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Mathematical Modeling and Analyzing of Piston Rings Used in Piston Cylinder attachment of the IC Engines

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ABSTRACT

This paper presents the piston ring sealing used in the piston cylinder attachment of the IC Engine. This developed model with the integrated model of gas and temperature in the arrangement as well as the displacement caused in the piston ring would be taken into account. Due to compression of the fuel, temperature may raises about 600 ^{o}C and pressure around 32 to 50 bar pressure so the thermal deformation takes place and wear of the piston ring occurs. Hence a mathematical model has been required for the safety operation of the piston ring and to obtain permissible limit range of working. This can be also implemented for the life time calculation. This paper describes about the assumptions made for obtaining the model as well as simulation of the obtained results in Solidworks as well as the Matlab Software.

KEYWORDS: *Mathematical model, Thermal deformation, displacement of rings, piston ring.*

I. INTRODUCTION

Piston ring acts as a sealing device to minimize the leakage caused in the system. It should maintain high degree of contact with the surface of the cylinder. Simultaneously, it would act as a slider bearing due to sliding motion of the piston along the surface of the cylinder and also lubricated hydro-dynamically. Hence, it should have low coefficient of friction. Also, it should be ensured that it consumes minimum lubrication oil and runs for a long time [5, 13, 18 and 23].

On considering the gas flow type, the most cases it would be assumed as the abyrinth sealing in which the gas may flow between the various stages by means of the gap between the rind and the cylinder. Various factors like pressure difference, Viscosity and some other factors influence the flow of the gas. [1] He developed model that would satisfy the perfect gas laws and flow may be considered as isoentropic or adiabatic flow, when the fluid flows through an orifice.

Position of the rings and force exerted by it are the two major factors considered by most of the researchers. It decides the inner and behind ring spacing is connected. When the volume of the behind ring is greater than the inner ring, the accumulation action would takes place. In order to obtain the fine results they developed the integrated model of the gas flow along with the model of the axial displacement of the rings placed within the grooves [12, 8, 25, 9, 22 and 24]. In [19] the coefficient of the flow depends on the pressure ratio before and after the orifice. The approach of the mass flux determination was implemented in the model [8, 9 and 20].

In most of the assumed adiabatic process, the flow would be assumed to be laminar and have low values of the Reynolds number usually less than 2000. The entire system may be assumed as the heat exchanger system (DOF = 3) where the exchange of the heat takes place between the gas and the surrounding walls [15, 19 and 20]. On considering the above factors [5,8] does not assumes the process as an isothermal process. Some authors [6, 9, 13 and 21] had developed the model to obtain various thermal parameters such as adiabatic index, temperature, pressure and so on.

On this article, we had assumed the process as an adiabatic or isoentropic process with laminar flow type so that the uniformity of the flow is obtained.

Reynolds Number < 2000

II. Design of Gas Flow Model

Piston Model- Stress Analysis

Figure 1 and 2 shows the solid model of the piston along with the piston ring design developed by using the SolidWorks software. The various parts are designed individually and the entire model was assembled using the Solidworks.

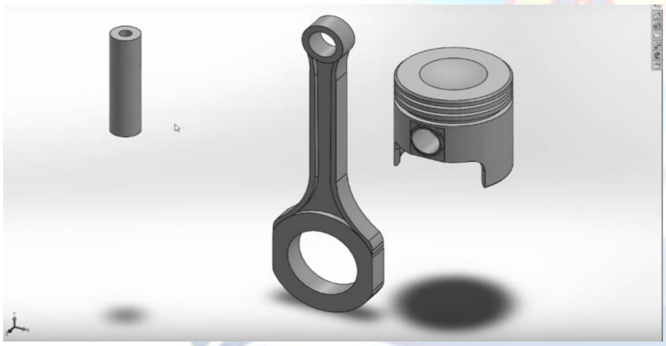

Figure 1 Part Model of the Piston

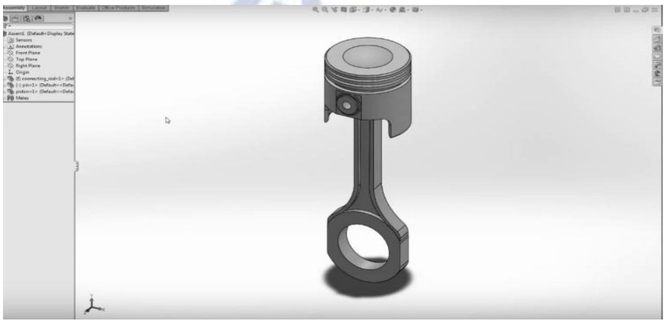

Figure 2 Assembled Model of the Piston

From the above mentioned figure, piston ring could be easily indentified. The above mentioned assembly was subjected to stress analysis for which the parameters are selected as shown in the Figure 3 and the stress induced in the part are indentified in the Figure 4.

Property	Value	Units
Elastic Modulus	7.9e+010	N/m^2
Poissons Ratio	0.34	N/A
Shear Modulus	2.6e+010	N/m^2
Density	2680	kg/m^3
Tensile Strength	380000000	N/m^2
Compressive Strength in X		N/m^2
Yield Strength	315000000	N/m^2
Thermal Expansion Coefficient	1.94e-005	/K
Thermal Conductivity	138	W/(m·K)
Specific Heat	850	J/(kg·K)
Material Damping Ratio		N/A

Figure 3 Selected Parameters

Figure 4 Stress Analysis

From the Figure 4 it should be noted that there would be more stress concentrated at the top of the piston arrangement that the stress concentration factor for the piston ring would be sufficiently more so that the design of the piston ring should be sufficient enough to withstand the stress and to capable for long life performance. Most of the load induced would be the distributed load.

Piston Ring Model – Force Analysis

Figure 5 shows the piston that can be used as the gas seal function in which the fluid flows from the top to bottom and the forces acting are resolved to three directions and they are:

1) Force along the X-axis on which the piston ring rests on.
2) Force along Y-axis which may be due to the fluid flow that would be restricted by the piston ring produces the downward movement.
3) Another force along Y-axis known as the reactive force that pushes and counter reacts the force which pushes the piston ring downwards.

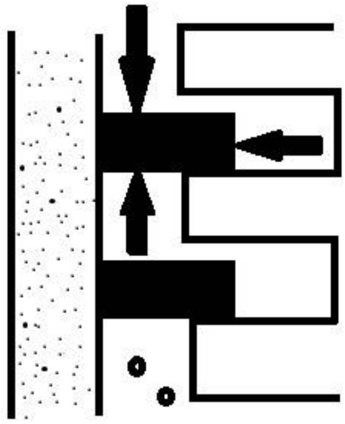

Figure 5 Gas Seal Function

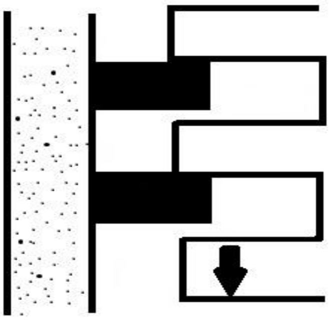

Figure 6 Gas Seal Function

Figure 6 denotes the movement of the piston ring from the bottom position to the top position after the gas flow takes place. As discussed the force analysis are shown in the Figure 7.

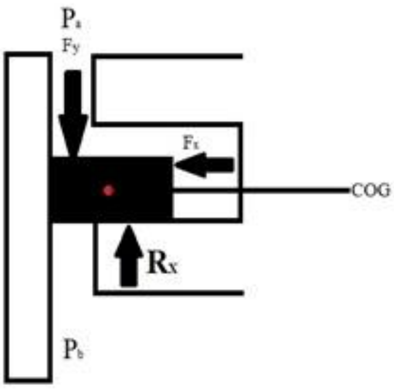

Figure 7 Force Analysis

In the Figure 7, F_X indicates the force along the X-axis, F_Y indicates the force along Y-axis and R_X be the reactive force developed. Here, COG is the Center of the Gravity in which the whole mass of the piston ring arte said to be concentrated and it can be easily calculated by considering as the rectangular cross section.

Assume that there is no leakage of gases.
The Horizontal Forces may be given as,

$$F_X = 0$$

Vertical Forces can be resolved as,

$$F_Y = -R_X$$

Summation of the horizontal and the vertical forces are assumed to be zero. So that the above mentioned equation becomes,

$$F_X + F_Y = F_X - R_X$$

Therefore, it may be noted that the forces exerted due to the gas flow must be less than the reactive force developed by the piston ring in order to achieve the effective sealing performance.

Simscape Model

The Solidworks model has been converted into .xml file and it have been imported into the Matlab environment to obtain the simscape model for the so designed piston ring as shown in the Figure 8.

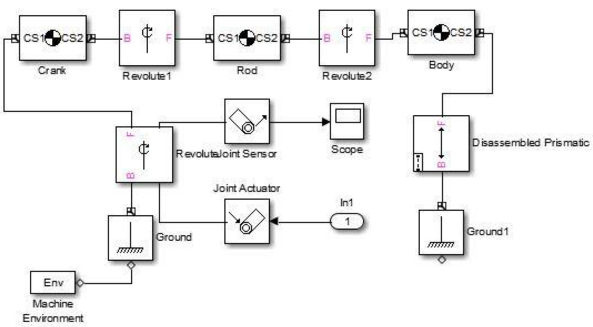

Figure 8 Simscape Model

III. Conclusion

From the analysis we could be able to find a conclusion that, for the Poisson ratio about 0.34 the value of the stress concentration factor is found to be minimum and hence the notch sensitivity reduces so the lifetime of the piston ring can be improved to a extent than in an ordinary condition. And the force should not exceed the yield point stress also the value of the thermal sensitivity should be low in order to have the low thermal stress.

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