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Design and Analysis of IC Engine Components

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Abstract: *Internal combustion (IC) Engine is a complex power generating machines and used widely in automotive industry. IC engine is not just a single component it is an assembly of various components. They are 1. Piston, 2. Connecting rod, 3. Crankshaft, and 4. Cylinder block. For the design of these components the Orginal dimensions are taken from the 110cc engine. After the selection of dimensions, the components are designed in the creo parametric 4.0 software. After the required design is achieved, the design is imported to the Ansys workbench 18.1 software. Then the material of the components is changed to the Aluminum alloy of AL6061 material from the existing design material of forged steel and low carbon steel. Now the design is ready to be tested in the Ansys software. For these components the thermal analysis and structural analysis are to be tested. In structural analysis the von misses stress and the total deformation of the particular component under force or pressure can be identified. And in thermal analysis the amount of heat that can be able to withstand by the component can be identified. For the piston, pressure and temperature is applied. And for connecting rod, crankshaft and cylinder block force and temperature are applied on it after performing meshing. The main objective of the project is to reduce the weight and obtain better stiffness compared to the former material used in the components.*

Keywords:IC Engine Component, Ansys, Analysis.

I. INTRODUCTION

An internal combustion engine (IC engine) is a type of heat engine that converts the chemical energy stored in fuel into mechanical energy through the process of combustion, or burning. The mechanical energy produced by the engine is typically used to power vehicles, machinery, and generators.

IC engines are classified into two categories: spark ignition (SI) engines and compression ignition (CI) engines. SI engines use a spark plug to ignite the fuel mixture, while CI engines rely on the high temperature and pressure created by compression of the air-fuel mixture to ignite the fuel.

The main components of an IC engine include the cylinder, piston, crankshaft, and valves. The engine operates on a four-stroke or two-stroke cycle, where the four-stroke cycle consists of intake, compression, power, and exhaust strokes, while the two-stroke cycle combines the intake and compression strokes and the power and exhaust strokes.

IC engines are commonly used in automobiles, motorcycles, boats, airplanes, and other applications that require internal combustion to generate mechanical energy. They are widely used because of their high efficiency, reliability, and versatility. However, they also have some drawbacks, including emissions of pollutants and noise, which has led to the development of alternative technologies such as electric and hybrid vehicles.

II. HISTORY OF IC ENGINE

The history of the internal combustion engine (IC engine) is a long and fascinating one, spanning over 150 years of innovation and development. From the early experiments of inventors like Etienne Lenoir and Nikolaus Otto, to the modern engines powering our cars and airplanes, the IC engine has undergone numerous changes and improvements to become the reliable and efficient power source we know today.

The first IC engine was built by Etienne Lenoir in 1859. This engine used a simple two-stroke design and burned coal gas as fuel, but was not very efficient and produced a lot of pollution. It was not until the late 1800s that significant advancements were made in the design of the IC engine. In 1876, Nikolaus Otto invented the four-stroke engine, which greatly improved efficiency and power output. The four-stroke engine became the standard design for gasoline-powered engines and is still widely used today.

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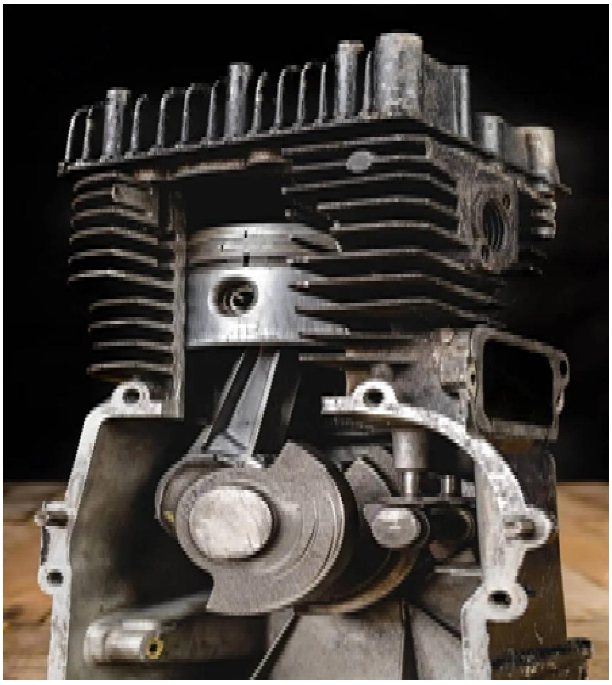

Figure 1: IC Engine

III. FUNCTIONS OF IC ENGINE

The function of an internal combustion engine (IC engine) is to convert the chemical energy stored in fuel into mechanical energy that can be used to power machinery or vehicles. The engine achieves this by following a specific set of steps, known as the four-stroke cycle, which is as follows:

1. Intake stroke: The piston moves downward, creating a vacuum that draws in a mixture of fuel and air into the cylinder through the intake valve.
2. Compression stroke: The piston moves upward, compressing the fuel and air mixture, which increases the temperature and pressure.
3. Power stroke: Once the mixture is compressed, a spark ignites it, causing it to rapidly expand and generate high pressure. This pressure pushes the piston down, which creates rotational force that can be used to power a machine or vehicle.
4. Exhaust stroke: The piston moves upward again, pushing the waste gases from the combustion process out of the cylinder through the exhaust valve.

This cycle is repeated continuously, with each stroke happening in sequence and the engine operating at high speed.
The IC engine has several components that work together to facilitate the four-stroke cycle. These include the cylinder, piston, crankshaft, connecting rod, valves, spark plug (in the case of a gasoline engine), and fuel injection system (in the case of a diesel engine).

The function of each component is as follows:

- Cylinder: Provides the housing for the piston and combustion process.
- Piston: Moves up and down within the cylinder to facilitate the four-stroke cycle.
- Crankshaft: Converts the linear motion of the piston into rotational motion that can be used to power a machine or vehicle.
- Connecting rod: Connects the piston to the crankshaft and transfers motion from the piston to the crankshaft.

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IV.DESIGN OF COMPONENTS

The design of internal combustion engine components is a critical aspect of engine development. The efficiency, power output, and longevity of the engine depend heavily on the proper design and optimization of its components. In this essay, we will discuss the various design aspects of IC engine components and their impact on engine performance.

Firstly, the engine block serves as the foundation of the engine, and its design must ensure strength, durability, and optimal cooling. The block must be able to withstand high temperatures and pressures generated by combustion, while also being lightweight to reduce overall engine weight. Furthermore, the design of the block must promote efficient cooling, with proper water jackets and cooling passages to prevent overheating.

Next, the cylinder head is responsible for housing the valves, combustion chamber, and camshaft. Its design must allow for efficient airflow through the ports and combustion chamber, while also maintaining a proper compression ratio. Additionally, the design of the cylinder head must account for the proper location and timing of the valves, allowing for optimal combustion.

The pistons and connecting rods are crucial components that translate the force generated by combustion into rotational motion through the crankshaft. The design of these components must ensure optimal strength and durability, while also being lightweight to reduce the reciprocating mass of the engine. Additionally, the piston and connecting rod design must allow for optimal combustion efficiency by ensuring proper compression and minimizing heat loss to the cylinder walls.

The crankshaft design is critical to the overall performance of the engine, as it is responsible for converting the reciprocating motion of the pistons into rotational motion. The design of the crankshaft must account for the proper balance of forces and ensure optimal strength and durability. Additionally, the crankshaft must be designed to minimize friction and bearing wear, improving engine efficiency and longevity.

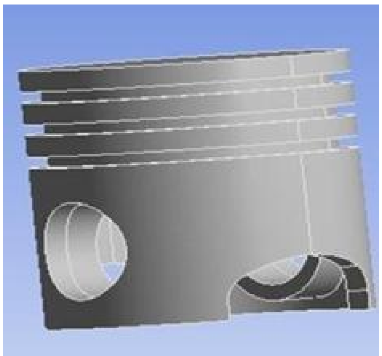

Figure2: Piston

Figure3: Connecting Rod

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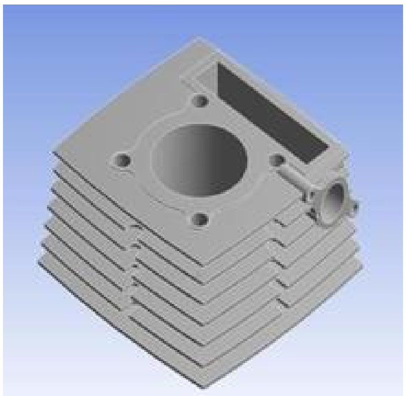

Figure4: Cylinder Block

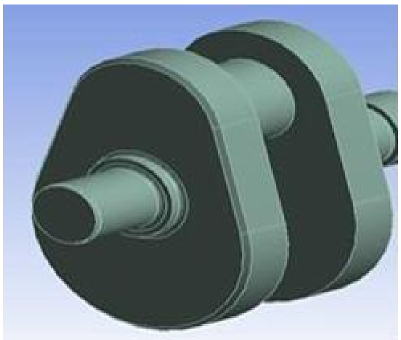

Figure5: Crankshaft

V. MATERIAL SELECTION

PARAMETERS	AL6061	AL6061+B4C
Density(g/cm^3)	2.7	2.68
Youngsmodulus(GPa)	70-80	195
Poisson'sratio	0.33	0.32

The selected materials are Al 6061+B4C, Al6061. Al6061 matrix with Boron carbide (B4C) that is 4% of B4C.The structural deformation of the components are identified due to the applied load on the respective components. The analysis is done using the static structural type of analysis system, for piston, The pressure (10 pa) is applied in its head. And for connecting rod the forces of tangential force, thrust force, Axial force are applied.

For Crank shaft, the applied forces are Thrust force (14.67N), Tangential Force (10.05N), Radial force (10.68N) and For the Cylinder block the steady state thermal analysis is conducted.

In this steady state thermal analysis, the total Heat flux of the component is identified by applying the load of about 600-degree Celsius inside the bore of the cylinder block.

VI. ANALYSIS

To optimize the design of these components and ensure their reliability, engineers use advanced computer-aided engineering (CAE) software such as ANSYS to analyse and simulate their behaviour under various operating conditions.

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One of the most critical components in an IC engine is the piston. The piston is responsible for converting the energy from the combustion process into mechanical motion that drives the crankshaft. ANSYS can be used to analyse the piston's structural integrity, stress distribution, and thermal behaviour. By modelling the piston's geometry, material properties, and boundary conditions, ANSYS can simulate the piston's behaviour during operation and identify potential failure modes such as fatigue, cracking, or overheating.

The connecting rod is another critical component in an IC engine. The connecting rod connects the piston to the crankshaft and is subjected to high forces and cyclic loading during engine operation. ANSYS can be used to analyze the connecting rod's stress distribution, fatigue life, and deformation under various operating conditions. By modeling the connecting rod's geometry, material properties, and boundary conditions, ANSYS can simulate the connecting rod's behavior and identify potential failure modes such as be the engine block is the main structural component of an IC engine and houses the cylinders, pistons, and crankshaft. ANSYS can be used to analyse the engine block's structural integrity, vibration behaviour, and thermal expansion. By modelling the engine block's geometry, material properties, and boundary conditions, ANSYS can simulate the engine block's behaviour during operation and identify potential failure modes such as cracking, deformation, or resonance.

In conclusion, ANSYS is a powerful tool for analysing and simulating the behaviour of IC engine components. By modelling the geometry, material properties, and boundary conditions of these components, ANSYS can simulate their behaviour under various operating conditions and identify potential failure modes. This analysis helps engineers optimize the design of these components for better performance, efficiency, and reliability, ultimately leading to more efficient and reliable IC engines.

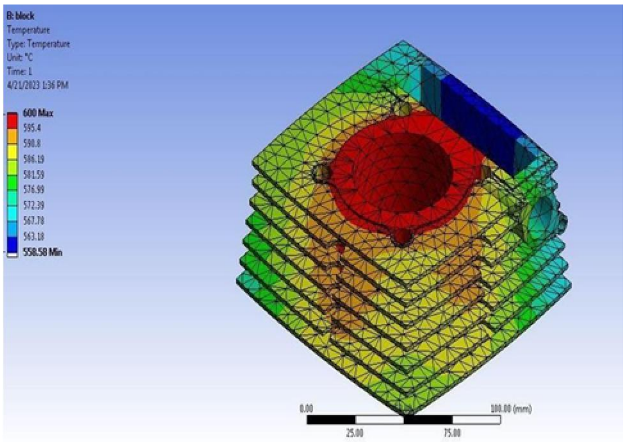

Figure 6:Thermal Analysis of Engine Block

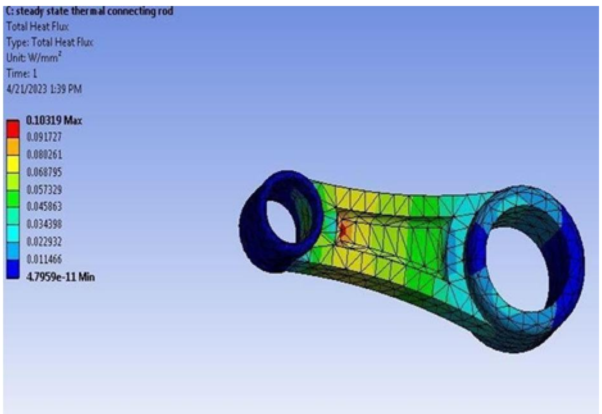

Figure 7:Thermal Analysis of Connecting Rod

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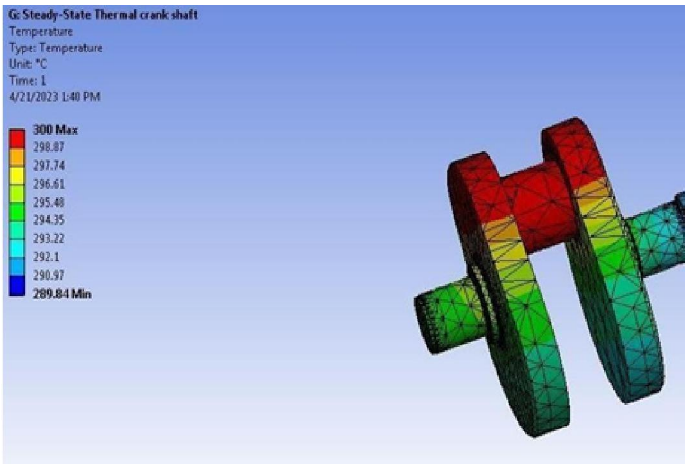

Figure 8:Thermal Analysis of Crank Shaft

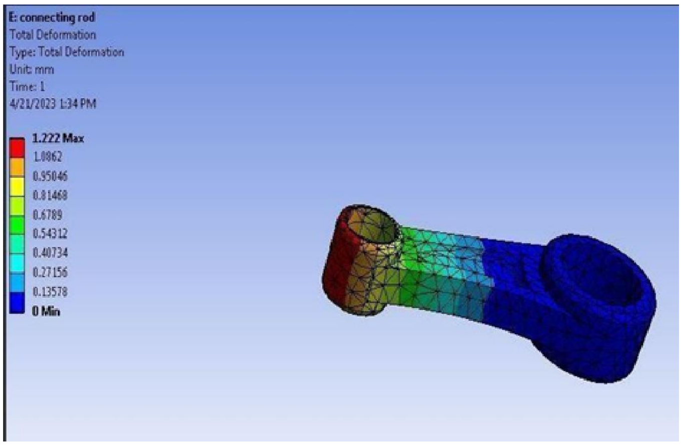

Figure 9:Structural Analysis of Connecting Rod

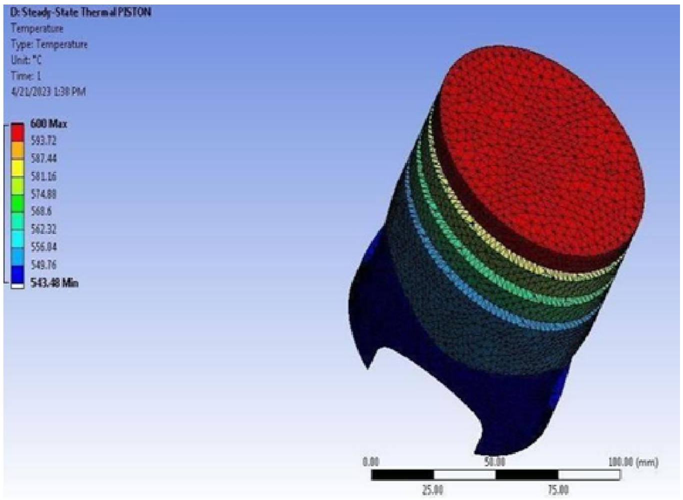

Figure 10: Thermal Analysis of Piston

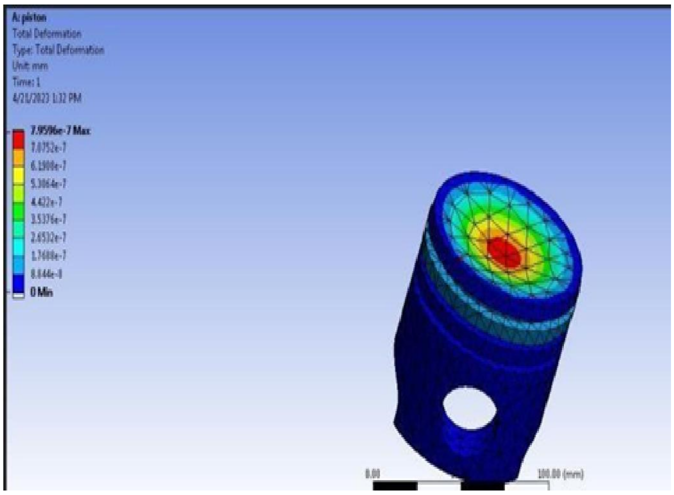

Figure 11: Structural Analysis of Piston

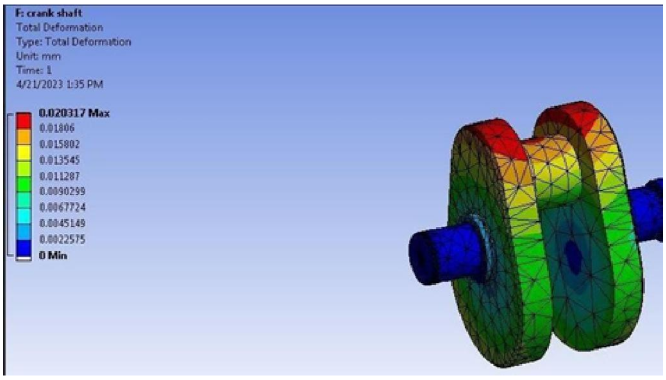

Figure 12: Structural Analysis of Crank Shaft

VII. CALCULATION

Heat Flow through the Piston Head (H) The heat flow through the piston head is calculated using the formula H=12.56 HK (T-T) Ky/sec

Where,

K-thermal conductivity of material which is 174.15W/mk

T = Temperature at center of piston head in °C. T=temperature at edges of piston head in °C?

(1) Indicated Power (I.P):

LP=B.P/ (J/s) taking = 80% 0.8 AL 3000 RPM, B. P= 36*10' (approx) IP=36*10/0.8

LP 45°10' (J/s).

(2) Indicated Mean Effective premere: IMG-1)-(-1) following dee are assumed of 115 Average length of stroke (131.8mm) P1264.18KPag

(3) Heat of Combustion chamber: - IP (Pe A-L-N/2)/60 kW N-3000 RPM

Πa

1-13 d. d=106.588 mm.)

(4) Length of stroke:

Vd 1.3. 1- 1.34

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1-137.8 mm

(5) Total Length of Cylinder:
L-159 mm (approx)
(5) Heat Flux & Volumetric heat generation.

Heat Flux Energy released / cylinder area. Heat Flux=128878.75/([]*d*1) Heat Flux=128878.75/ II*0.106 0.158) = 2.45MJ/m²
Heat generation/volume = 128878.5/(Π1/4*d²*1)

Heat generation/volume = 92.478M.J/m³) Consider a 150cc engine type air cooled 4-stroke
Bore Stroke (mm)-57-58.6 Displacement=149.5CC
Maximum Power = 13.8bhp at 8500rpm Maximum Torque = 13.4Nm at 6000rpm Compression Ratio = 9.35/1

• Density of petrol at 288.855 K 737.22*1 kg/mm3
• Molecular weight M-114.228 g/mole Ideal gas constant R- 8.3143 J/mmk
From gas equation, PV=m.Rspecific. T Where, P = Pressure, V = Volume, m = Mass Rspecific = Specific gas constant T= Temperature Mass = density volume m -737.22E-9*150E3 m = 0.11 kg Rspecific = R/M Rspecific = 8.3143/0.114228 Rspecific = 72.76
P=m.Rspecific. T/V P=0.11 72.786*288.85/150E3

P = 15.4177 MPa P - 16 MPA.)
D= Bore Diameter, Pmax = Maximum cylinder pressure Force on piston = Fp= [#D? Pmax.]/4 = 14.514 KN
= inclination of connecting rod with the line of stroke; 0 = crank angle
Sing sin e L/R sin 35 >=8.24°

Now, thrust force on connecting rod = FoFo=Fp/cos o Therefore, Fo= 14.675 KN

Now, Force on crankshaft will have tangential and radial components

a)Tangential force on crankshaft:
Fr=Fo sin (0+ 4) = 10.05 KN

b)Radial force on crankshaft: FR - Fo cos (0+)-10.68 KN

VIII. CONCLUSIONS

Internal combustion engines (IC engines) are complex machines that require many components to function properly. The main components of an IC engine include the engine block, cylinder head, pistons, connecting rods, crankshaft, camshaft, valves, spark plugs or injectors, and the fuel system. These components work together to intake air and fuel into the engine, compress it, ignite it, and exhaust the resulting gases. The engine block serves as the main structural component of the engine, containing the cylinders and often the crankcase. The cylinder head sits atop the block and contains the combustion chambers, valves, and sometimes the camshaft. The pistons move up and down within the cylinders, connected to the crankshaft by connecting rods. The crankshaft converts the reciprocating motion of the pistons into rotational motion. The camshaft controls the opening and closing of the valves, allowing air and fuel to enter and exhaust gases to exit the engine. Spark plugs or injectors are used to ignite the air and fuel mixture within the combustion chamber, and the fuel system delivers fuel to the engine. Overall, each component of an IC engine plays an important role in the engine's function, and any issues with one component can impact the performance and efficiency of the entire engine.

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