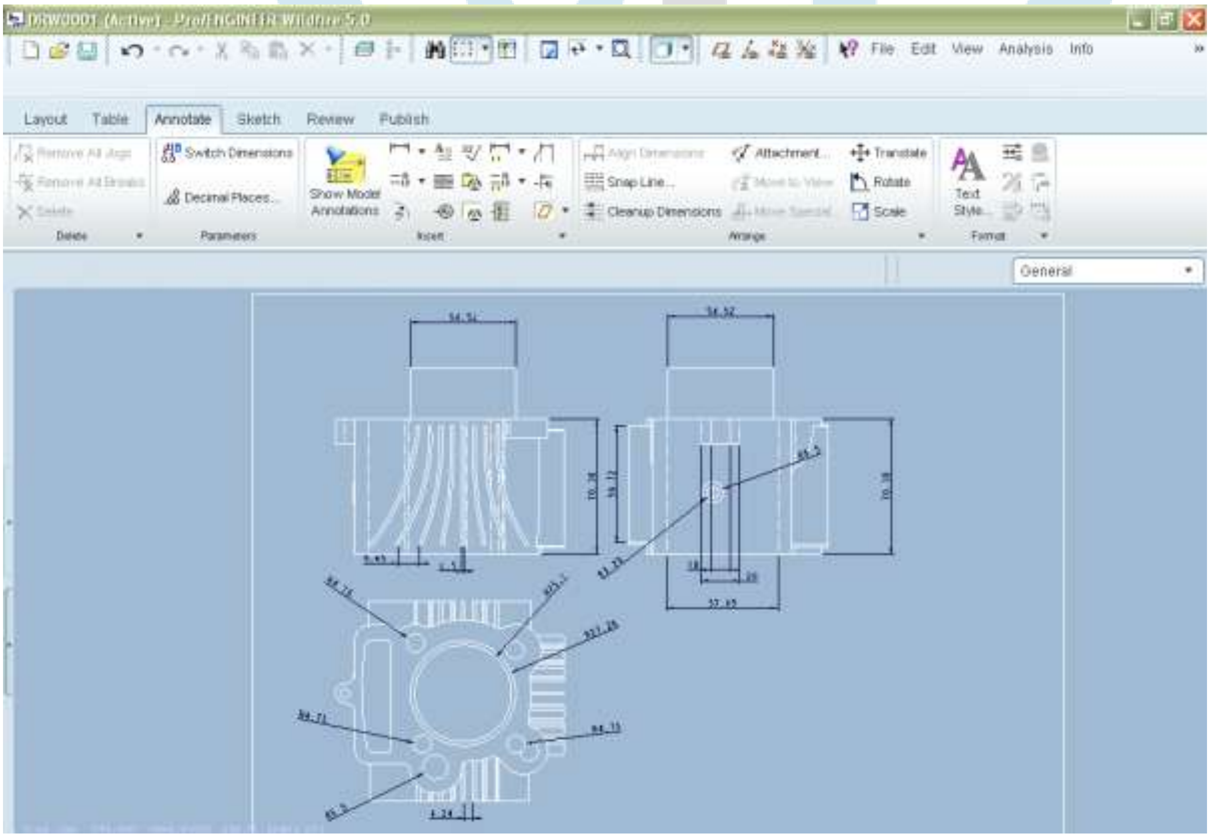

Figure 6.2.9 : Modified drafting model

7. INTRODUCTION TO FEA

Finite Element Analysis (FEA) was first developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variational calculus to obtain approximate solutions to vibration systems. Shortly thereafter, a paper published in 1956 by M. J. Turner, R. W. Clough, H. C. Martin, and L. J. Topp established a broader definition of numerical analysis. The paper centered on the "stiffness and deflection of complex structures".

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.

There are generally two types of analysis that are used in industry: 2-D modeling, and 3-D modeling. While 2-D modeling conserves simplicity and allows the analysis to be run on a relatively normal computer, it tends to yield less accurate results. 3-D modeling, however, produces more accurate results while sacrificing the ability to run on all but the fastest computers effectively. Within each of these modeling schemes, the programmer can insert numerous algorithms (functions) which may make the system behave linearly or non-linearly. Linear systems are far less complex and generally do not take into account plastic deformation. Non-linear systems do account for plastic deformation, and many also are capable of testing a material all the way to fracture.

FEA uses a complex system of points called nodes which make a grid called a mesh. This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. Regions which will receive large amounts of stress usually have a higher node density than those which experience little or no stress. Points of interest may consist of: fracture point of previously tested material, fillets, corners, complex detail, and high stress areas. The mesh acts like a spider web in that from each node, there extends a mesh element to each of the adjacent nodes. This web of vectors is what carries the material properties to the object, creating many elements.

A wide range of objective functions (variables within the system) are available for minimization or maximization:

- Mass, volume, temperature
- Strain energy, stress strain
- Force, displacement, velocity, acceleration
- Synthetic (User defined)

There are multiple loading conditions which may be applied to a system. Some examples are shown:

- Point, pressure, thermal, gravity, and centrifugal static loads
- Thermal loads from solution of heat transfer analysis
- Enforced displacements
- Heat flux and convection
- Point, pressure and gravity dynamic loads

Each FEA program may come with an element library, or one is constructed over time. Some sample elements are:

- Rod elements
- Beam elements
- Plate/Shell/Composite elements
- Shear panel
- Solid elements
- Spring elements
- Mass elements
- Rigid elements
- Viscous damping elements

7.1 Types of Engineering Analysis

Structural analysis consists of linear and non-linear models. Linear models use simple parameters and assume that the material is not plastically deformed. Non-linear models consist of stressing the material past its elastic capabilities. The stresses in the material then vary with the amount of deformation as in.

Vibrational analysis is used to test a material against random vibrations, shock, and impact. Each of these incidences may act on the natural vibrational frequency of the material which, in turn, may cause resonance and subsequent failure.

Fatigue analysis helps designers to predict the life of a material or structure by showing the effects of cyclic loading on the specimen. Such analysis can show the areas where crack propagation is most likely to occur. Failure due to fatigue may also show the damage tolerance of the material.

Heat Transfer analysis models the conductivity or thermal fluid dynamics of the material or structure. This may consist of a steady-state or transient transfer. Steady-state transfer refers to constant thermo properties in the material that yield linear heat diffusion.

7.2 Results of Finite Element Analysis

FEA has become a solution to the task of predicting failure due to unknown stresses by showing problem areas in a material and allowing designers to see all of the theoretical stresses within. This method of product design and testing is far superior to the manufacturing costs which would accrue if each sample was actually built and tested.
In practice, a finite element analysis usually consists of three principal steps:

1. **Preprocessing**: The user constructs a model of the part to be analyzed in which the geometry is divided into a number of discrete sub regions, or elements," connected at discrete points called nodes." Certain of these nodes will have fixed displacements, and others will have prescribed loads. These models can be extremely time consuming to prepare, and commercial codes vie with one another to have the most user-friendly graphical "preprocessor" to assist in this rather tedious chore. Some of these preprocessors can overlay a mesh on a preexisting CAD file, so that finite element analysis can be done conveniently as part of the computerized drafting-and-design process.
2. **Analysis**: The dataset prepared by the preprocessor is used as input to the finite element code itself, which constructs and solves a system of linear or nonlinear algebraic equations

   Kijuj = fi

   where u and f are the displacements and externally applied forces at the nodal points. The formation of the K matrix is dependent on the type of problem being attacked, and this module will outline the approach for truss and linear elastic stress analyses. Commercial codes may have very large element libraries, with elements appropriate to a wide range of problem types. One of FEA's principal advantages is that many problem types can be addressed with the same code, merely by specifying the appropriate element types from the library.

3. **Postprocessing**: In the earlier days of finite element analysis, the user would pore through reams of numbers generated by the code, listing displacements and stresses at discrete positions within the model. It is easy to miss important trends and hot spots this way, and modern codes use graphical displays to assist in visualizing the results. A typical postprocessor display overlays colored contours representing stress levels on the model, showing a full field picture similar to that of photo elastic or moiré experimental results.

8. INTRODUCTION TO ANSYS

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated, or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyze by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations.

ANSYS is the standard FEA teaching tool within the Mechanical Engineering Department at many colleges. ANSYS is also used in Civil and Electrical Engineering, as well as the Physics and Chemistry departments.

ANSYS provides a cost-effective way to explore the performance of products or processes in a virtual environment. This type of product development is termed virtual prototyping.

With virtual prototyping techniques, users can iterate various scenarios to optimize the product long before the manufacturing is started. This enables a reduction in the level of risk, and in the cost of ineffective designs. The multifaceted nature of ANSYS also provides a means to ensure that users are able to see the effect of a design on the whole behavior of the product, be it electromagnetic, thermal, mechanical etc.

8.1 Generic Steps to Solving any Problem in ANSYS

Like solving any problem analytically, you need to define (1) your solution domain, (2) the physical model, (3) boundary conditions and (4) the physical properties. You then solve the problem and present the results. In numerical methods, the main difference is an extra step called mesh generation. This is the step that divides the complex model into small elements that become solvable in an otherwise too complex situation. Below describes the processes in terminology slightly more attune to the software.

8.1.1.Build Geometry

Construct a two or three dimensional representation of the object to be modeled and tested using the work plane coordinate system within ANSYS.

8.1.2 Define Material Properties

Now that the part exists, define a library of the necessary materials that compose the object (or project) being modeled. This includes thermal and mechanical properties.

8.1.3Generate Mesh

At this point ANSYS understands the makeup of the part. Now define how the modeled system should be broken down into finite pieces.

8.1.4 Apply Loads

Once the system is fully designed, the last task is to burden the system with constraints, such as physical loadings or boundary conditions.

8.1.5 Obtain Solution

This is actually a step, because ANSYS needs to understand within what state (steady state, transient… etc.) the problem must be solved.

8.1.6 Present the Results

After the solution has been obtained, there are many ways to present ANSYS’ results, choose from many options such as tables, graphs, and contour plots.

8.2 Specific Capabilities of ANSYS

8.2.1 Structural

Structural analysis is probably the most common application of the finite element method as it implies bridges and buildings, naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools.

- **Static Analysis -** Used to determine displacements, stresses, etc. under static loading conditions. ANSYS can compute both linear and nonlinear static analyses. Nonlinearities can include plasticity, stress stiffening, large deflection, large strain, hyper elasticity, contact surfaces, and creep.

- **Transient Dynamic Analysis -** Used to determine the response of a structure to arbitrarily time-varying loads. All nonlinearities mentioned under Static Analysis above are allowed.

- **Buckling Analysis -** Used to calculate the buckling loads and determine the buckling mode shape. Both linear (eigenvalue) buckling and nonlinear buckling analyses are possible.

In addition to the above analysis types, several special-purpose features are available such as **Fracture mechanics**, **Composite material analysis**, **Fatigue**, and both **p-Method and Beam analyses.**

Modal Analysis - A modal analysis is typically used to determine the vibration characteristics (natural frequencies and mode shapes) of a structure or a machine component while it is being designed. It can also serve as a starting point for another, more detailed, dynamic analysis, such as a harmonic response or full transient dynamic analysis.

Modal analyses, while being one of the most basic dynamic analysis types available in ANSYS, can also be more computationally time consuming than a typical static analysis. A reduced solver, utilizing automatically or manually selected master degrees of freedom is used to drastically reduce the problem size and solution time.

Harmonic Analysis - Used extensively by companies who produce rotating machinery, ANSYS Harmonic analysis is used to predict the sustained dynamic behavior of structures to consistent cyclic loading. Examples of rotating machines which produced or are subjected to harmonic loading are:

- Turbines
    - Gas Turbines for Aircraft and Power Generation
    - Steam Turbines
    - Wind Turbine
    - Water Turbines
    - Turbopumps
- Internal Combustion engines
- Electric motors and generators
- Gas and fluid pumps
- Disc drives

A harmonic analysis can be used to verify whether or not a machine design will successfully overcome resonance, fatigue, and other harmful effects of forced vibrations.

8.2.2 Thermal

ANSYS is capable of both steady state and transient analysis of any solid with thermal boundary conditions.

Steady-state thermal analyses calculate the effects of steady thermal loads on a system or component. Users often perform a steady-state analysis before doing a transient thermal analysis, to help establish initial conditions. A steady-state analysis also can be the last step of a transient thermal analysis; performed after all transient effects have diminished. ANSYS can be used to determine temperatures, thermal gradients, heat flow rates, and heat fluxes in an object that are caused by thermal loads that do not vary over time. Such loads include the following:

- Convection

- Radiation

- Heat flow rates

- Heat fluxes (heat flow per unit area)

- Heat generation rates (heat flow per unit volume)

- Constant temperature boundaries

A steady-state thermal analysis may be either linear, with constant material properties; or nonlinear, with material properties that depend on temperature. The thermal properties of most material vary with temperature. This temperature dependency being appreciable, the analysis becomes nonlinear. Radiation boundary conditions also make the analysis nonlinear. Transient calculations are time dependent and ANSYS can both solve distributions as well as create video for time incremental displays of models.

8.2.3 Fluid Flow

The ANSYS/FLOTRAN CFD (Computational Fluid Dynamics) offers comprehensive tools for analyzing two-dimensional and three-dimensional fluid flow fields. ANSYS is capable of modeling a vast range of analysis types such as: airfoils for pressure analysis of airplane wings (lift and drag), flow in supersonic nozzles, and complex, three-dimensional flow patterns in a pipe bend. In addition, ANSYS/FLOTRAN could be used to perform tasks including:

- Calculating the gas pressure and temperature distributions in an engine exhaust manifold
- Studying the thermal stratification and breakup in piping systems
- Using flow mixing studies to evaluate potential for thermal shock
- Doing natural convection analyses to evaluate the thermal performance of chips in electronic enclosures
- Conducting heat exchanger studies involving different fluids separated by solid regions.

8.2.4 Coupled Fields

A *coupled-field analysis* is an analysis that takes into account the interaction (coupling) between two or more disciplines (fields) of engineering. A piezoelectric analysis, for example, handles the interaction between the structural and electric fields: it solves for the voltage distribution due to applied displacements, or vice versa. Other examples of coupled-field analysis are thermal-stress analysis, thermal-electric analysis, and fluid-structure analysis.

Some of the applications in which coupled-field analysis may be required are pressure vessels (thermal-stress analysis), fluid flow constrictions (fluid-structure analysis), induction heating (magnetic-thermal analysis), ultrasonic transducers (piezoelectric analysis), magnetic forming (magneto-structural analysis), and micro-electro mechanical systems (MEMS).

8.2.5 THERMAL ANALYSIS

Thermal analysis is a branch of materials science where the properties of materials are studied as they change with temperature. Several methods are commonly used - these are distinguished from one another by the property which is measured.

Thermal Analysis is also often used as a term for the study of Heat transfer through structures. Many of the basic engineering data for modelling such systems comes from measurements of heat capacity and Thermal conductivity.

9. THERMAL ANALYSIS OF FIN BODY

ORIGINAL MODEL

MODEL IMPORTED FROM PRO/ENGINEER

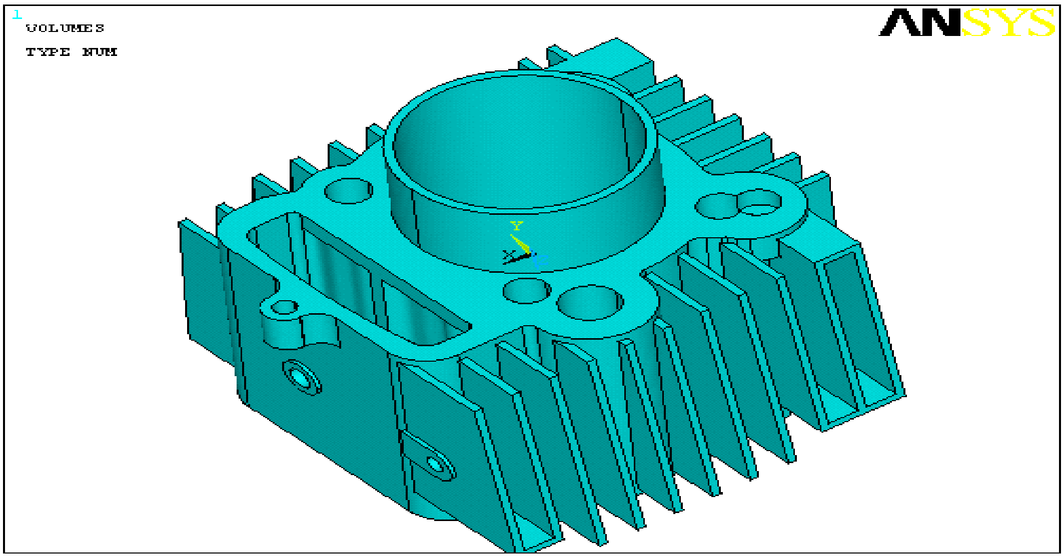

Figure 9.1 : basic model imported from pro/E

MESHED MODEL

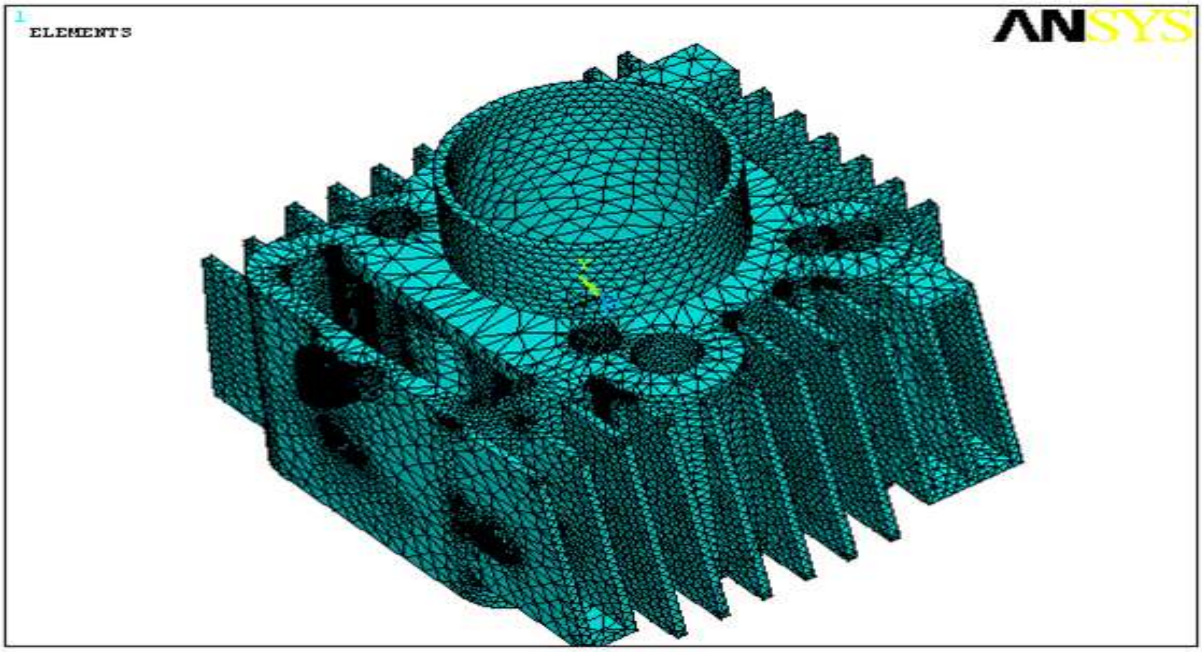

Figure 9.2 : Meshed model

10. RESULTS

CAST IRON

MATERIAL PROPERTIES:

Thermal Conductivity – 0.05 w/mmk

Specific Heat –500 J/kg °C

Density –7.1 g/cc

LOADS:

Temperature -550 K

Film Coefficient – 39.9 w/m^2K

Bulk Temperature – 283 K

Solution – Solve – Current LS

NODAL TEMPERATURE:

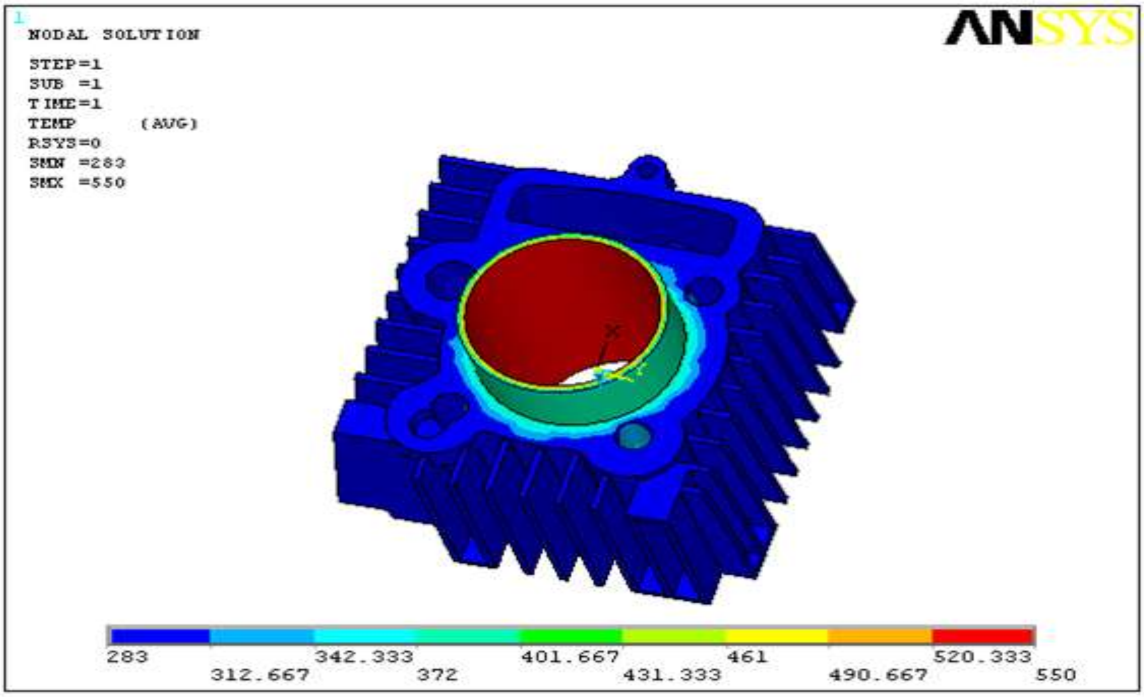

Figure 10.1: nodal temperature of CI

THERMAL GRADIENT SUM

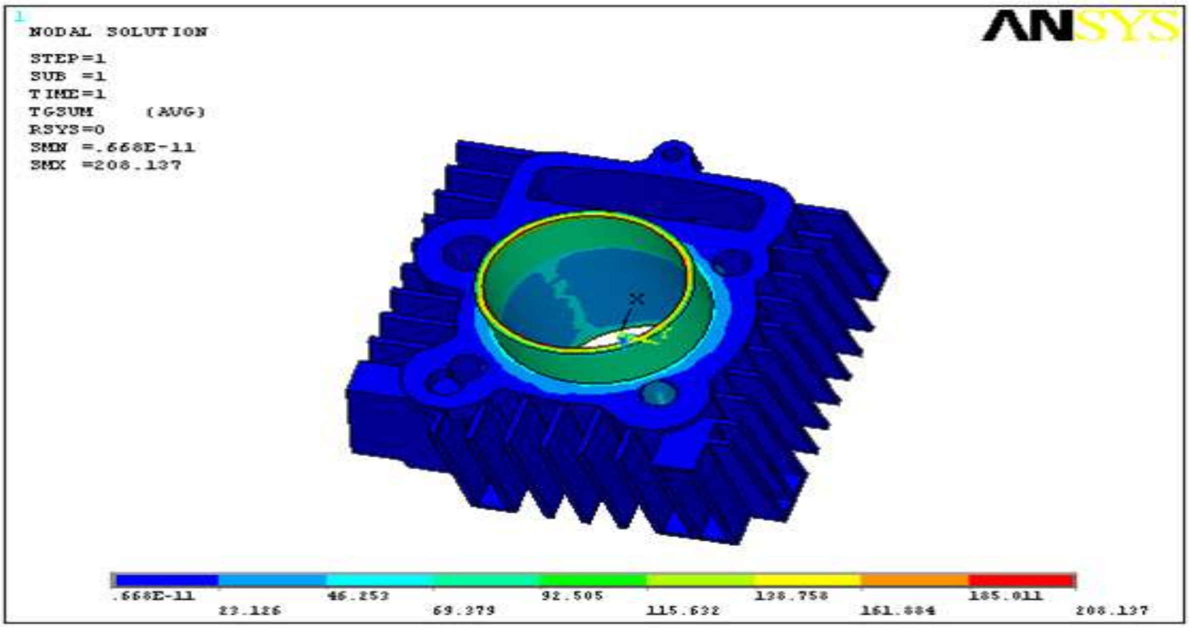

Figure 10.2 : Thermal gradient sum of CI

THERMAL FLUX SUM

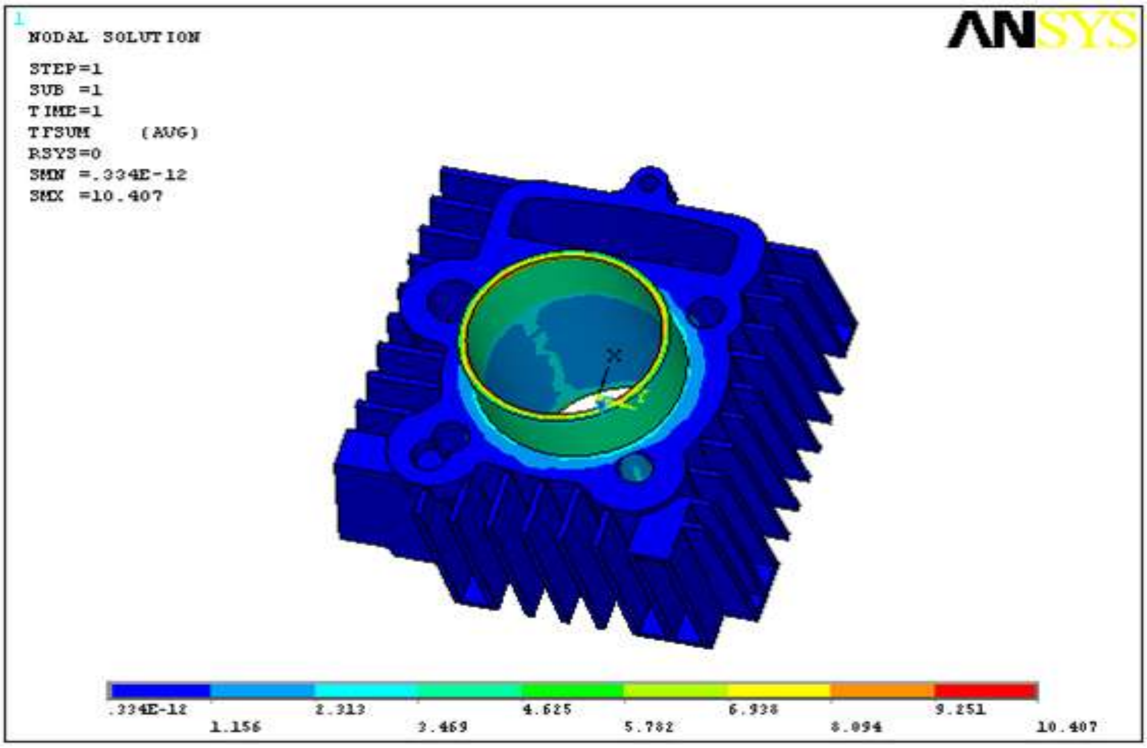

Figure 10.3 : Thermal flux sum of CI

ALUMINUM ALLOY 6082

MATERIAL PROPERTIES:

Thermal Conductivity –180 w/mk

Specific Heat – 0.963 J/g °C

Density – 2.7 g/cc

LOADS:

Temperature -550 K

Film Coefficient –39.9 w/m^2 K

Bulk Temperature – 283 K

Solution– Solve - Current LS file – Ok

NODAL TEMPERATURE:

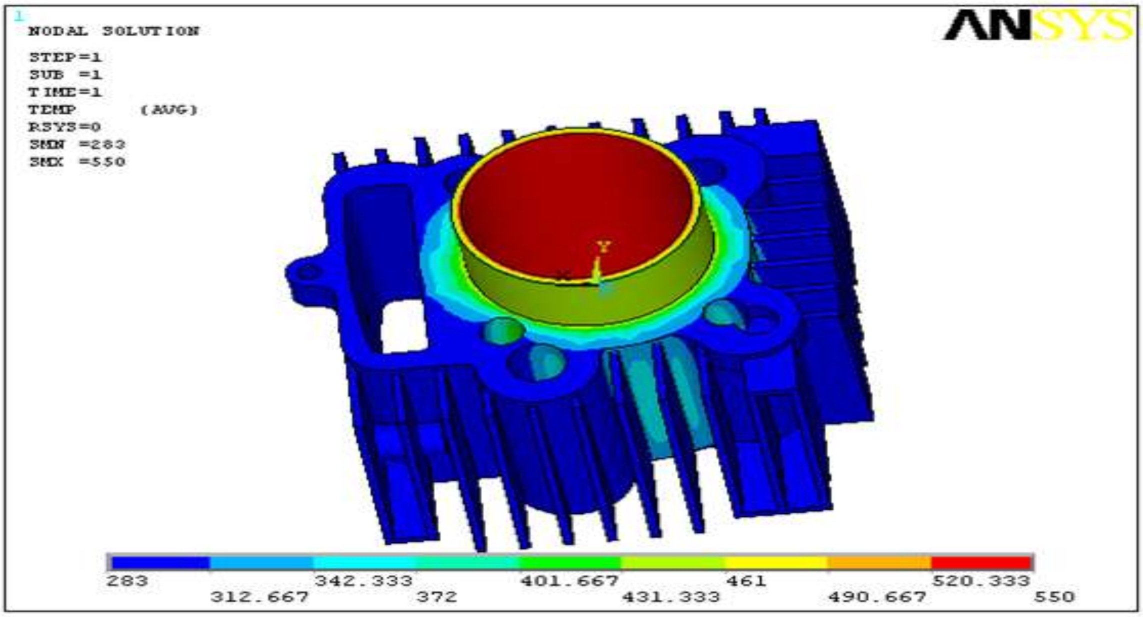

Figure 10.4 : Nodal temperature of Al 6082

THERMAL GRADIENT SUM

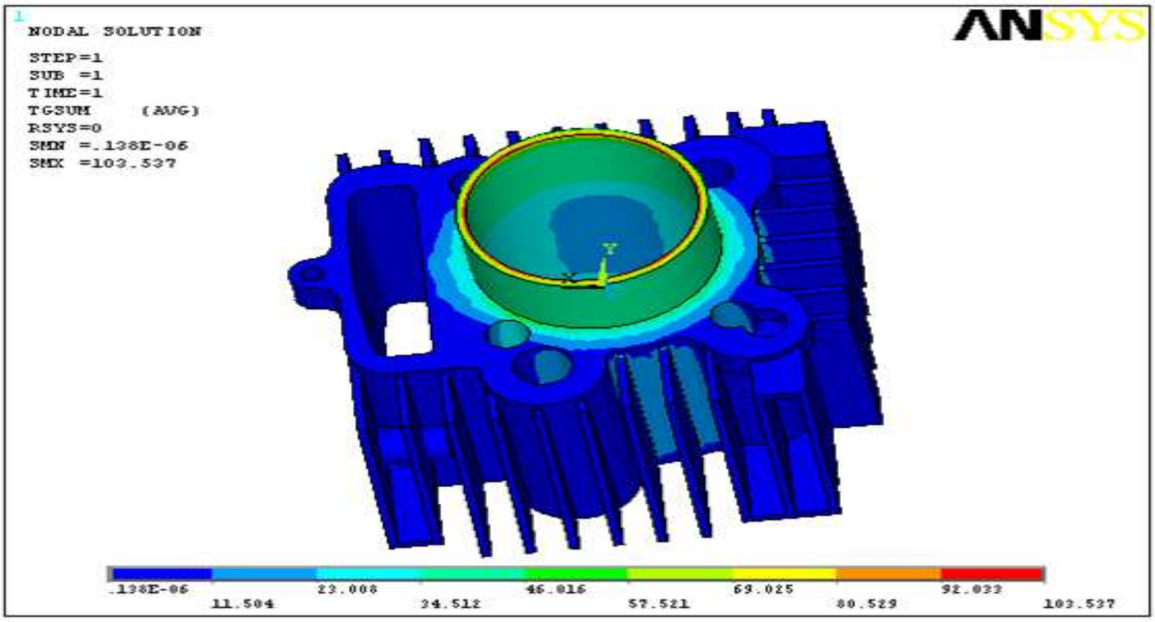

Figure 10.5 : Thermal gradient sum of Al 6082

THERMAL FLUX SUM

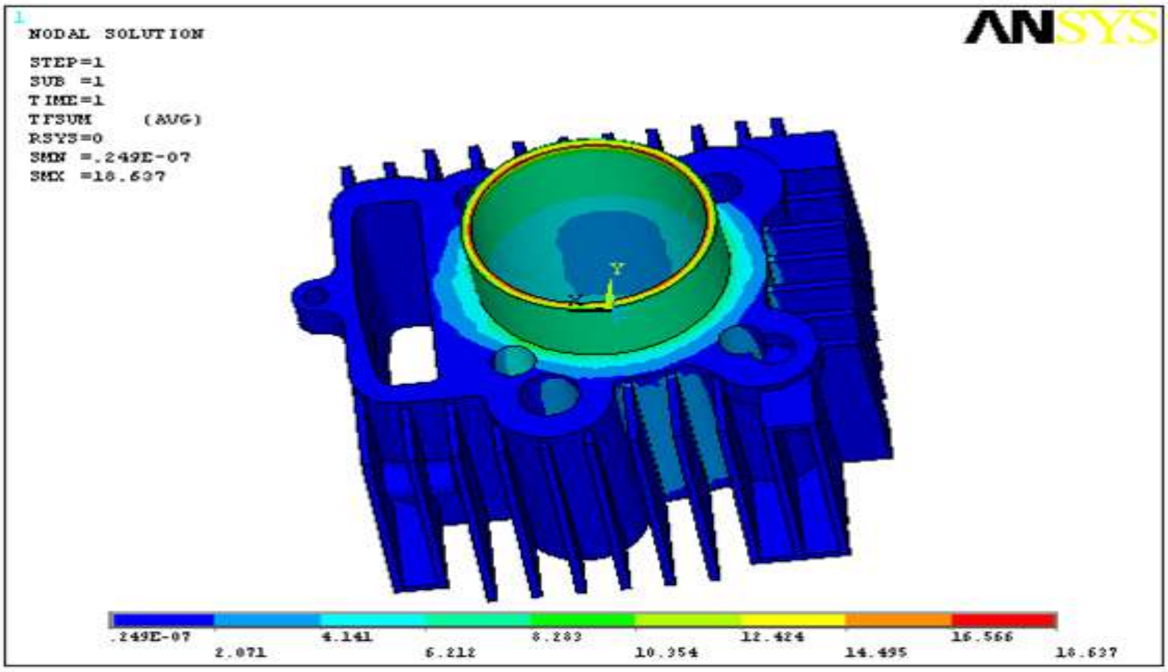

Figure 10.6 : Thermal flux sum of Al 6082

COPPER

MATERIAL PROPERTIES:

Thermal Conductivity –63 w/mk

Specific Heat – 14 ℃

Density – 7.5 g/m^3

LOADS:

Temperature -550 K

Film Coefficient –39.9 w/m^{2}K

Bulk Temperature – 283 K

Solution – Solve - Current LS file – Ok

NODAL TEMPERATURE:

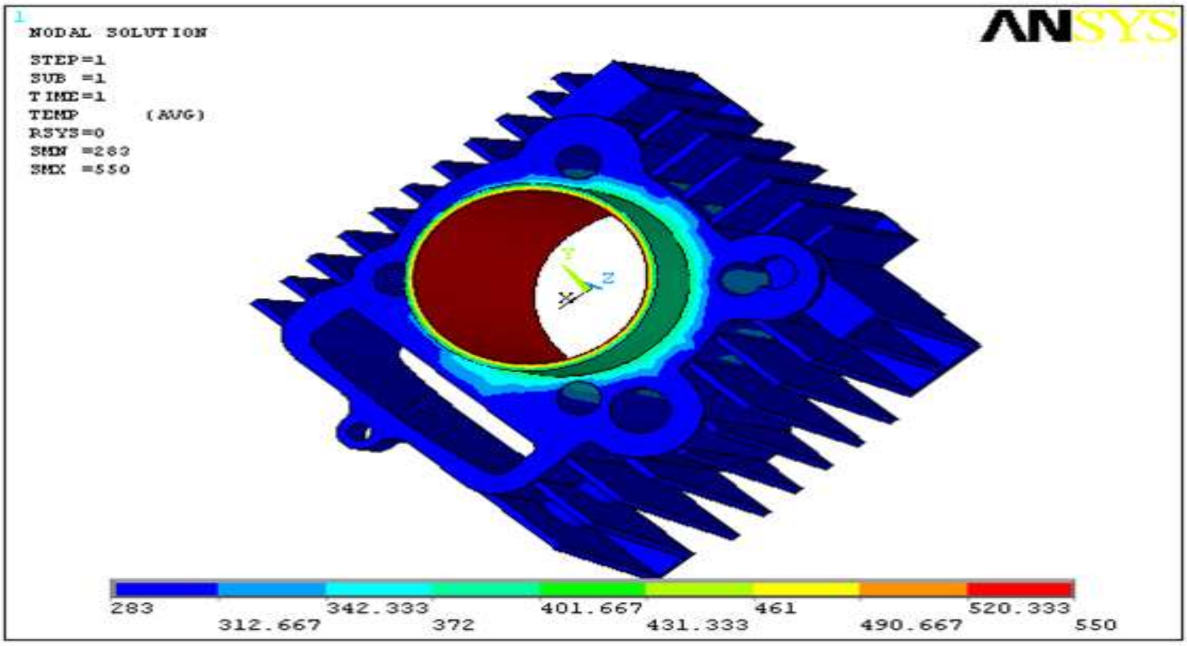

Figure 10.7 : Nodal temperature of Cu

THERMAL GRADIENT SUM

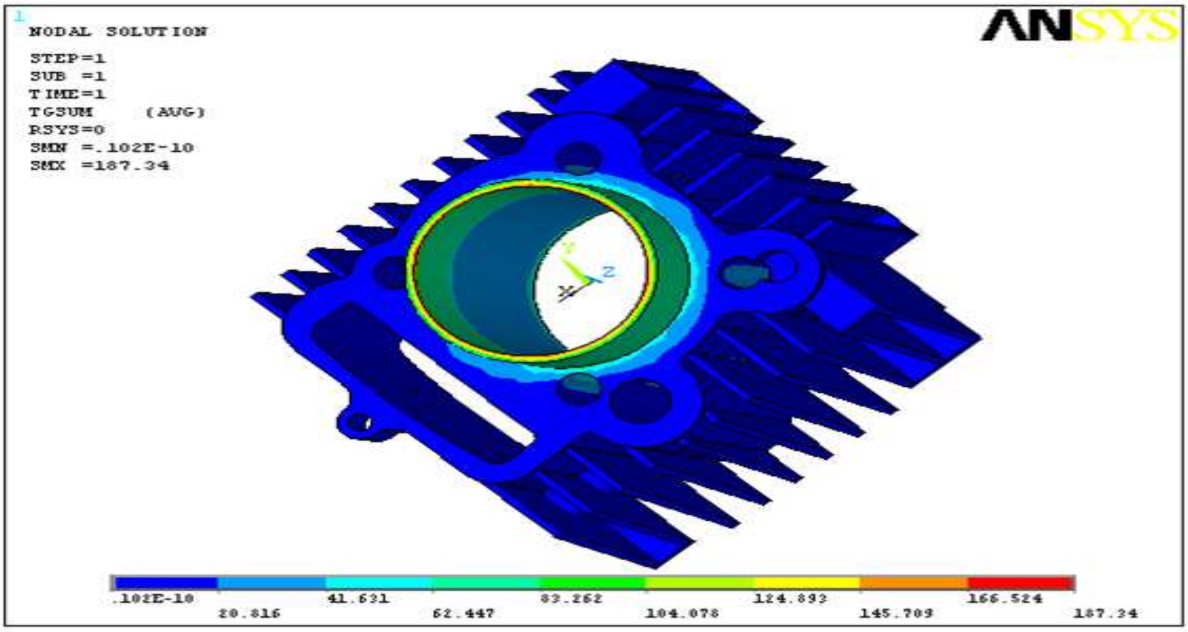

Figure 10.8 : Thermal gradient sum of Cu

THERMAL FLUX SUM

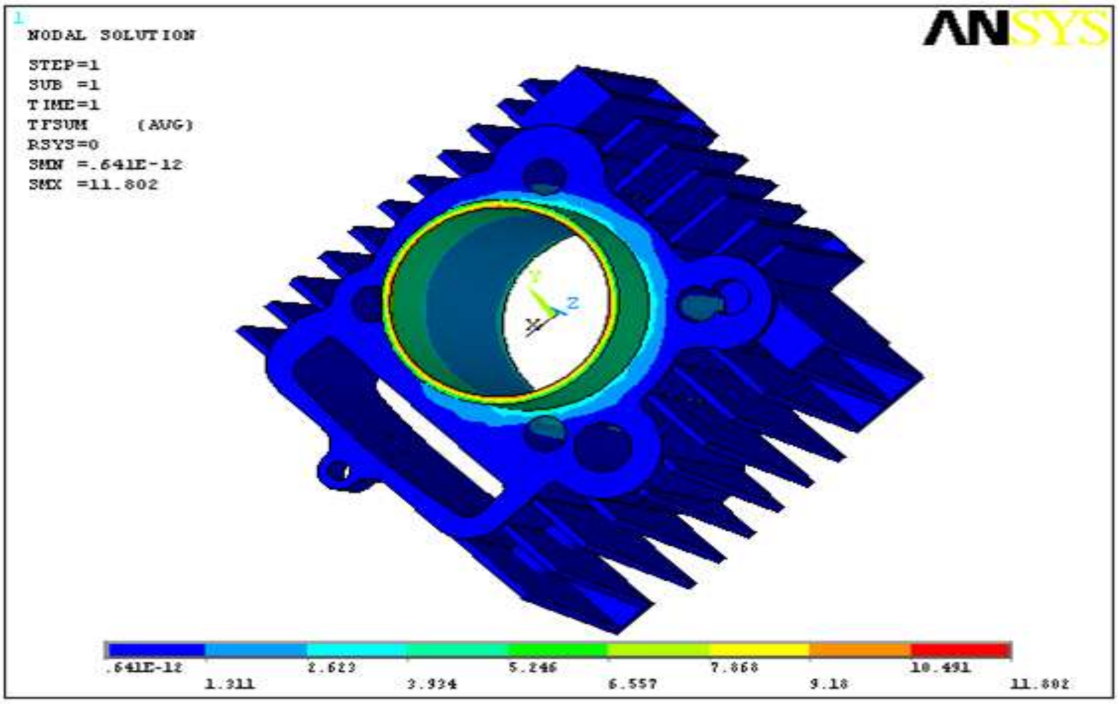

Figure 10.9 : Thermal flux sum of Cu

11. MODIFIED MODEL RESULTS

CAST IRON

MODEL IMPORTED FROM PRO/ENGINEER

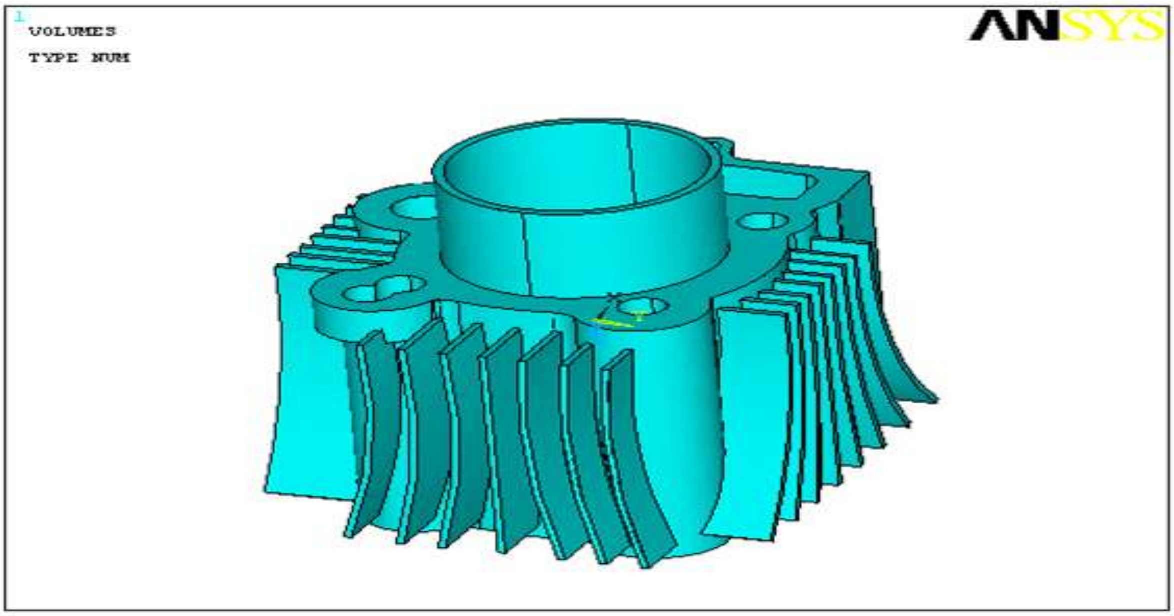

Figure 11.1 : modified model imported from pro/E

MESHED MODEL

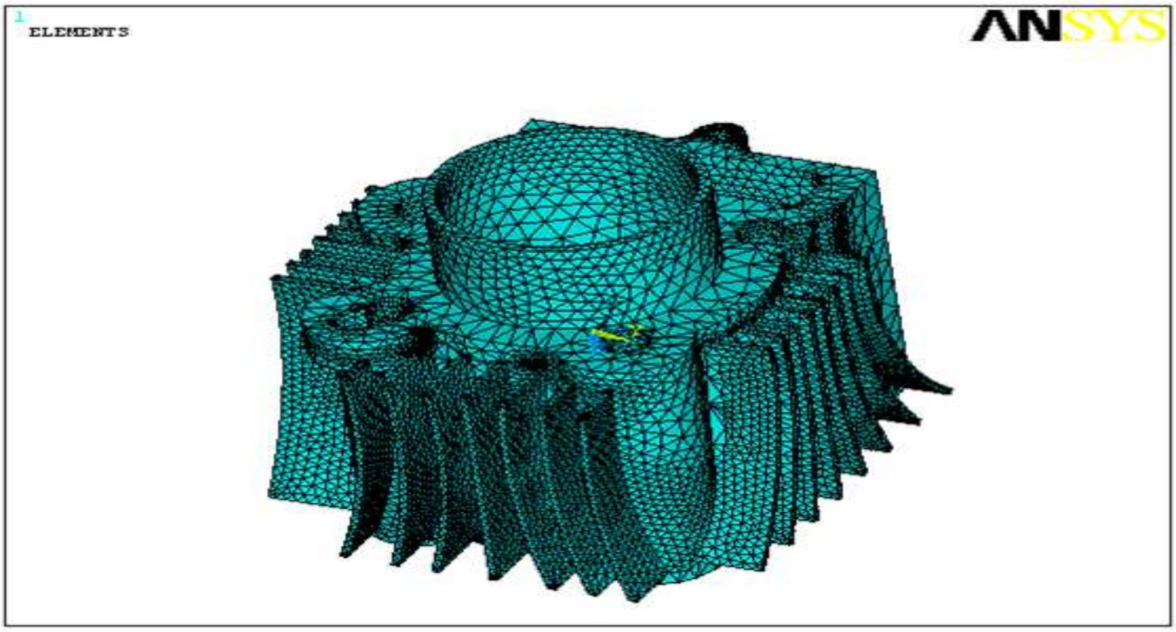

Figure 11.2 : modified meshed model

CAST IRON

MATERIAL PROPERTIES:

Thermal Conductivity – 0.05 w/mmk

Specific Heat –500 J/kg ºC

Density –7.1 g/cc

LOADS:

Temperature -550 K

Film Coefficient – 39.9 w/m^2K

Bulk Temperature – 283 K

Solution – Solve – Current LS

NODAL TEMPERATURE

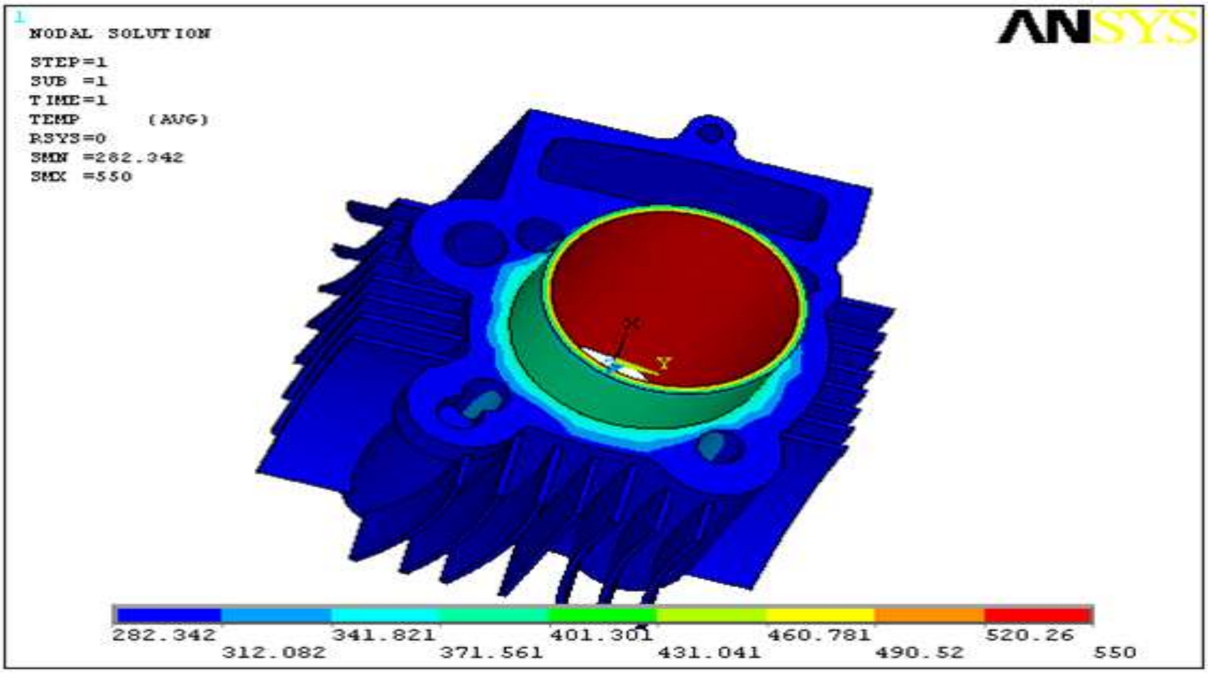

Figure 11.3 : modified nodal temp of CI

THERMAL GRADIANT VECTOR SUM

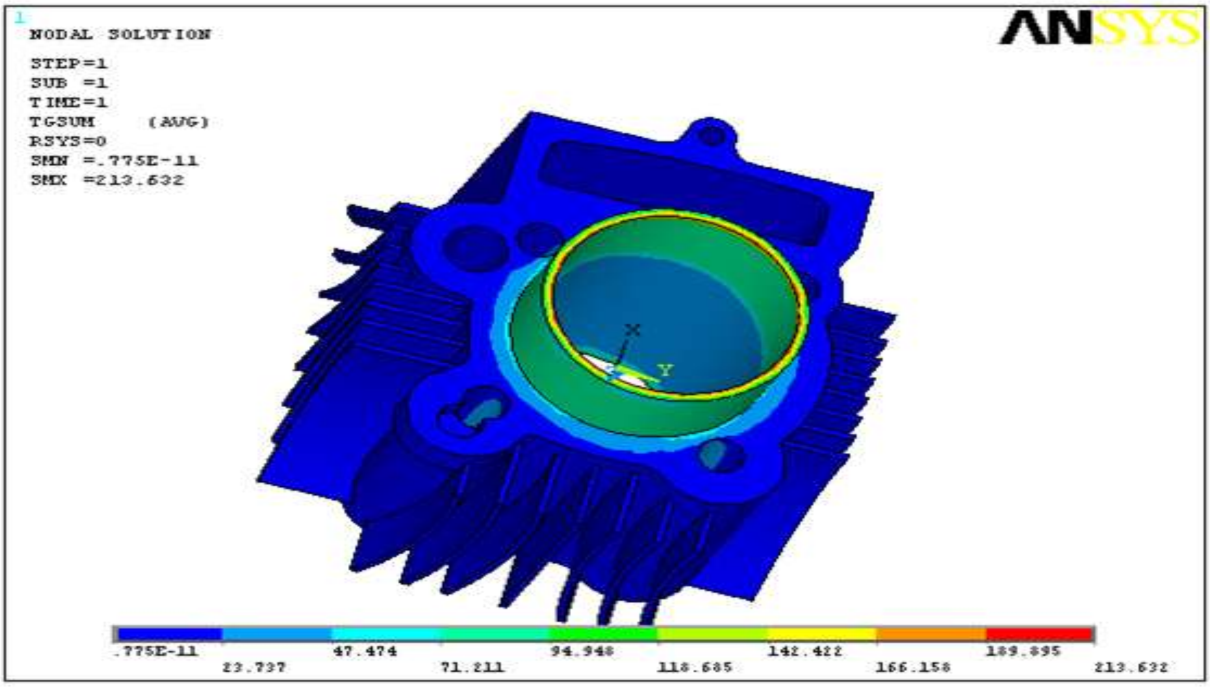

Figure 11.4 : modified thermal gradient vector sum of CI

THERMAL FLUX

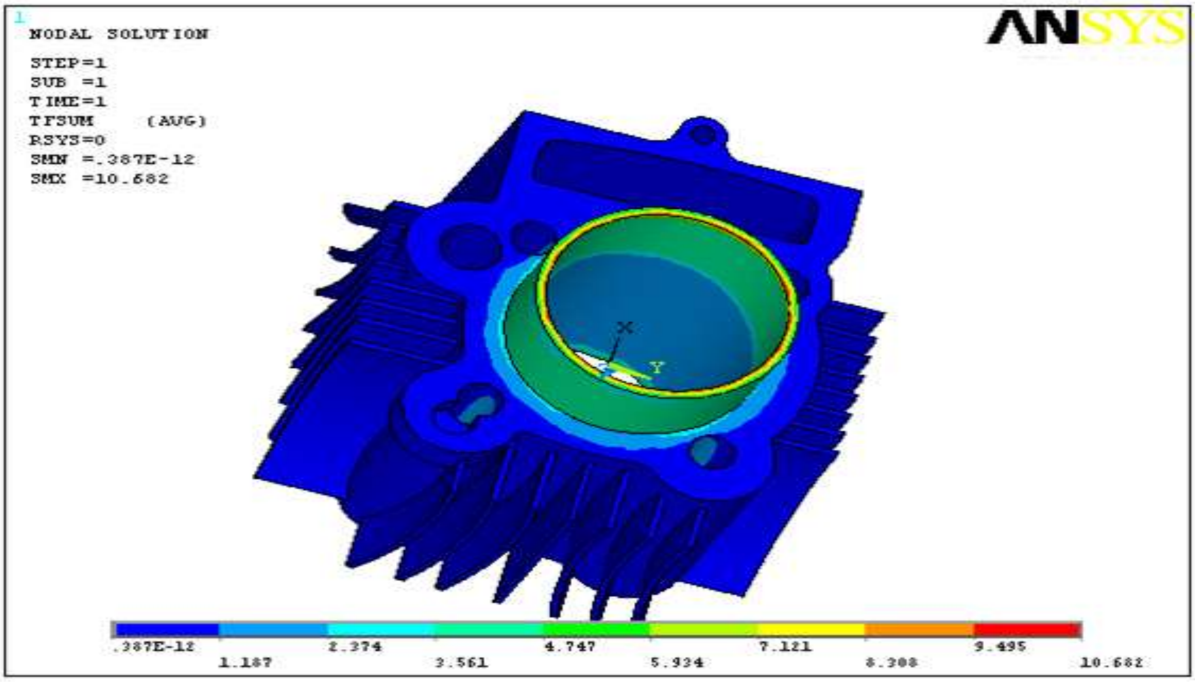

Figure 11.5 : modified thermal flux of CI

ALUMINUM ALLOY 6082

MATERIAL PROPERTIES:

Thermal Conductivity –180 w/mk

Specific Heat – 0.963 J/g °C

Density – 2.7 g/cc

LOADS:

Temperature -550 K

Film Coefficient – 39.9 W/m^2K

Bulk Temperature – 283 K

Solution– Solve - Current LS file – Ok

NODAL TEMPERATURE

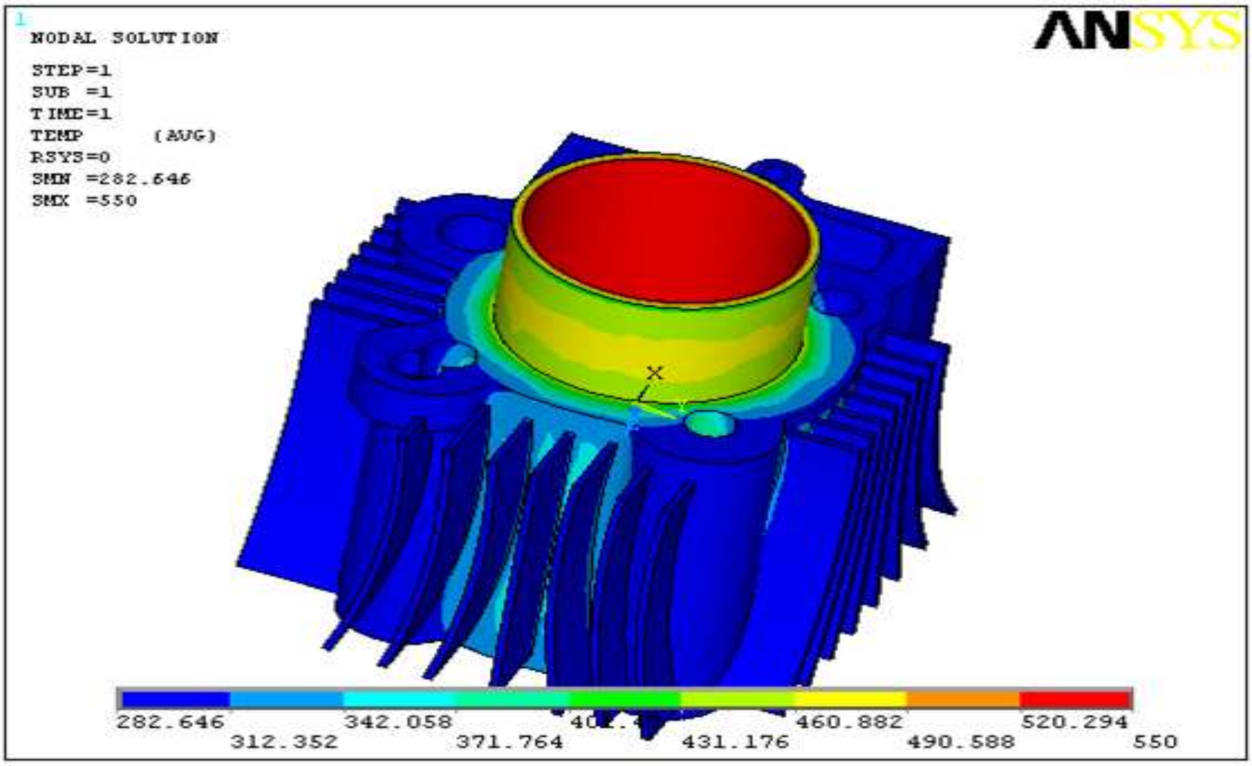

Figure 11.6 : modified nodal temperature of Al 6082

THERMAL GRADIENT SUM

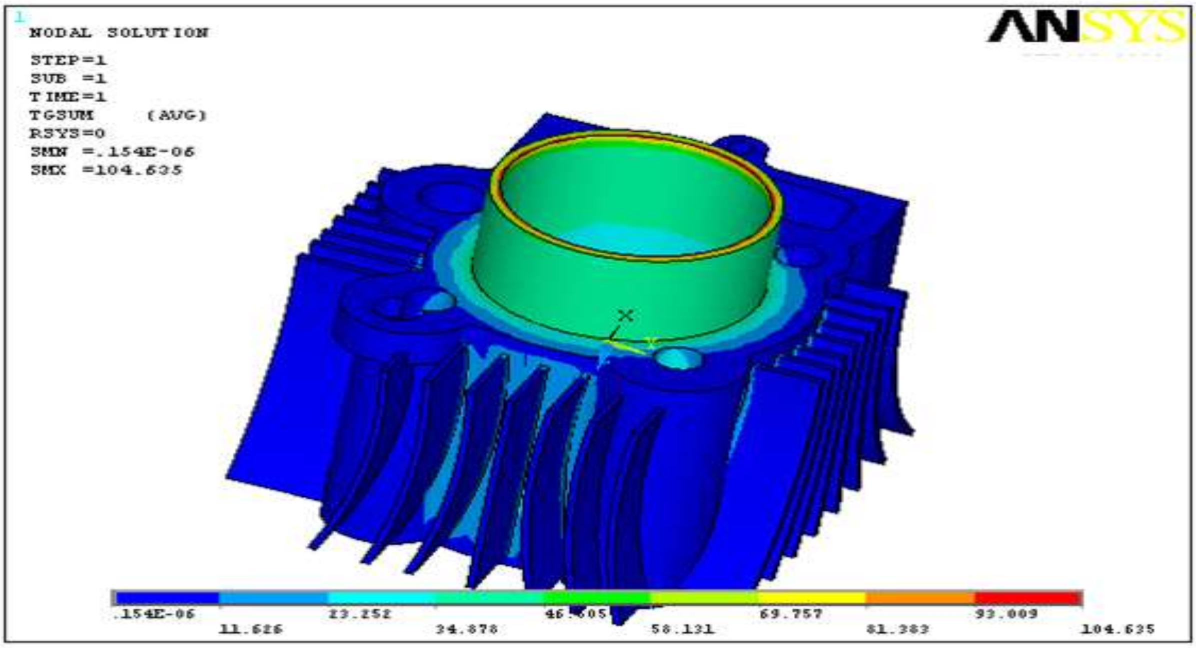

Figure 11.7 : modified thermal gradient sum of Al 6082

THERMAL FLUX SUM

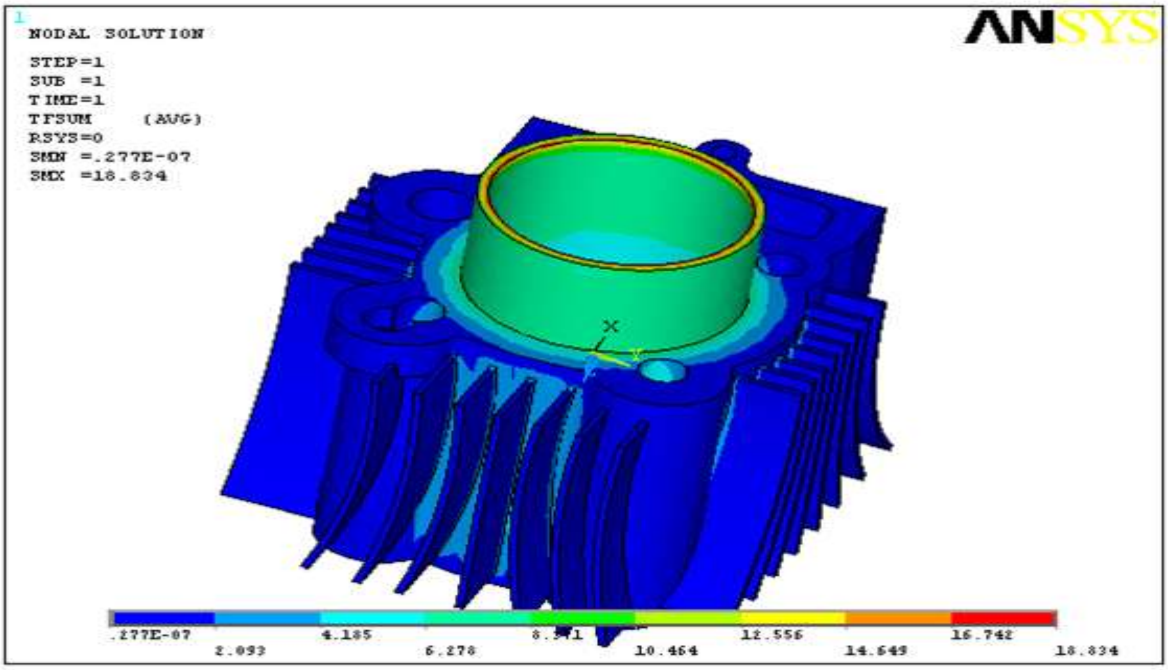

Figure 11.8 : modified thermal flux sum of Al 6082

COPPER

MATERIAL PROPERTIES:

Thermal Conductivity –63 w/mk

Specific Heat – 14 ºC

Density – 7.5 g/m

LOADS:

Temperature -550 K

Film Coefficient –0.0399 w/mmK

Bulk Temperature – 283 K

Solution – Solve - Current LS file – Ok

NODAL TEMPERATURE

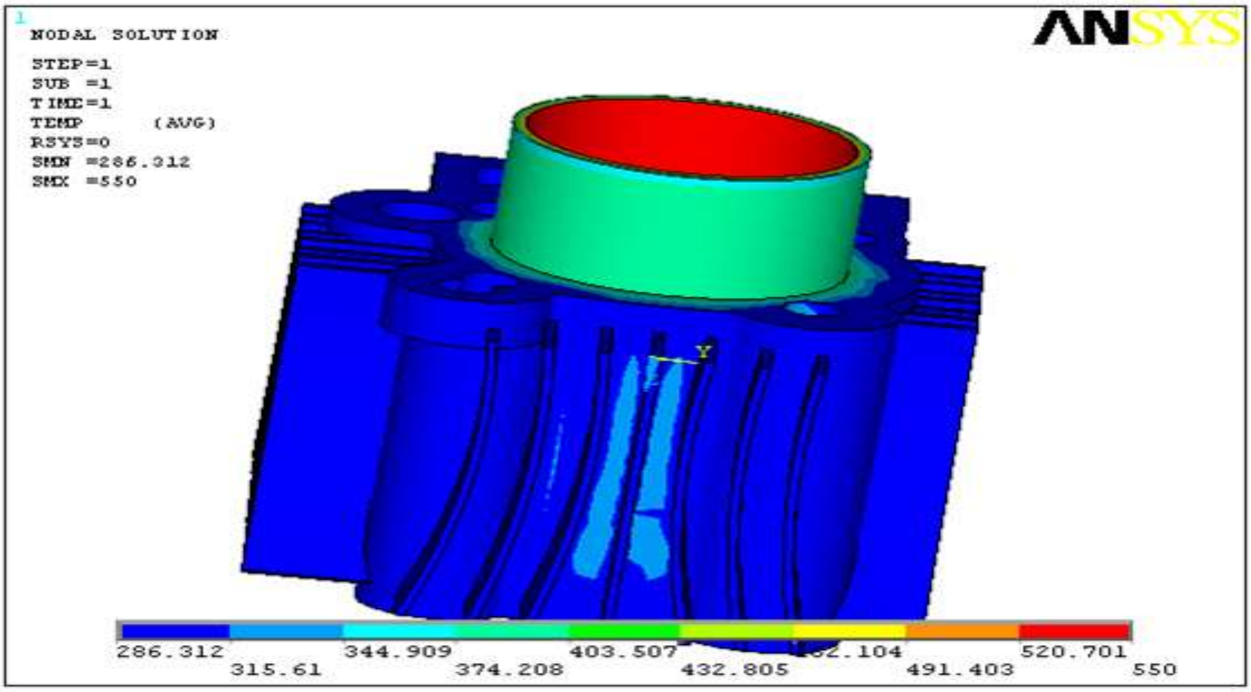

Figure 11.9 : modified nodal temperature of Cu

THERMAL GRADIENT SUM

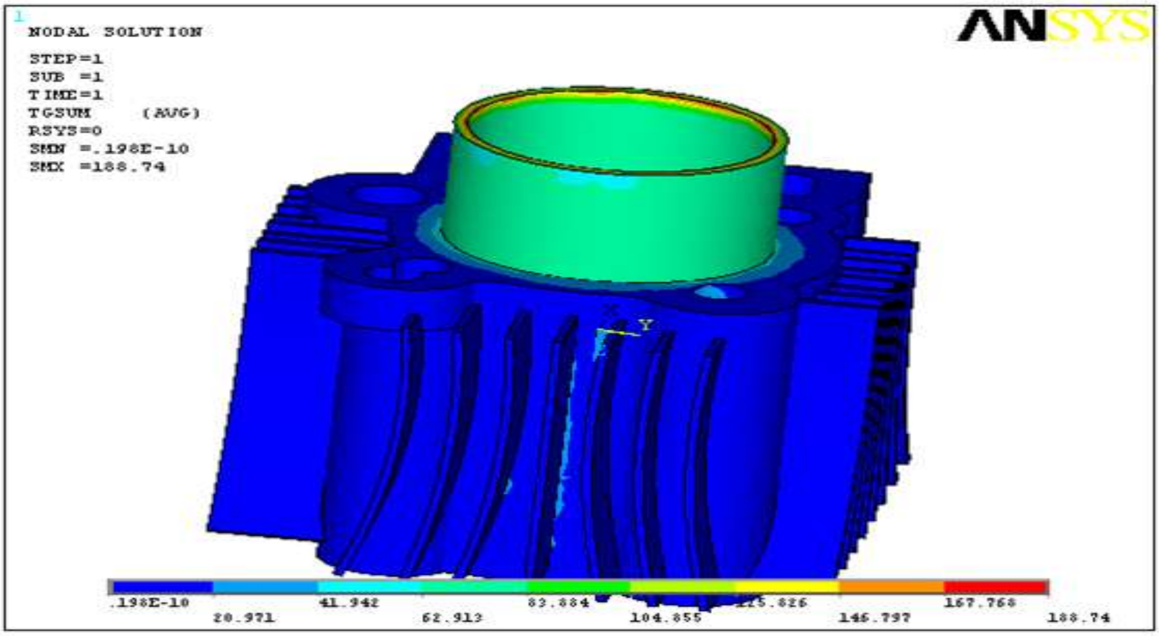

Figure 11.10 : modified thermal gradient sum of Cu

THERMAL FLUX SUM

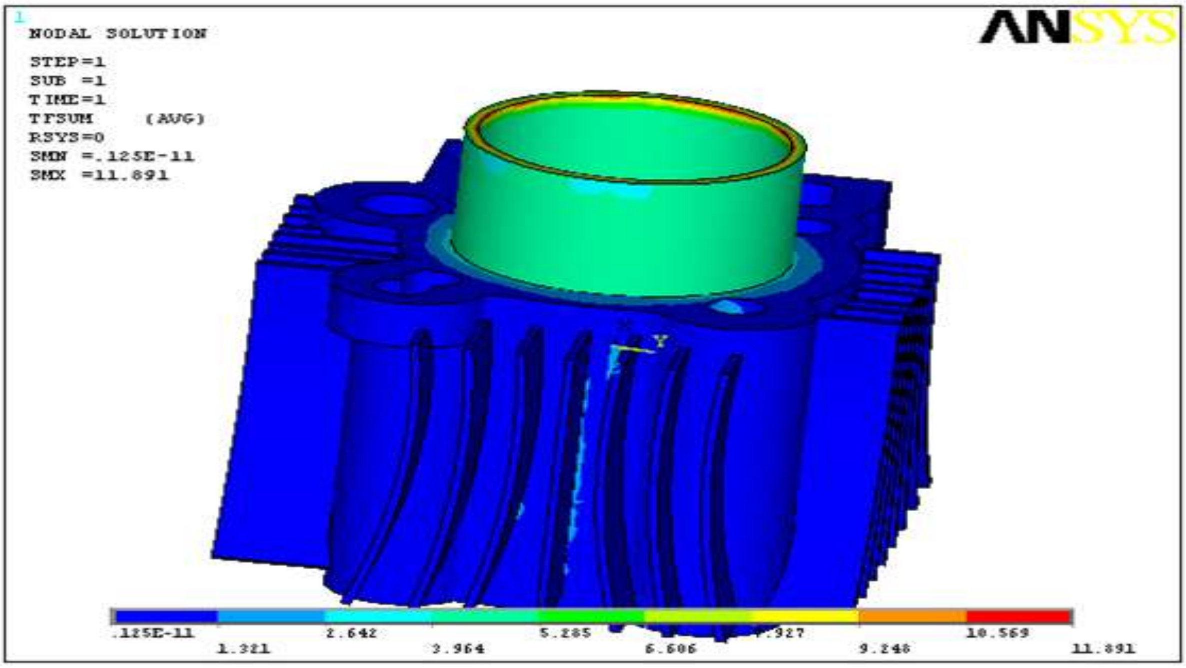

Figure 11.11 : modified thermal flux sum of Cu

12. THEORETICAL CALCULATIONS

12.1 HEAT TRANSFER THROUGH FINS

Fin Thickness - 2mm and Fin Distance - 7.5mm

Length of fin (L)=65.3mm=0.06538m

Width of fin (W)=53.71mm=0.05371m

Thickness δ=2mm

2δ=4mm=0.004m

Perimeter of fin (P) =2W+4δ

=2×53.71+4×2=115.42mm=0.11542m

Cross sectional area of fin A_c=L×W=65.38×53.71=3511.5598mm^2

=0.0035115m^2

K=conductivity of fin material =50w/mk

=0.05w/mmk

h=heat transfer coefficient =39.9w/m^{2}k=0.0399 w/mm^{2}k

$$m=\sqrt{\frac{hp}{kA_c}}==\sqrt{\frac{0.11542\times39.9}{50\times0.003511}}=5.12184\ 1/m^2$$

Θ=T-T_a=237K

Where T=temperature of cylinder head=550K

T_a=atmospheric temperature=313K

x=distance measured from base of fin=70.38mm=0.07038m

$$\Theta=\Theta_o\times\left(\frac{h\cos hml+km\sin hml}{mk\cos hml+h\sin hml}\right)\times\sinh mx$$

$$237=\Theta_o\times\left(\frac{39.9\times\cos(39.9\times5.12184\times0.06538)+50\times5.12184\sin(39.9\times5.12184\times0.0653)}{5.1218\times50\times\cos(39.9\times5.1218\times0.0653)+39.9\times\sin(39.9\times5.1218\times0.06538)}\right)\times\sin(39.9\times5.12184\times0.0703)$$

Θ_o=246.9800K

HEAT LOST BY FIN

$$Q=KA_cm\Theta_o\left(\frac{h\cos hml+km\sin hml}{mk\cos hml+h\sin hml}\right)$$

$$Q=50\times0.003511\times5.12184\times246.98\times(0.9595)=213.0755w/m$$

EFFECTIVENESS OF FIN

$$\epsilon=\frac{\text{heat lost with fin}}{\text{heat lost without fin}}$$

$$\epsilon=\frac{1}{\sqrt{B_i}}\left(\frac{\sqrt{B_i}+\tanh(\sqrt{B_i}\times l)}{1+\sqrt{B_i}+\tanh(\sqrt{B_i}\times l)}\right)$$

Where B_i=biot number

$$B_i=\frac{h\times\delta}{k}=\frac{39.9\times0.002}{50}=1.596\times10^{-3}$$

$$\epsilon=\frac{1}{\sqrt{1.596\times10^{-3}}}\left(\frac{\sqrt{1.596\times10^{-3}}+\tan 39.9(\sqrt{1.596\times10^{-3}}\times0.06538)}{1+\sqrt{1.596\times10^{-3}}+\tan 39.9(\sqrt{1.596\times10^{-3}}\times0.06538)}\right)=3.16121$$

NOTE : Effectiveness should be more than 1

12.2 THERMAL FLUX CALCULATIONS

Contact area A = 4019 mm^2

Fin area = 3109.38mm^2

Cylinder out side area =15026.4 mm^2

Over all surface area = 4427+15026.4

= 19462.4mm^2

T_i = Inside temperature = 550K

T_o = Outside temperature =313K

ΔT = 277K

d = 50.2 mm

CAST IRON

Film coefficient = U = 39.9w/m^{2}K = 0.0000399W/mm^{2}K

Heat flux

Heat flow q = UAΔT

= 0.0399×4019×237

= 38004.8697w

Heat Flux h = q/a =38004.8697/19462.4= 1.9527 w/mm^2

ALUMINUM ALLOY 6082

Film coefficient = U = 0.0399 w/ mmk

Heat flux

Heat flow $q = UA\Delta T$

=38004.8697w

Heat Flux h = q/a =38004.8697/19462.4= 1.9527 w/mm^2

COPPER

Film coefficient = U = 0.0399 w/ mmk

Heat flux

Heat flow $q = UA\Delta T$

=38004.8697w

Heat Flux h = q/a =38004.8697/19462.4= 1.9527 w/mm^2

12.3 FIN THICKNESS 1.5 MM FIN DISTANCE 9.8 MM FOR COMBUSTION SIDE AND 4.25 FOR OPP SIDE :

Length of fin (L)=61.8638mm =0.06186m

Width of fin (W)=61.4588mm=0.0614588m

Thickness δ=1.5mm

2δ=3mm=0.003m

Perimeter of fin (P) =2W+4δ

=2×61.45+4×1.5=128.9mm=0.1289m

Cross sectional area of fin A_c=L×W=61.8638×61.4588=3802.074911mm^2

=0.003802m

K=conductivity of fin material =50w/mk

=0.05w/mmk

h=heat transfer coefficient =39.9w/m^2k=0.0399 w/mm^2k

$m=\sqrt{\frac{hp}{kA_c}}==\sqrt{\frac{0.1289\times39.9}{50\times0.003802}}$ =5.20141 $1/m^2$

ϴ=T-T_a=237k

Where T=temperature of cylinder head=550k

T_a=atmospheric temperature=313k

x=distance measured from base of fin=61.4558mm=0.0614558 m

$\Theta=\Theta_o\times(\frac{h\cos hml+km\sin hml}{mk\cos hml+h\sin hml})\times\sinh mx$

$237=\Theta_o\times(\frac{39.9\times\cos(39.9\times5.20141\times0.06186)+50\times5.20141\sin(39.9\times5.20141\times0.06186)}{5.2041\times50\times\cos(39.9\times5.20141\times0.06186)+39.9\times\sin(39.9\times5.20141\times0.06186)})\times\sin(39.9\times5.20141\times0.0614558)$

Θ_o=2913.623958

Heat lost by fin

$Q=KA_cm\Theta_o(\frac{h\cos hml+km\sin hml}{mkc\,os hml+h\sin hml})$

$=50\times0.003802\times5.20141\times2913.62395\times(0.3684)=1839.2026w/m$

Effectiveness of fin

$\epsilon=\frac{\text{heat lost with fin}}{\text{heat lost without fin}}$

$\epsilon = \frac{1}{\sqrt{B_i}}\left(\frac{\sqrt{B_i}+\tanh\left(\sqrt{B_i \times l}\right)}{1+\sqrt{B_i}+\tanh\left(\sqrt{B_i \times l}\right)}\right)$

Where B_i=biot number

$B_i=\frac{h\times\delta}{k}=\frac{39.9\times0.0015}{50}=1.197\times10^{-3}$

$\epsilon=\frac{1}{\sqrt{1.197\times10-3}}\left(\frac{\sqrt{1.197\times10-3}+\tan 39.9\left(\sqrt{1.197\times10-3}\times0.06186\right)}{1+\sqrt{1.197\times10-3}+\tan 39.9\left(\sqrt{1.197\times10-3}\times0.06186\right)}\right)=1.8105$

Effectiveness should be more than 1

12.4 FIN THICKNESS 4mm

Contact area A = 2492.8847 mm

Fin area = 2382.987mm

Cylinder outside area =15092mm

Over all surface area = 19207mm

T_i Inside temperature = 550K

T_o Outside temperature =313K

ΔT = 273K

d = 50.2 mm

CAST IRON:

Film coefficient = U = 0.0399w/mmK

Heat flux

Heat flow q = UAΔT

= 0.0399×2492.8847×237

= 23573.4655w

Heat Flux h = q/a =23573.4655/19207= 1.22733w/mm^2

ALUMINUM ALLOY 6082

Film coefficient = U = 0.0399 w/ mmk

Heat flux

Heat flow q = UAΔT

= 0.0399×2492.8847×237

= 23573.4655w

Heat Flux h = q/a =23573.4655/19207= 1.22733w/mm^2

COPPER

Film coefficient = U = 0.0399 w/ mmk

Heat flux

Heat flow q = UAΔT

= 0.0399×2492.8847×237

= 23573.4655w

Heat Flux h = q/a =23573.4655/19207= 1.22733w/mm^2

13. RESULTS AND DISCUSSIONS

ORIGINAL MODEL

Table 13.1 Original model values

	CAST IRON	COPPER	ALUMINUM ALLOY 6082
WEIGHT (Kg)	2.35	2.48	0.8936
NODAL TEMPERATURE (K)	550	550	550
THERMAL GRADIENT (K/mm)	208.137	187.34	103.537
THERMAL FLUX (W/mm^2)	10.407	11.802	18.637

MODIFIED MODEL

Table 13.2 Modified model values

	CAST IRON	COPPER	ALUMINUM ALLOY 6082
WEIGHT (Kg)	2.126	2.24	0.808
NODAL TEMPERATURE (K)	550	550	550
THERMAL GRADIENT (K/mm)	213.632	188.74	104.635
THERMAL FLUX (W/mm^2)	10.682	11.891	18.834

14. CONCLUSION

In this thesis, a cylinder fin body for Passion Plus 100cc motorcycle is modeled using parametric software Pro/Engineer. The original model is changed by changing the geometry of the fin body, distance between the fins and thickness of the fins.

Present used material for fin body is Cast Iron. In this thesis, thermal analysis is done for all the three materials Cast Iron, Copper and Aluminum alloy 6082. The material for the original model is changed by taking the consideration of their densities and thermal conductivity. Density is less for Aluminum alloy 6082 compared with other two materials so weight of fin body is less using Aluminum alloy 6082. Thermal conductivity is more for copper than other two materials.

By observing the thermal analysis results, thermal flux is more for Aluminum alloy than other two materials and also by using Aluminum alloy its weight is less, so using Aluminum alloy 6082 is better.

15. FUTURE SCOPE

The shape of the cylinder fin body is modified and proven analytically that it can be used. But more experiments have to be done on that modified model to check the feasibility of the arrangement in the two wheeler. Since the shape of the fins of modified model is curved, the cost for manufacturing is also to be considered. Since to manufacture this model, if the cost is very high, it is not preferable since it may increase the cost of two wheeler.

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