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Design and Analysis of Five Cylinder Radial Engine

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ABSTRACT
Radial engines have been used for a long time in the aviation industry where high performance and less space consumption were required. But with the inception of turbine engines they turned obsolete. Through this paper we will be validating a 5-cylinder MOKI-S 400 against the operating conditions and verified using FEA program. The designing of the engine is done using Catia V5 and Factor of Safety is obtained through analysis in ANSYS.

General Terms
<u>Young's modulus</u>: It is the ratio of stress along an axis to strain.

<u>Yield stress</u>: It is that value of stress after which the material ceases to behave elastically.

<u>Factor of safety</u>: It is the ratio of maximum stress that a material can withstand to the estimated stress that a material will undergo during its life.

<u>Poisson's ratio</u>: It is the negative of the ratio of transverse to axial strain.

Keywords
Crankshaft, internal combustion engine, piston pin, FEM, fatigue, equivalent stress, piston rings.

1. INTRODUCTION
The Radial Engine is a reciprocating type internal combustion engine configuration in which the cylinders point outward from a central crankshaft like the spokes on a wheel. In a Radial Engine, the pistons are connected to the crankshaft with a master-and-articulating-rod assembly. One of the pistons has a master rod with a direct attachment to the crankshaft. The remaining pistons pin their connecting rods` attachments to rings around the edge of the master rod. Extra "rows" of radial cylinders can be added in order to increase the capacity of the engine without adding to its diameter.

2. FEM DETAILS AND MATERIAL PROPERTIES

2.1 Material data
Table 1. Mechanical properties

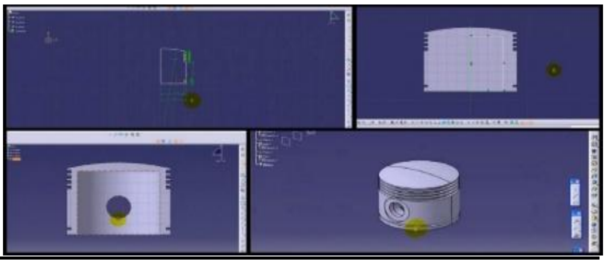
Material	Y(Pa)	μ	B(Pa)	G(Pa)
Al 7075	7.17E10	0.33	7.02E10	2.69E10
Al 4032-T6	7.0E10	0.33	6.86E10	2.63E10
Al 2117-T4	7.1E10	0.33	6.96E10	2.66E10
12L14 steel	2.0E10	0.28	1.51E11	7.81E10

2.2 Assumptions
- Material is homogenous and isotropic.
- Any type of non-linearity won't be considered in analysis.
- Analysis carried out was steady state.
- Current design will be considered as baseline design.

3. DESIGN AND DETAILS OF MODEL PARTS
During the designing of the engine we used construction parameters of already designed engines.

3.1 Piston
<u>Material</u>: Aluminum alloy 4032-T6

<u>Construction in catia V5:</u>



3.2 Piston Bolt
<u>Shaft material</u>: Steel 12L14

<u>Rivet material</u>: Aluminum alloy 2117-T4

Piston bolts are made of a Precision shaft and two little rivets that are connected to the shaft at the ends. The piston bolt is

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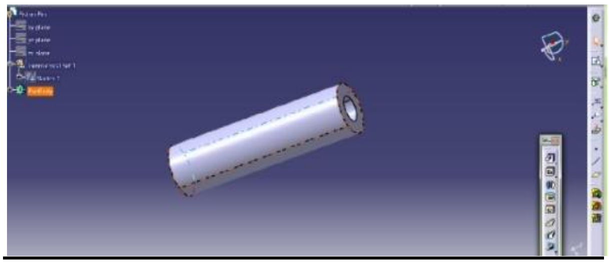
subjected to varying in size and direction load, causing surface tension pressure, bending and shear.

Construction in Catia V5

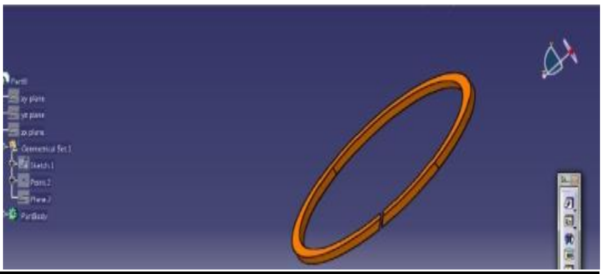


3.3 Piston Rings

Material: Steel 12L14

Piston rings provide a tight cylinder space. They work at high temperature and variable loads. The piston material should have high elasticity, durability and low coefficient of friction with the cylinder walls. Materials that are used for these rings are alloy cast iron with chromium, nickel, copper titanium and other materials.

Catia V5 construction

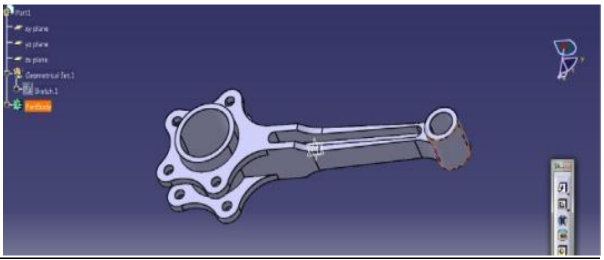


3.4 Master Rod

Material: Aluminum alloy 7075

When the engine is working the piston rod is under direction gas forces and inertia forces. That is why it is made of high quality steel with high resistance of fatigue. The piston rod is contained by upper head, trunk and lower head.

Catia V5 construction

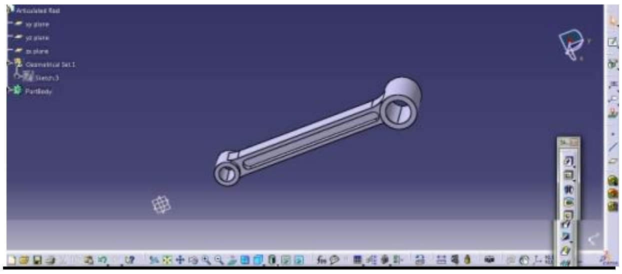


3.5 Auxiliary Rod

Material: Aluminum alloy 7075

The auxiliary rods are the connecting rods between the master rod and the other pistons of the radial engine.

Catia V5 construction



4. FEA of baseline design

4.1 Stress on master rod and piston assembly

Applied load: 8.3 Mpa

Piston

Table 2. Mechanical property values for piston

Material	Total deformation	Equivalent stress	Yield stress	FOS
AL 4032-T6	3.4633E-004m	6.863E+007 Pa	3.31E+008Pa	4.822

At master rod

Table 3. Mechanical property values for Master Rod

Material	Total deformation	Equivalent stress	Yield stress	FOS
AL 7075	2.2059E-004m	1.4511E+008 Pa	1.4556E+008 Pa	1.003

At piston rings

Table 4. Mechanical property value for piston rings

Material	Total deformation	Equivalent stress	Yield stress	FOS
Steel 12L14	2.6824E-004 m	1.5717E+008 Pa	2.35E+008 Pa	1.495

At piston bolt

Table 5. Mechanical property values for piston bolt

Material	Total deformation	Equivalent stress	Yield stress	FOS
AL 2117-T4	2.5742E-004 m	1.3901E+008 Pa	1.65E+008	1.186

Effect on total assembly

Table 6. Total deformation and equivalent stress values for whole assembly

Material	Total deformation	Equivalent stress
Mentioned Above all	3.4671E-004	1.5717E+008

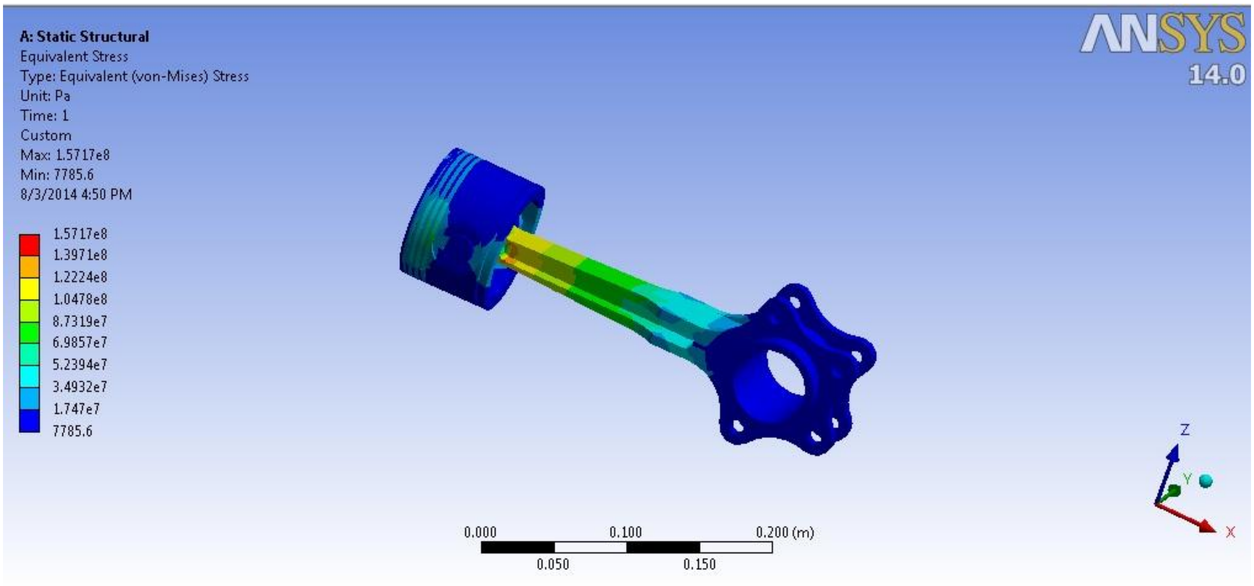


Fig 1: Equivalent Stress Analysis of final Assembly

5. CONCLUSION

The designing of a radial engine is indeed a very complicated process which involves series of other processes and design calculations that are needed to be performed for designing. Although not that used nowadays radial engine was very helpful in aerospace transportation and mainly used because of its small weight and size. That makes it comfortable and suitable for any machine that is close of space. Despite of its small size and weight it does not make it less powerful than other engines.

We designed this engine in two stages, first of which was gathering the information about the orientation and working of the engine and detailed process of its designing which was done on Catia V5. The next stage was the stress analysis of the engine so as to know the behavior of its various parts under desired performance conditions. it was noted that all the parts were under the design limits of yield stress for given pressure conditions and finally the Factor of Safety was calculated for the given engine.

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