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Analysis of a Single Cylinder Combustion Engine Using CFD

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Abstract -If we consider the reasons for the Environmental Pollution from the last few decades, it is clear that most of the pollution is because of the hike in the usage of "Fossil fuels" in the transportation. Our attempts to build much energy efficient vehicles and demand for these vehicles are increasing accordingly. From the practical observations we can clearly understand that the UN-burnt fuels in the combustion chamber of an automobile engine causes the pollution and this UN-burnt fuels (carbon particles) will come out through muffler present to the automobile, which causes the pollution in the environment by releasing them. Our project is to understand these effects in a much more meticulous way and suggest few developments that can be made in this particular field. For this we would like to take up the case study of the single cylinder spark ignition engine of 4 stroke and their current efficiency level and the major drawbacks of them. Today, the use of software tools in the field of research and Industry has become inevitable because of the complexities that we are facing at present and the ease with which such problems can be solved using these tools. For an Engineer of this generation, it is a need to be proficient in using these tools. Hence, we would like to model the combustion system in ICEM-CFD and make the analysis of this in CFD.

Keywords- UN, ICEM-CFD, CFD.

I. INTRODUCTION

The basic idea of internal combustion engine is shown in Fig. (Basic idea of I.C. engine). The cylinder, which is closed at one end, is filled with a mixture of fuel and air. As the crankshaft turns it pushes cylinder. The piston is forced up and compresses the mixture in the top of the cylinder. The mixture is set alight and, as it burns, it creates a gas pressure on the piston, forcing it down the cylinder.

This motion is shown by arrow '1'. The piston pushes on the rod, which pushes on the crank. The crank is given rotary (turning) motion as shown by the arrow '2'. The flywheel fitted on the end of the crankshaft strokes energy and keeps the crank turning steadily.

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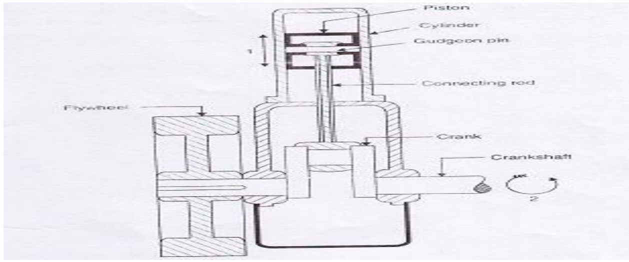

Fig. Basic idea of I.C. engine

Constructional details of I.C. Engines

A cross-section of an air-cooled I.C. engine with principal parts is shown in

Fig. (Air-cooled I.C. engine).

A. Parts common to both Petrol and Diesel engine:

1. Cylinder,
2. Cylinder head,
3. Piston,
4. Piston rings,
5. Gudgeon pin,
6. Connecting rod,
7. Crankshaft,
8. Crank,
9. Engine bearing,
10. Crank case.
11. Flywheel,
12. Governor,
13. Valves and valve operating mechanism.

B. Parts for Petrol engines only:

1. Spark plug,
2. Carburetor,
3. Fuel pump.

C. Parts for Diesel engine only:

1. Fuel pump,
2. Injector.

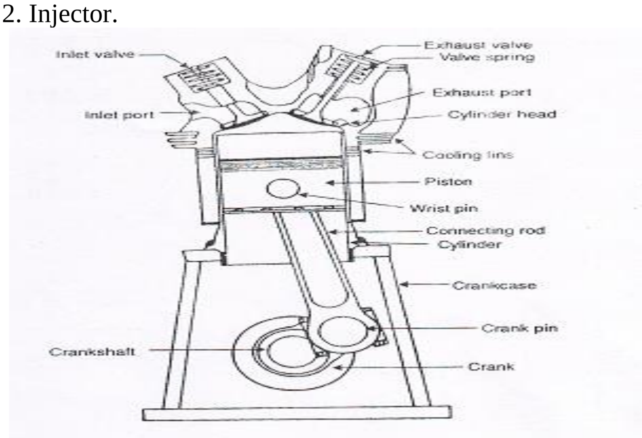

Fig. Air-cooled I.C. engine

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The details of the I.C. Engine parts are:

1. Cylinder -It is one of the most important part of the engine, in which the piston moves to and fro in order to develop power. The engine cylinder has to withstand a high pressure (more than 50 bar) and temperature (more than 2000 deg C). Thus the material for the engine cylinder should be such that it can retain sufficient strength at such a high pressure and temperature. For ordinary engines, the cylinder is made of ordinary cast iron. But for heavy-duty engines, it is made of steel alloys or aluminum alloys.

Sometimes, a liner or sleeve is inserted into the cylinder, which can be replaced when worn out. As the material required for liner is comparatively small, it can be made of alloy cast iron having long life and sufficient resistance to rapid wear and tear to the fast moving reciprocating parts.

2. Cylinder head- It is fitted on one end of the cylinder, and act as a cover to close the cylinder bore. Generally, the cylinder head contains inlet and exit valves for admitting fresh charge and exhausting the burnt gases. In petrol engines, the cylinder head also contains a spark plug for igniting the fuel-air mixture, towards the end of compression stroke. But in diesel engines, the cylinder head contain nozzles, (i.e. fuel valve) for injecting the fuel into the cylinder.

The cylinder head is cast as one piece and bolted to one end of the cylinder. The cylinder block and cylinder head are made from the same material. A copper or asbestos gasket is provided between the engine cylinder and cylinder head to make an airtight joint.

3. Piston – It is considered as the heart of an I.C. engine, whose main function is transmit the force exerted by the burning of charge to the connecting rod. The piston is generally made of aluminium alloys, which are light in weight. They have good heat conducting property and also greater strength at higher temperature.

4. Piston rings –These are circular rings and made of special steel alloys, which retain elastic properties even at high temperatures. The piston rings are housed in the circumferential grooves provided on the outer surface of the piston. Generally, there are two sets of rings mounted for the piston. The function of the upper rings is to provide airtight seal to prevent leakage of theburnt gases into the lower portion. Similarly, the function of the lower rings is to provide effective seal to prevent leakage of the oil into the engine cylinder.

5. Connecting rod – It is a link between the piston and crankshaft, whose main function is to transmit force from the piston to the crankshaft. Moreover, it converts reciprocating motion of the piston into circular motion of the crankshaft, in the working stroke. The upper (i.e. smaller) end of the connecting rod is fitted to the piston and the lower (i.e. bigger) end of the crank.

The special steel alloys or aluminium alloys are used for the manufacture of connecting rods. A special care is required for the design and manufacture of connecting rod, as it is subjected to alternatively compressive and tensile stresses as well as bending stresses.

6. Crankshaft – It is considered as the backbone of an I.C. engine whose function is to covert the reciprocating motion of the piston into the rotary motion with the help of connecting rod. This shaft contains one or more eccentric portions called cranks. Thispart of the crank, to which bigger end of the connecting rod is fitted, is called crank pin. Special steel alloys are used for the manufacture of crankshaft. A special care is required for the design and manufacture of crankshaft

7. Crank case – It is a cast iron case, which holds the cylinder and crankshaft of an I.C. engine. It also serves as a sump for the lubricating oil. The lower portion of the crankcase is known as bedplate, which is fixed with the help of bolts.

8. Flywheel – It is a big wheel, mounted on the crankshaft, whose function is to maintain its speed constant. It is done by storing excess energy during power stroke, which, is returned during other stroke.

Sequence Of Operation

The *sequences of operation in a cycle are* as follows:

1. **Suction stroke** – In this stroke, the fuel vapour in correct proportion is applied to the engine cylinder.
2. **Compression stroke**–. In this stroke, the fuel vapor is compressed in the engine cylinder.
3. **Expansion stroke** –In this stroke, the fuel vapour is fired just before the compression is complete. It results in the sudden rise of pressure, due to expansion of the combustion products in the engine cylinder. This sudden rise of pressure pushes the piston with a great force, and rotates the crankshaft. The crankshaft, in turn, drives the machine connected to it.
4. **Exhaust stroke** – In this stroke, the burnt gases (or combustion products) are exhausted from the engine cylinder, so as to make space available for the fresh fuel vapour.

Combustion

In spark ignition (SI) engines, petrol or gasoline is used as fuel, while in compression ignition (CI) engines, diesel is used as fuel. Petrol engines are lightweight and achieve higher speed. Diesel engines, on the other hand, are heavy engines and achieve lesser speeds. Other differences below:

The most prominent difference between Spark Ignition (SI) and Compression Ignition (CI) engines is the type of fuel used in each. In SI engines petrol or gasoline is used as fuel, hence these engines are also called petrol engines. In CI engines diesel is used as fuel, hence they are also called diesel engines. Here are some other major differences between the SI and CI engines:

1) **Type of cycle used**: In the case of SI engines, the Otto cycle is used. In this cycle, addition of heat or fuel combustion occurs at a constant volume. The basis of working of CI engines is the Diesel cycle. In this cycle the addition of heat or fuel combustion occurs at a constant pressure.

2) **Introduction of fuel in the engine**: In the case of SI engines, during the piston's suction stroke, a mixture of air and fuel is injected from cylinder head portion of the cylinder. The air-fuel mixture is injected via the carburetor that controls the quantity and the quality of the injected mixture. In the case of CI engines, fuel is injected into the combustion chamber towards the end of the compression stroke. The fuel starts burning instantly due to the high pressure. To inject diesel in SI engines, a fuel pump and injector are required. In CI engines, the quantity of fuel to be injected is controlled but the quantity of air to be injected is not controlled.

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3) **Ignition of fuel**: By nature petrol is a highly volatile liquid, but its self-ignition temperature is high. Hence for the combustion of this fuel a spark is necessary to initiate its burning process. To generate this spark in SI engines, the spark plug is placed in the cylinder head of the engine. The voltage is provided to the spark plug either from the battery or from the magneto. With diesel, the self-ignition temperature is comparatively lower. When diesel fuel is compressed to high pressures, its temperature also increases beyond the self-ignition temperature of the fuel. Hence in the case of CI engines, the ignition of fuel occurs due to compression of the air-fuel mixture and there is no need for spark plugs.

4) **Compression ratio for the fuel**: In the case of SI engines, the compression ratio of the fuel is in the range of 6 to 10 depending on the size of the engine and the power to be produced. In CI engines, the compression ratio for air is 16 to 20. The high compression ratio of air creates high temperatures, which ensures the diesel fuel can self-ignite.

5) **Weight of the engines**:In CI engines the compression ratio is higher, which produces high pressures inside the engine. Hence CI engines are heavier than SI engines.

6) **Speed achieved by the engine**: Petrol or SI engines are lightweight, and the fuel is homogeneously burned, hence achieving very high speeds. CI engines are heavier and the fuel is burned heterogeneously, hence producing lower speeds.

7) **Thermal efficiency of the engine**:In the case of CI engines the value of compression ratio is higher; hence these engines have the potential to achieve higher thermal efficiency. In the case of SI engines the lower compression ratio reduces their potential to achieve higher thermal efficiency.

Both SI and CI engines can work either on two-stroke or four stroke cycle. Both the cycles have been described below:

1) **Four-stroke engine**: In the four-stroke engine the cycle of operations of the engine are completed in four strokes of the piston inside the cylinder. The four strokes of the 4-stroke engine are: suction of fuel, compression of fuel, expansion or power stroke, and exhaust stroke. In 4-stroke engines the power is produced when piston performs expansion stroke. During four strokes of the engine two revolutions of the engine's crankshaft are produced.

2) **Two-stroke engine**: In case of the 2-stroke, the suction and compression strokes occur at the same time. Similarly, the expansion and exhaust strokes occur at the same time. Power is produced during the expansion stroke. When two strokes of the piston are completed, one revolution of the engine's crankshaft is produced.

In 4-stroke engines the engine burns fuel once for two rotations of the wheel, while in 2-stroke engine the fuel is burnt once for one rotation of the wheel. Hence the efficiency of 4-stroke engines is greater than the 2-stroke engines. However, the power produced by the 2-stroke engines is more than the 4-stroke engines.

Abnormal Combustion*:*

In normal combustion, the flame initiated by spark travels across the combustion chamber in a fairly uniform manner under certain operating conditions the combustion deviates from its normal course leading to the loss of performance and possible damage to the engine. This type of combustion may be termed as abnormal combustion or knocking combustion. The consequences of this abnormal combustion process are loss of power, recurring preignition and mechanical damage to the engine

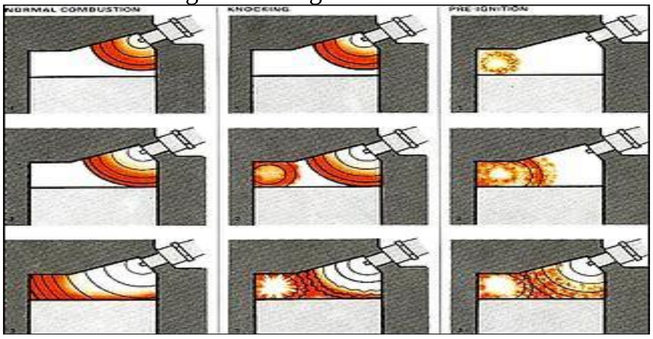

Fig: NORMAL COMBUSTION, KNOCKING, PRE-IGNITION

II. ANALYSIS

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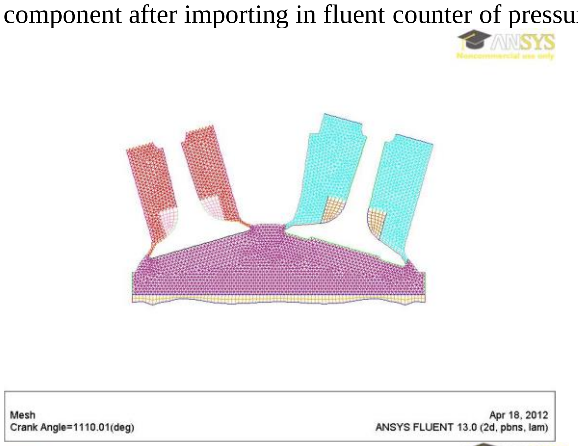
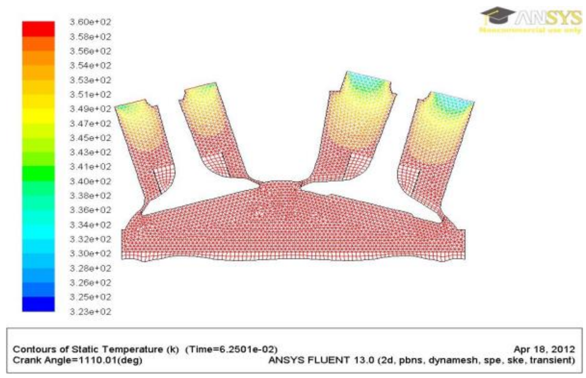


III. COUNTERS OF TEMPERATURE



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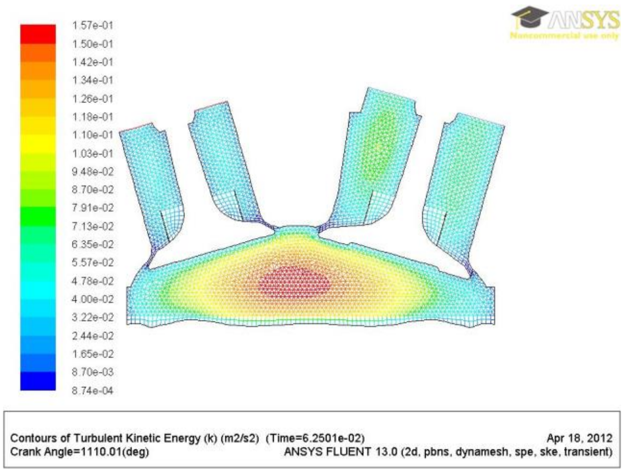
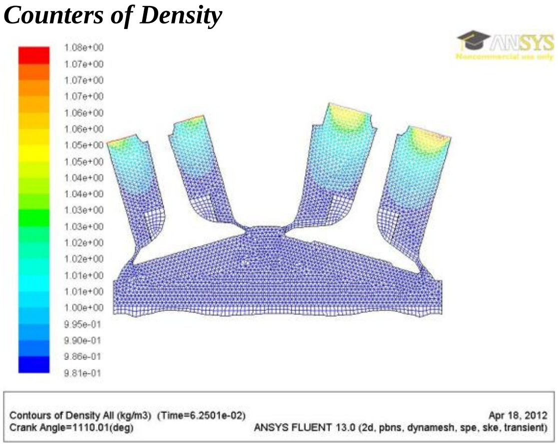
Counters of turbulence



Counters of Density



IV. CONCLUSION

A model was imported from ICEM CFD to ANSYS FLUENT and their counters are plotted as shown above. It was found that pressure and temperature distribution at the top of cylinder near inlet and exhaust valves is not uniform, which is resulting in un-burnt fuel particles coming out through exhaust valve due to abnormal combustion. Design modifications have to be done in order to make the pressure and temperature distribution along the top of the cylinder near inlet and exhaust valve should be uniform. By this we can reduce the un-burnt fuel and decrease the environmental pollution. In this way the efficiency of the engine can be increased.

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