Creep Failure in a Piston

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Abstract – Engines are subjected to many kinds of mechanical stresses which include fatigue, creep and so on. Due to the pre and post combustion of fuel in engine, knocking and mechanical damage to engine parts occur frequently. This further leads to engine malfunction and hence reduces working life as well as efficiency. Among many other factors leading to engine damage, this research work specifically focuses on CREEP FAILURE in piston and engine parts.

Keywords – Piston, Creep, Failure, Stress, Engine,IC Engine, ANSYS

INTRODUCTION TO CREEP FAILURE

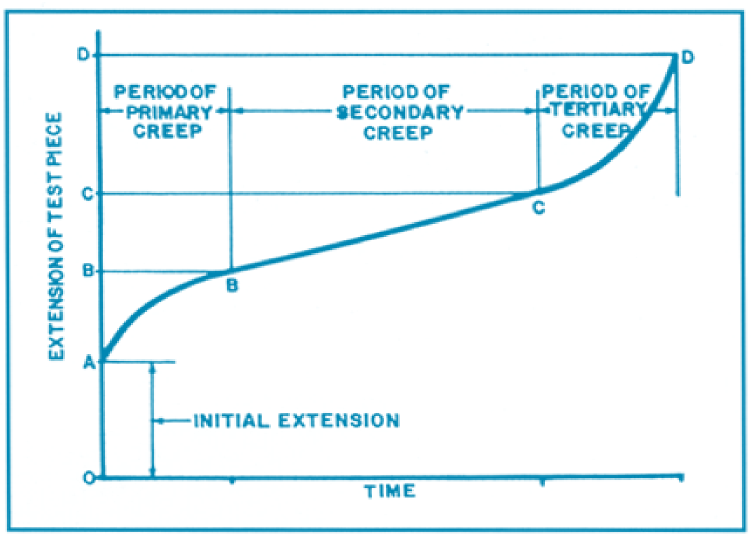
Creep is the application of mechanical stress well below yield point of the material, which occurs over a wide span of time.

The are three stages of creep failure

- Primary Creep (Stage I): It marks the beginning of the failure and occurs at a faster rate. It follows a decreasing parabola in Strain-Time curve.

- Secondary Creep (Stage II): In this stage the material's failure becomes steady, this stage is also called a steady state creep. It follows a straight line in Strain-Time curve.

- Tertiary Creep (Stage III) : In this stage the creep accelerates and finally leads to the necking and hence failure of the material. It follows a increasing parabola in Strain-Time curve.



ENHANCEMENT OF CREEP BY HEATING

- Engines undergo high temperature operation due to proper and improper timed- combustion.
- This generates an environment favorable for piston failure by creep.
- The cyclic action of a piston provides stress on the piston head for a long term, and heat enhances the activity. This, combined with improper lubrication and insufficient cooling will lead to a condition drastically affecting engine parts.

WHY PISTON ?

Piston is one of the most essential parts of an engine. It is responsible for oscillatory motion of the connecting rod, which further rotates the crankshaft, and hence helps convert chemical energy of combustion into mechanical motion. Without the piston element, engines would cease to exist. The piston is exposed to four strokes : suction stroke, compression stroke, power stroke and exhaust stroke.

During the power stroke the piston is subjected to extreme conditions , namely high exposure to heat(300 degrees Celsius) and pressure (3.5 MPa). Consequently, during the exhaust stroke it reaches approx. 400 degrees Celsius as well.

Both these strokes involving high heat conditions, and repeated mechanical stress well below the yield point of the piston's material for a prolonged span of time pushes the piston to be in a condition vulnerable to creep failure, as it subsequently matches all the respective criteria required for creep failure.

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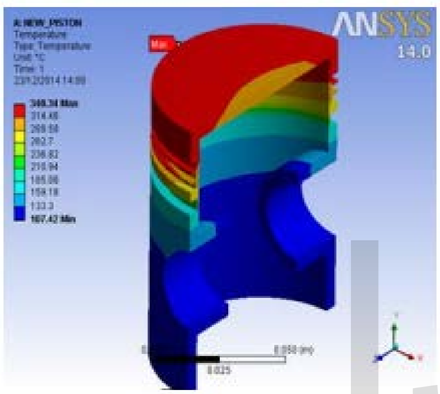
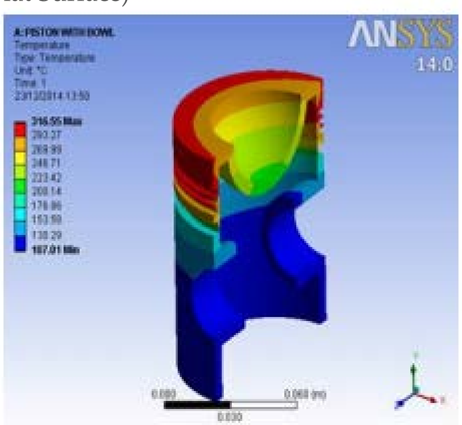
EXPERIMENTAL EVIDENCE (ALUMINUM ALLOY FLAT PISTON AND ALUMINUM ALLOY BOWL PISTON)

We used the following set up for our experimental analysis for our research topic:

1. Engine : 4- stroke single cylinder(KIRLOSKAR/AV1)
2. Pistons : Al alloy flat and Al alloy bowl
3. Stroke length : 110 mm
4. Method of cooling : Water-cooling
5. Fuel : Diesel
6. Method of Ignition : Compression ignition
7. Software used : ANSYS 14.0



Temperature Distribution for aluminum alloy (Flat Surface)



Temperature Distribution for aluminum alloy (Bowl Surface)

Properties	Aluminum Alloy Flat Piston	Aluminum Alloy Bowl Piston
Temperature (ºC)	340.34	316.55
Deformation (m)	0.00026	0.00031
Heat Flux (W/m^2)	3.28×10^6	3.19×10^6
Shear Stress (Pa)	3.29×10^7	5.51×10^7
Thermal Stress (Pa)	1.135×10^8	1.12×10^8

RESULTS AND DISCUSSION

In the above experimental setup, we used Al alloy flat piston and Al alloy bowl piston for our analysis. Here we used a four-stroke single cylinder engine (KIRLOSKAR/AV1) and used the engine's piston for efficiency analysis in reference to creep failure in pistons.

Here we used ANSYS 14.0 software to analyze the subsequent Temperature, Deformation, Heat Flux, Shear Stress and Thermal Stress with respect to both types of piston. This in turn led us to the calculation of mechanical efficiency after a period of consequent application of thermal and structural stresses (Stress due to mechanical application and heat). Hence, by our findings through our experimental analysis, we arrived at the conclusion that the above mentioned thermal and structural stresses does in fact lead to the creep failure, satisfying all the conditions for it namely high heat exposure and repeated mechanical stresses for a long span of time, which does nothing but reduce the engine efficiency, leading to engine failure in the distant future.

This problem is inevitable as the temperature and the pressure conditions aren't changeable. Hence there is a need to resolve this problem. Two important and maybe the only solutions to the problem may be sufficient lubrication, which will reduce the direct mechanical contact

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between surfaces, and cooling which will reduce the exposure temperature of the piston in discussion here.

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