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Research Paper

MULTI-BODY DYNAMIC ANALYSIS OF AN IC ENGINE PISTON FOR SHAPE OPTIMIZATION

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Piston in an internal combustion engine is subjected to gas force. In internal combustion engine, piston is one of the important components parts defined as cylindrical components that moves up and down in the cylinder bore by force produce during the combustion process. The features of the piston are piston head, piston pin bore, piston pin, skirt, ring groove, ring land and piston ring. In this work the connecting rod of a Kirloskar TV1 diesel engine producing a rated output of 5.2Kw at 1500rpm is considered for the study. Load curves are obtained from the pressure - crank angle plots. Gas forces and inertia forces are calculated from these curves. Finite element analysis software ANSYS13 is used to study the stress distribution and deformation in the Piston. The dimensions are physically measured to obtain the CAD model of connecting rod in CATIA V5. Since the weight of the piston has considerable influence on its dynamic behavior, an optimization study was performed on a Aluminum forged piston with a consideration for reduction in weight, stress

Keywords: Piston, FEA, Weight optimization, MBD

INTRODUCTION

In an engine purpose of piston is to transfer force from expanding gas in the cylinder to the crankshaft via a piston rod or connecting rod. The piston primarily subjected to gas forces directly. So piston has to be designed to withstand these direct gas pressure conditions.

As an important part in an engine, piston endures the cyclic gas pressure and the inertial forces at work, and this working condition may cause the fatigue damage of piston, such as piston side wear, piston head/crown cracks and so on. It also has to withstand the load because of gas pressure generated during compression stroke of the engine cycle.

Therefore for efficient design it is inevitable to analyze the stresses induced in the piston using FEM technique or some other advanced technical design.

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INTERNAL COMBUSTION ENGINES

Engine Parts

The essential parts of automobile engine are as follows: cylinder block, cylinder head, crank case, piston, piston rings, piston pin, connecting rod, crank shaft, fly wheel, valves and mechanism.

Piston

Piston is considered to be one of the most important parts in a reciprocating engine in which it helps to convert the chemical energy obtained by the combustion of fuel into useful mechanical power. The purpose of the piston is to provide a means of conveying the expansion of the gasses to the crankshaft, via the connecting rod, without loss of gas fromabove or oil from below. Piston is essentially cylindrical plug that moves up and down in the cylinder. It is equipped with piston rings to provide a good seal between the cylindrical wall and piston.Although the piston appears to be a simple part, it actually quite complex from the design point of view. The efficiency and economy of the engine primarily depends on the working of piston. It must operate in the cylinder with minimum of friction and should be able to with stand the high explosive force developed in the cylinder and also the very high temperature ranging from 2000 °C to over 2800 °C during operation. The piston should be as strong as possible, however its weight should be minimized as for as possible in order to reduce the inertia due to its reciprocating mass .

Functions of Piston

- To receive the thrust force generated by explosion of the gas in the cylinder and transmits it to the connecting rod.
- To reciprocate in the cylinder as a gas tight plug causing suction, compression, expansion and exhaust stroke.
- To form a guide and bearing to the small end of the connecting rod and to take the side thrust due to the obliquity of the rod.

The top of the piston is called head ring grooves are located at the top circumference portion of the piston. Portion below the ring grooves is called skirt. The portion of the piston that separates the grooves is called the lands. Some pistons have a groove in the top land called a heat dam which reduces heat to the rings. The piston bosses are Those reinforced section of the piston designed to hold the piston pin.

Piston Materials

The material used for pistons is mainly aluminium alloy. Aluminium pistons can be either cast or forged. Cast iron is also used for pistons. In early years cast iron was almost universal material for pistons because it posses excellent wearing qualities, coefficient of expansion and general suitability in manufacture. But due to the reduction of weight in reciprocating parts, the use of aluminium for piston was essential. To obtain equal strength a greater thickness of metal is necessary. But some of the advantage of the light metal is lost. Aluminium is inferior to cast iron in strength and wearing qualities, and its greater coefficient of expansion necessitates greater clearance in the cylinder to avoid the risk of seizure. the heat conductivity of aluminium is about thrice that of cast iron and this combined with the greater thickness necessary for strength, enables and aluminium alloy piston to run at much lower temperature than a cast iron one (200 °C to 250 °C as compared with 400 °C to 450 °C) as a result carbonized oil doesn't form on the underside of the piston, and the crank case therefore keeps cleaner.

This cool running property of aluminium is now recognized as being quite as valuable as its lightness. Indeed; pistons are sometimes made thicker than necessary for strength in order to give improved cooling.

DESCRIPTION OF IC ENGINE MODELS FOR FINITE ELEMENT STUDY

The Table 1 shows engine details.

Table 1: Engine Specifications

S. No.	Description	Specification
1	Engine Type	Kirlosker TV1
2	Cylinder Bore	87.5mm
3	Stroke	110mm
4	Engine rpm	1500rpm
5	Compression ratio	17.5:1
6	Rated Output	5.2Kw @ 1500rpm
7	Dynamometer	Eddy current type

Figure 1: Computerized IC Engine Setup to Obtain P-θ Diagram

All the dimensions and mass of connecting rod are obtained by physically measuring the connecting rod at Bharat engineering works, Bijapur. Single cylinder Four Stroke Diesel Engine (Test Rig).

Formulae

Gas force= F_g =A x P

Table 2: Force Calculations

S. No.	θ in Deg	Angle in time (sec)	Pressure in bar	Gas Forces in N
1	0	0	3.04	1828.0142
2	36	0.004	2.53	1521.3407
3	72	0.008	2.62	1575.4596
4	108	0.012	2.53	1521.3407
5	144	0.016	2.79	1677.6841
6	180	0.02	2.87	1725.7897
7	216	0.024	2.79	1677.6841
8	252	0.028	3.04	1828.0142
9	288	0.032	4.64	2790.1269
10	324	0.036	11.56	6951.2646
11	360	0.04	56.09	33728.065
12	367	0.0408	73.05	43926.4602
13	396	0.044	30.2	18159.8781
14	432	0.048	8.27	4972.9202
15	468	0.052	4.05	2435.3478
16	504	0.0560	3.37	2026.4499
17	540	0.06	2.53	1521.3407
18	576	0.064	1.52	914.0071
19	612	0.068	1.86	1118.45607
20	648	0.072	2.36	1419.1163
21	684	0.076	2.78	1671.6709
22	720	0.08	3.21	1930.2387

Figure 2: Load Curve

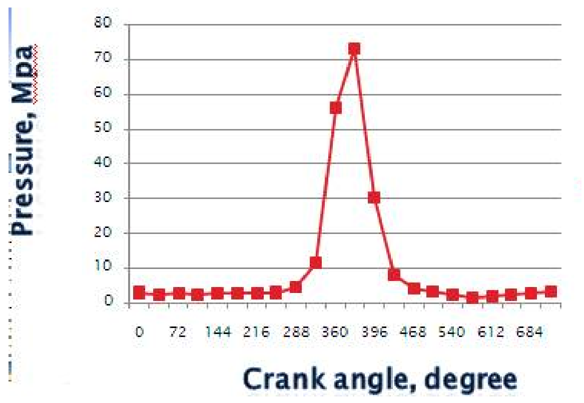


Figure 3: Meshed Piston

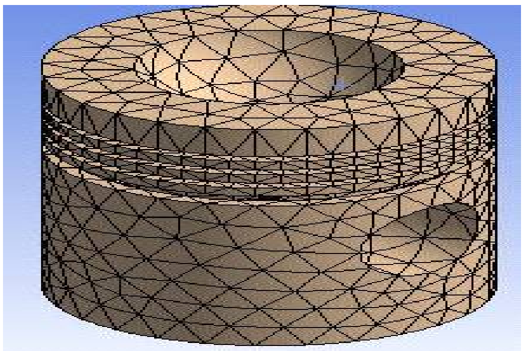


Figure 4: Boundary Condition

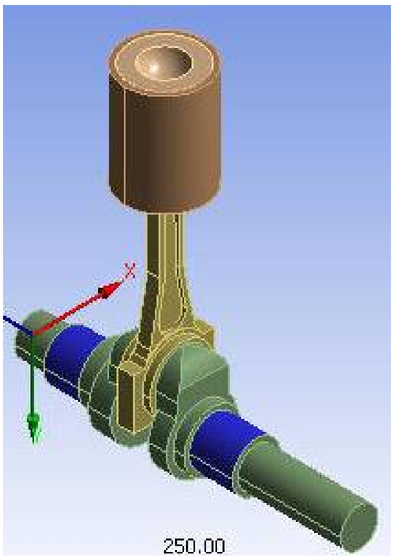
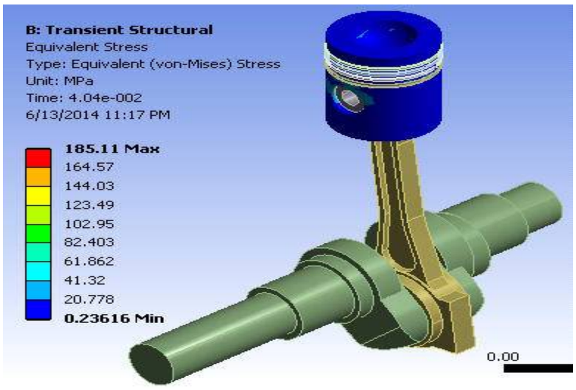


Figure 5: Von Mises Stress Plot Before Shape Optimization

Figure 6: Von mises Stress Plot after Optimization



CONCLUSION

- The results obtained are analyzed and the points of high stress concentration are located.
- Then efforts are put to redistribute and minimize the induced maximum stress by introducing chamfering and filleting.
- The results obtained show a satisfactory reduction.
- With chamfering and filleting the value of induced maximum von mises stress

reduced by 34.03% ,von mises strain reduced by 33.99%.

- Induced normal stress is reduced by 44.9%, and induced normal stress is reduced by 37%.
- Weight is optimized by 0.16%.

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