DESIGN ANALYSIS AND OPTIMIZATION OF INTERNAL COMBUSTION ENGINE PISTON USING CAE TOOL ANSYS

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ABSTRACT

In internal combustion engines, exhaust system plays a vital role in the improvement of the combustion efficiency. A good conditioned exhaust system increase the performance of the engine. To analyse the exhaust energies available at different engine operating conditions and to develop an exhaust system for maximum utilization of available energy at the exhaust of engine cylinder is studied. Design of each device should offer minimum pressure drop across the device, so that it should not adversely affect the engine performance. Backpressure acting on engine is most important controllable factor which basically deteriorates the engine and emission control performance. The angle of the exhaust system is taken as 22^0 and 30^0

Keywords: *Exhaust system, Design, and ANSYS analysis.*

1.0 INTRODUCTION:

Energy efficient exhaust system development requires minimum fuel consumption and maximum utilization of exhaust energy for reduction of the exhaust emissions and also for effective waste energy recovery system such as in turbocharger, heat pipe etc. from C.I. engine. To analyse the exhaust energies available at different engine operating conditions and to develop an exhaust system for maximum utilization of available energy at the exhaust of engine cylinder is studied. A piston is a component of reciprocating IC engines. It is the moving component with in a cylinder and is made of gas-tight by piston rings. In an engine, piston is used to transfer force from expanding gas in the cylinder to the crankshaft via a piston rod. Piston endures the cyclic gas pressure and the inertial forces at work, and this working condition may cause the fatigue damage of the piston, such as piston side wear, piston head cracks and so on. So there is a need to optimize the design of piston by considering various parameters in this project the parameter selected are analysis of piston by applying pressure force acting at the top of the piston and thermal analysis ofpiston at various temperatures at the top of the piston in various strokes. This analysis could be useful for designengineers for modification of piston at the time of design. The work is focused on reducing the backpressure in the exhaust system to increase the combustion efficiency using ANSYS. In ANSYS analysis, various diffuser models with different angels were simulated using the appropriate boundary conditions and fluid properties specified to the system with suitable assumptions. The back pressure variations in various models are discussed in this project.

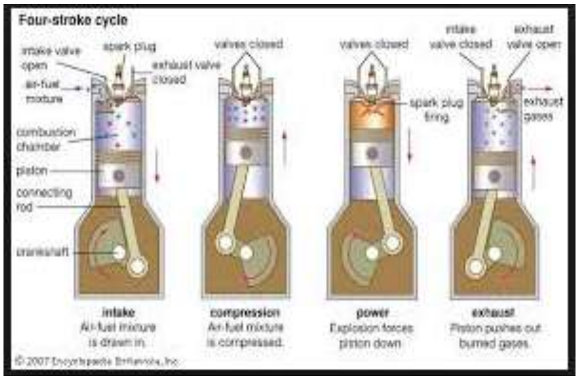

Figure 1.1 four stroke cycle

Backpressure on engine cylinder is completely dependent on exhaust system design, its operating condition and atmospheric pressure (i.e. almost constant). The exhaust system routes exhaust gas from the engine and exhaust it into the environment, while providing noise attenuation, after treatment of the exhaust gas to reduce emissions and energy recovery.

1.2TYPES OF PISTONS:

TRUNK PISTONS

Trunk pistons are long relative to their diameter. They act both as a piston and cylindrical crosshead. As the connecting rod is angled for much of its rotation, there is also a side force that reacts along the side of the piston against the cylinder wall. A longer piston helps to support this.Trunk pistons have been a common design of piston since the early days of the reciprocating internal combustion engine. They were used for both petrol and diesel engines, although high speed engines have now adopted the lighter weight slipper piston.A characteristic of most trunk pistons, particularly for diesel engines, is that they have a groove for an oil ring below the dudgeon pin, in addition to the rings between the dudgeon pin and crown.

CROSSHEAD PISTONS

Large slow-speed Diesel engines may require additional support for the side forces on the piston. These engines typically use crosshead pistons. The main piston has a large piston rod extending downwards from the piston to what is effectively a second smaller-diameter piston. The main piston is responsible for gas sealing and carries the piston rings.

SLIPPER PISTONS:

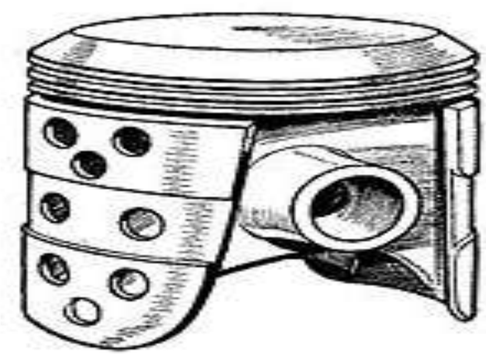

Figure 1.2 Slipper piston

A slipper piston is a piston for a petrol engine that has been reduced in size and weight as much as possible. In the extreme case, they are reduced to the piston crown, support for the piston rings, and just enough of the piston skirt remaining to leave two lands so as to stop the piston rocking in the bore. The sides of the piston skirt around the gudgeon pin are reduced away from the cylinder wall.

DEFLECTOR PISTONS:

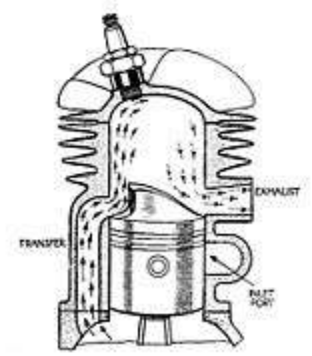

Figure 1.3 Two-stroke deflector piston

Deflector pistons are used in two-stroke engines with crankcase compression, where the gas flow within the cylinder must be carefully directed in order to provide efficient scavenging. With cross scavenging, the transfer (inlet to the cylinder) and exhaust ports are on directly facing sides of the cylinder wall. To prevent the incoming mixture passing straight across from one port to the other, the piston has a raised rib on its crown. This is intended to deflect the incoming mixture upwards, around the combustion chamber.

PISTON DESIGN FEATURES

1. Have sufficient mechanical strength and stiffness.
2. Can effectively block the heat reached the piston head.
3. High temperature corrosion resistance.
4. Dimensions as compact as possible, in order to reduce the weight of the piston

OBJECTIVES

1. Analytical design of piston using Hero Karizma ZMR specifications.
2. Obtaining design of piston using Solid works 2013 and then imported in ansys 15.0
3. Meshing of design model using ANSYS 15.
4. Analysis of piston by stress analysis and thermal analysis method.
5. Comparing the performance of two aluminium alloy piston under structural and thermal analysis process.
6. Identification of the suitable aluminium alloy material for manufacturing of the piston under specifiedconditions.In a reciprocating piston engine, the connecting rod connects the piston to the crank or crankshaft. In modern automotive internal combustion engines, the connecting rods are most usually made of steel for production engines, but can be made of aluminium (for lightness and the ability to absorb high impact at the expense of durability) or titanium (for a combination of strength and lightness at the expense of affordability) for high performance engines, or of cast iron for applications such as motor scooters.

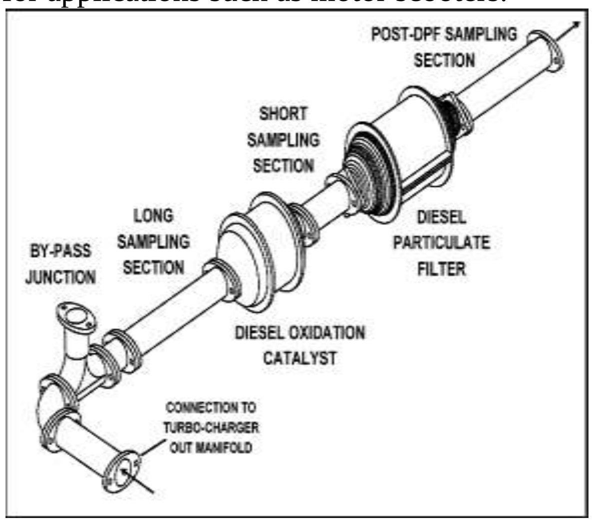

Figure 3: internal combustion engine piston

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CONSTRUCTION OF PISTON:

The top of piston is known by many names such as crown, head or ceiling and is thicker than bottom portion. Bottom portion is known as skirt. There are grooves made to accommodate the compression rings and oil rings. The groove, made for oil ring, is wider and deeper than the grooves made for compression ring. The oil ring scraps the excess oil which flows into the piston interior through the oil return holes and thus avoiding reaching the combustion chamber but helps to lubricate the gudgeon pin to some extent. In some designs the oil ring is provided below the gudgeon pin boss .The space between the grooves is called as lands. The diameter of piston always kept smaller than that of cylinder because the piston reaches a temperature higher than cylinder wall and expands during engine operation. The space between the cylinder wall and piston is known as piston clearance. The diameter of the piston at crown is slightly less than at the skirt due to variation in the operating temperatures. Again the skirt itself is also slightly tapered to allow for unequal expansion due to temperature difference as we move vertically along the skirt the working temperature is not uniform but slightly decrease.

3PISTON COOLING METHODS:

Advantage and disadvantages of water cooled and oil cooled pistons Coolant used for cooling a piston of marine diesel engine: The coolant used for removing and conveying the heat from a piston may be either fresh water, distilled water or lubricating oil. Water has the ability to remove more heat than lubricating oil (specific heat of water approximately 4 and lubricating oil 2 and temperature difference 14oC for water and 10oC for lube oil) Modern engines have oil cooled pistons. The piston rod is utilised to carry the oil to and from the piston. The rod is hollow, and has a tube running up its centre.

Disadvantages:

i) The piston cooling water conveyance piston and attendant gear must be kept out of the crankcase as far as possible, due to the danger of contamination of the crankcase lubricating oil by water leakage. In other word, the jacket cooling water and piston cooling system should have separate which having their own pumps, coolers, piping etc.

2.0 LITERATURE REVIEW:

[1] Law et al., 2001 where the exhaust valve remains open throughout the intake stroke; another is the exhaust recompression strategy. demonstrated that the variable valve timing strategy has a strong influence on the gas exchange process, which in turn influences the engine parameters and the cylinder charge properties, hence the control of the HCCI process.

[2] Young chul R et, al., 2012. A multi-dimensional CFD code, KIVA-ERC-Chemkin, that is coupled with Engine Research Center (ERC)-developed sub-models and the Chemkin library, was employed. The oxidation chemistry of the fuels was calculated using a reduced mechanism for primary reference fuel,

which was developed at the ERC. The results show that the combustion behavior of DI gasoline sprays and their emission characteristics are successfully predicted and are in good agreement with available experimental measurements for a range of operating conditions. It is seen that gasoline has much longer ignition delay than diesel for the same combustion phasing, thus NOx and particulate emissions are significantly reduced compared to the corresponding diesel cases.

3.0 METHODOLOGY:

Let,
IP = indicated power produced inside the cylinder (W)
N = engine speed (rpm)
L = length of stroke (mm)
A = cross-section area of cylinder (mm2)
mp = mass of the piston (Kg)
V = volume of the piston (mm3)
tH = thickness of piston head (mm)
D = cylinder bore (mm)
Pmax = maximum gas pressure or explosion pressure (Mpa)
σt = allowable tensile strength (Mpa)
σut = ultimate tensile strength (Mpa)
K = thermal conductivity (W/m K)
Tc = temperature at the centre of the piston head (K)
Te = temperature at the edge of the piston head (K)
HCV = Higher Calorific Value of fuel (KJ/Kg) = 48000 KJ/Kg

ANALYSIS OF THE MODEL:

Here Stress analysis of the piston model has been performed to obtain the value and parameters at which the piston would be damaged. Damages may have different origins: mechanical stresses; thermal stresses; wear mechanisms; temperature degradation, oxidation mechanisms; etc. For this analysis parameters like Pressure,Temperature, Thermal Stress. have been used and to discuss the effects of these parameters on the model are as follows:

PRESSURE:

When air-fuel mixture is ignited, pressure from the combustion gases is applied to the piston head, forcing the piston towards the crankshaft. Due to the pressure at the piston head, there are mainly two critical areas: piston pin holes and localized areas at the piston head. Subsequently will be presented different engine pistons where the cracks initiated on those areas. The pressurized gases travel through the gap between the cylinder wall and the piston. The upward motion of the piston is against the pressure of the gases. The causes a tremendous effect on the piston head leading to its damage and deformation of the piston head.

After designing the model in CATIA, the CAT FILE has been converted to IGES format. This format enables the design to be compatible in the ANSYS software. After importing the design in ANSYS, the process of analysis begins. The different steps performed for the proper analysis of the model are as follows:

MESHING THE MODEL:

Mathematically, the structure to be analysed is subdivided into a mesh of finite sized elements of simple shape. Within each element, the variation of displacement is assumed to be determined by simple polynomial shape functions and nodal displacements. Equations for the strains and stresses are developed in terms of the unknown nodal displacements.

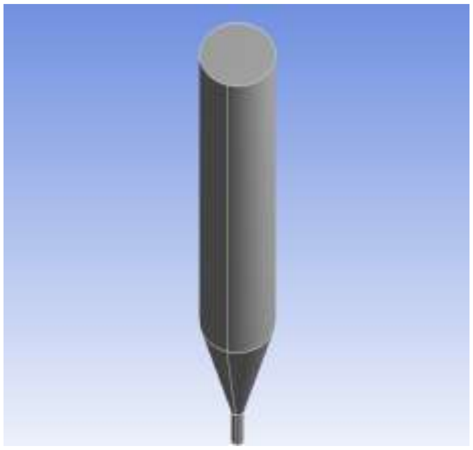


Figure3.1: shows the structural design of exhaust system of engine

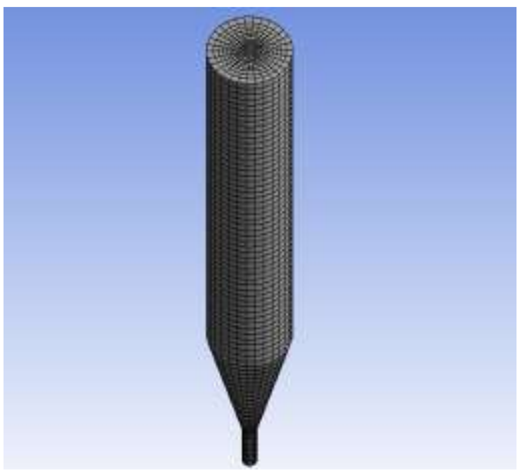


Figure 3.2 shows the total meshing of the engine exhaust system

4.0 RESULTS AND DISCUSSIONS

The constructed piston in Solid works is analyzed using ANSYS V15.0 and the results are depicted below.Combustion of gases in the combustion chamber exerts pressure on the head of the piston during power stroke.Fixed support has given at surface of pinhole. Because the piston will move from top dead center to bottom deadcenter with the help of fixed support at pinhole

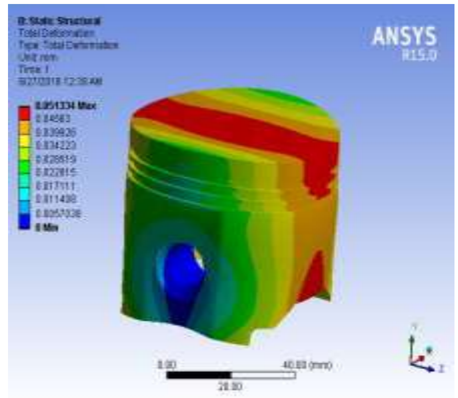


FIGURE 4.1 TOTAL DEFORMATION

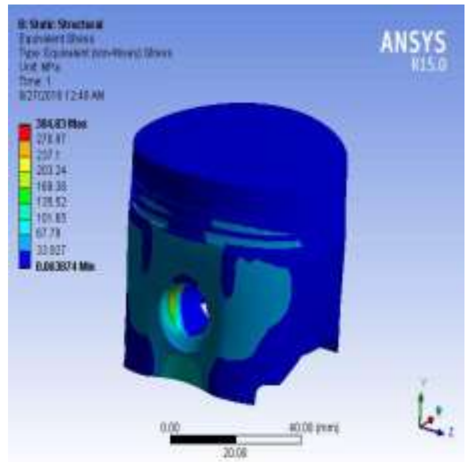


FIGURE 4.2 VON MISSES STRESS

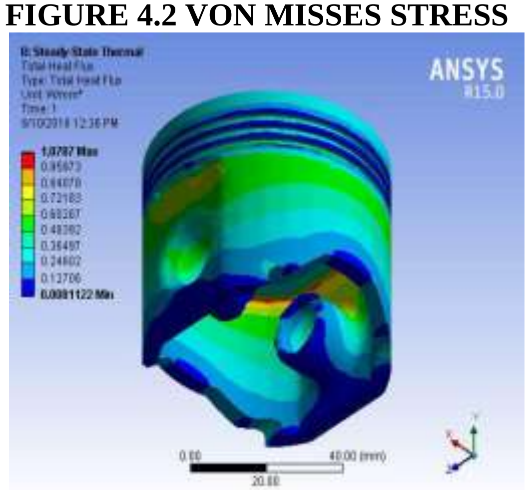
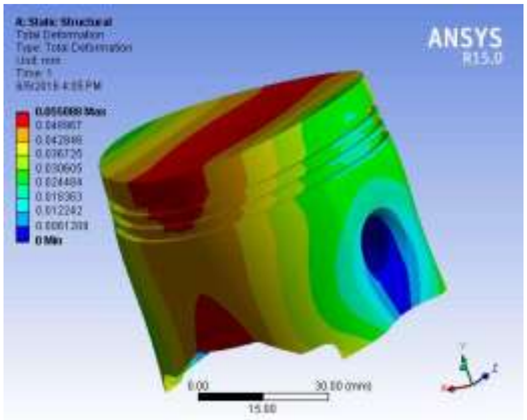
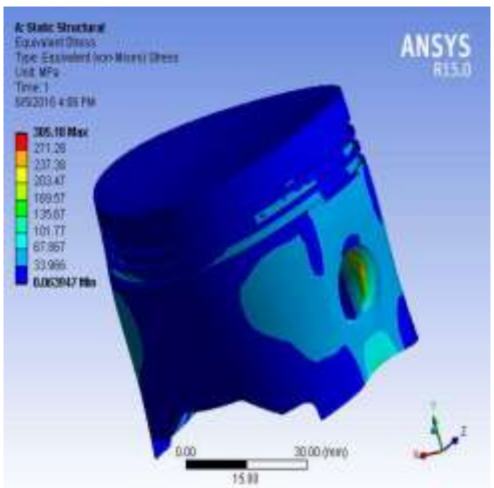


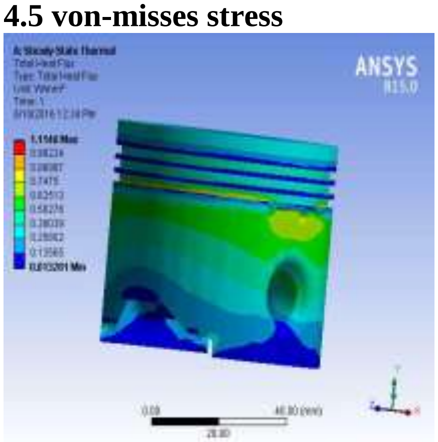
FIGURE 4.3 TOTAL HEAT FLUX PISTON:



4.4 Total deformation



4.5 von-misses stress



4.6 Total heat flux

5. CONCLUSIONS: The decrease in back pressure is shown using contour and Pressure Vs Distance diagram. The flow is made efficient by decreasing the exhaust gas back pressure in the exhaust system design. The geometry, which gives minimum pressure drop and hence minimum backpressure, is the optimized geometry. Again for the optimized geometry ANSYS results would be finding out. Also the Non-dimensional stiffness rigidity is sufficiently high. Finally it can be stated that 3-D ANSYS simulation can be used as a strong and useful tool for design or optimization of Exhaust system.

FUTURE SCOPE

In every internal combustionengine, piston plays an important role in working and producing results. Piston forms a guide and bearing for the small end of connecting rod and also transmits the force of explosion in the cylinder, to the crank shaft through connecting rod. The piston will be most useful for designengineering section

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