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Dynamic sealing design for Wankel Engines

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ABSTRACT

The development of the Wankel engine is mainly dependent on the solution of the apex and face seal. In the Wankel engine, one of the major disadvantages of power loss is the improper sealing between the rotor and cylinder wall. To overcome this problem we can use the following modified design of sealing. This dynamic seal provides efficient sealing and along with this, a modified lubrication system is also implemented which helps to prevent the burning loss of lubricating oil inside the cylinder. This two possible modification can help to get lower wear and tear of seals, lower exhaust emission gases and also it will help to prevent the loss of lubrication oil inside the engine.

Keywords*— Wankel engine, Apex sealing, Lubrication, Rotor*

1. INTRODUCTION

In different kind of compressors, pumps, hydraulic motors and combustion engines rotary pistons are used from the 18th century [1]. Several steam engines with rotary pistons were patented in the 19th century. And later on, internal combustion engines were produced with the same design in the 19th century. The Wankel engine was also invented during 1954 by German engineer Felix Wankel [2]. In all these machines continuous and tight separation of working volumes is very important. To achieve such tight and active conditions we need an effective seal [3]. But the designing and construction of such seals are very difficult due to dynamic mechanisms of the units. The same problem also applied to the Wankel engines in which the tight sealing is required between the oval rotary piston and the epitrochoid housing wall. Along with these three seals, one more seal is also required on side walls of the piston for vertical gas leakage prevention.

2. CONSTRUCTION OF WANKEL ENGINE

In this internal combustion engine rotor which acts as a piston is kept inside epitrochoid shape housing. The rotor of the Wankel engine consists of three faces which act as a combustion chamber. The rotor rotates about the eccentric shaft at the same time it rotates around its own axis. [1]

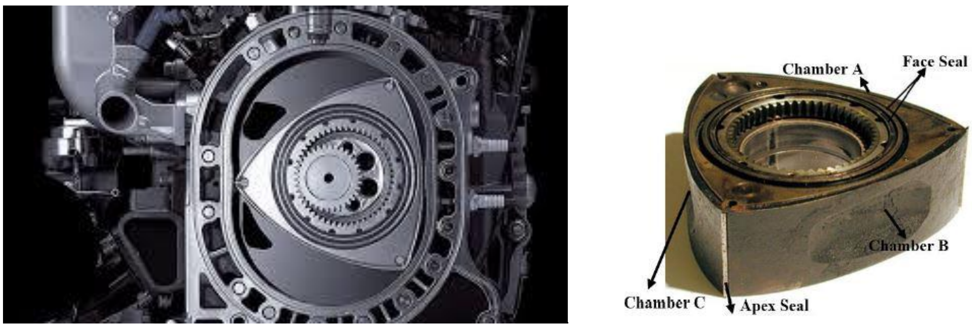


Fig. 1: Construction of Wankel engine

The rotor inside this engine contains two different types of sealing one is apex sealing and second faces sealing. This both seals provide a sealing effect between rotor and engine housing to prevent the gases coming out of the engine. [12] Apex seal provides a sealing effect between the edge of the rotor and housing wall of engine and face sealing is used between the side wall of the rotor and engine. As shown in picture this different sealing are used on different place of the rotor. These seals are typically made out of the same material which is used to make piston rings for conventional engines. These seals are equipped with the spring or flexible strip to overcome the force acting during combustion on seals and also to make a dynamic contact between the rotor and wall housing. The pushing element like spring is very necessary for this seals but this mechanism also leads to the friction of the seal material. To avoid this friction a dynamic lubrication system is also required which will feed the lubricant to the seals in the proper amount. To provide lubrication for the seals the wall housing is covered with oil from inside. Due to this conventional lubrication, the Wankel engine does not meet the latest EURO regulation.

3. CONVENTIONAL APEX SEAL DESIGN IN WANKEL ENGINE

As shown below in picture 1 the apex seals are made of a flat plate with the same material of the piston ring. Total of three apex seals is used in this rotor design. To get a constant contact between flat plate and housing wall a retainer flat strip of flexible material is used. The length of the plate depends on the depth of the flat working chamber. Generally, the height of the plate is three times longer than the thickness of the plate [4]. The thickness depends on the size and proportions of the trajectory of the apex seals plate.

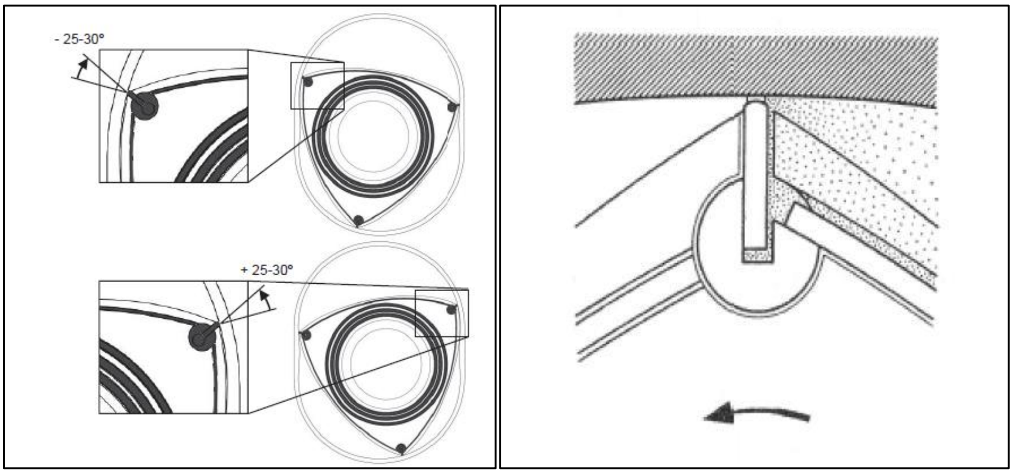


Fig. 2: Conventional seal design in the Wankel engine

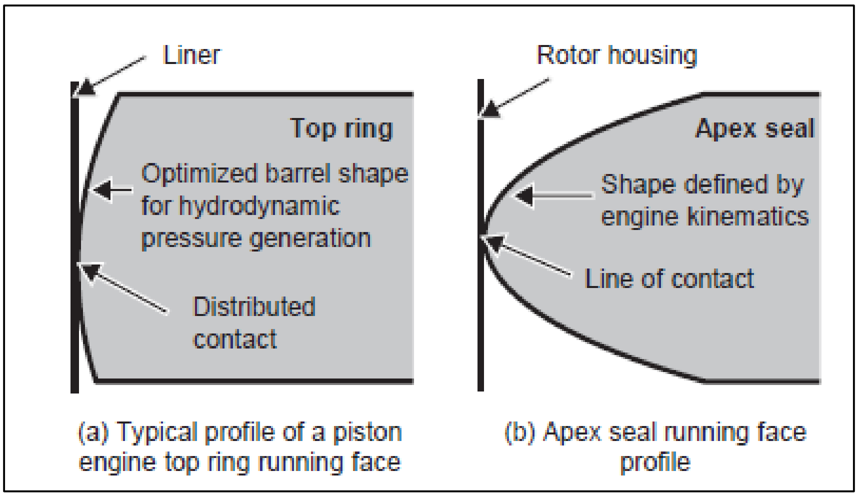


Fig. 3: Comparison between conventional piston top ring cross-section and Wankel apex seal

Numerous empirical studies and research are done to wear rates of the apex seals for different materials, coating, and working conditions. [4-11] Knoll et al. [12] presented a few apex seal dynamic models in his paper.

4. DIFFERENT FORCES ACTING ON THE APEX SEAL

Fig.4 represents the apex seal and the forces which are acting on it are mentioned. This conventional seal free body diagram helps to understand the principal type of forces: gas force (Downward direction), spring force (Upper direction), the contact reaction forces and friction. Gas forces are initiated by gas pressure created inside the chamber. The opposing force is created by the spring which helps to provide the sealing. The contact forces are created by the reaction forces and frictional forces are proportional to the contact forces and opposite in relative motion direction.

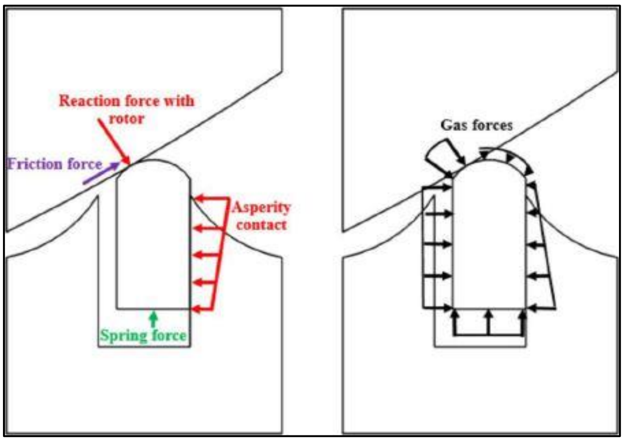


Fig. 4: Major acting forces on Apex Seal

5. CONVENTIONAL LUBRICATION SYSTEM IN WANKEL ENGINE

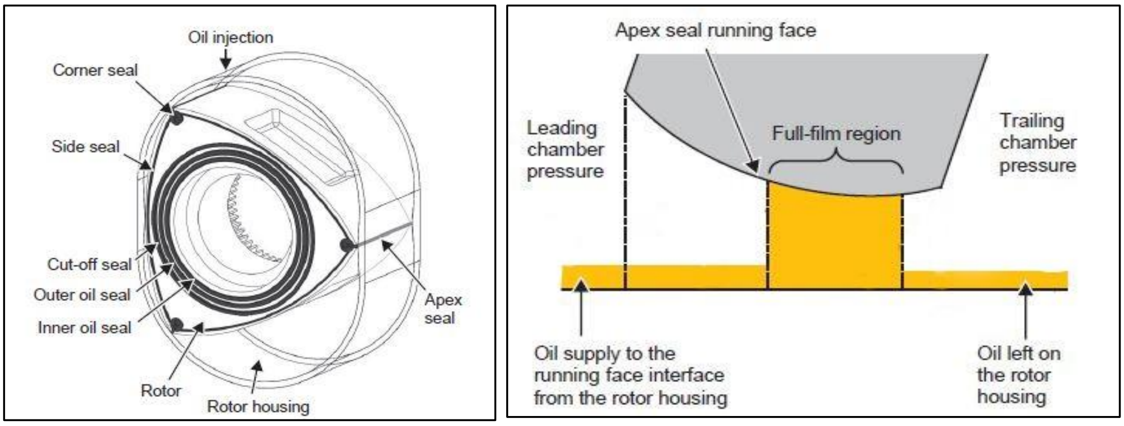


Fig. 5: Lubrication System and oil contact with the apex sealing in Wankel engine [14]

In the Wankel engine, the lubrication between the rotor and wall housing is an unavoidable requirement due to continuous friction. For this purpose inside the housing wall of the engine at different locations lubrication holes are provided. These holes are connected to the lubrication pump. Due to this design, the lubricant is injected inside the chamber and the complete chamber wall and rotor wall will be covered with the lubricant. As shown in fig.5. The lubrication equation, pressure boundary equation and mass conservation,

Disadvantages of this lubricating system are- excessive lubricating oil requirement, loss of lubricating oil during combustion, emission level increment, increment in total maintenance, unnecessary lubrication of engine parts. [13]

6. NEW IMPROVED DESIGN

As shown below in the following picture a possible new design of apex seal can be used which can be more effective than the conventional one. This design is developed by using CATIA V5 designing software.

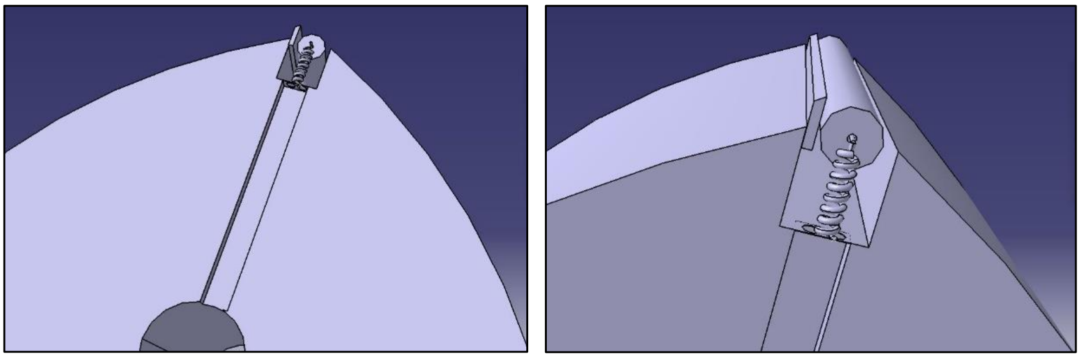


Fig. 6: Improved design of sealing

In this design instead of a single flat apex seal, we have to use one roller seal and one flat seal as shown in the figure. The roller will be joined to the central shaft which allows it to rotate freely in the specified area. This central shaft will be connected to spring and the other end of the spring will be connected inside the cavity of the rotor. Beside this roller one flat plate with brush seal is used. The purpose behind using a brush seal is to get back the lubricant inside the cavity of the rotor from where it comes. So that less lubricant will get used and loss of lubricant will be prevented drastically.

7. NEW POSSIBLE DESIGN OF LUBRICATION SYSTEM

To provide better and economic lubrication inside the Wankel engine we have to use a system which provides lubricating oil as per requirement and also must be helpful to prevent the oil loss by burning the oil inside the chamber during combustion. For such an idle system we can use a cavity inside the rotor this cavity opens to apex seals and the other end will be connected near the eccentric shaft of the rotor. The lubrication pump will provide the lubricant to the cavity and due to centrifugal force lubricant will get equally distributed to each end of the rotor where the apex seals are installed. The design of the apex seal will help to prevent the lubricant loss.

Here to calculate the gas pressure and leakage flow we can use Poiseuille flow because of the gases in channel flow at a greater speed than the apex. [16] The gas flow can be calculated by integrating the cubic height of the channel.

$$q = \frac{\Delta P}{12\mu \int_0^{Lc} h^{-3} dx_c}$$

In which ΔP is the pressure difference at both ends of the channels, calculated based on pressure readings of the combustion chamber, μ is the dynamic viscosity of the fuel, h is the height of the channel, x_c is the distance in channel direction [15-16]. Here the gas flow is considered as an incompressible for the calculation ease.

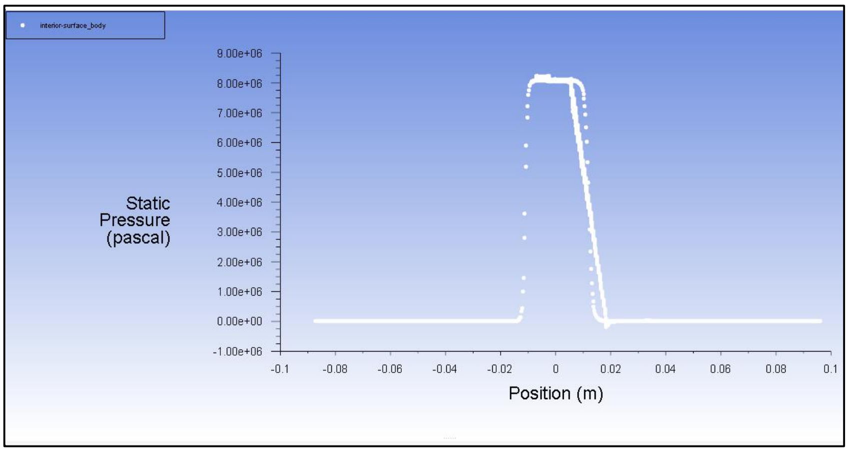


Fig. 7: Static Pressure graph inside the oil channel and near the end of the channel for one rotation

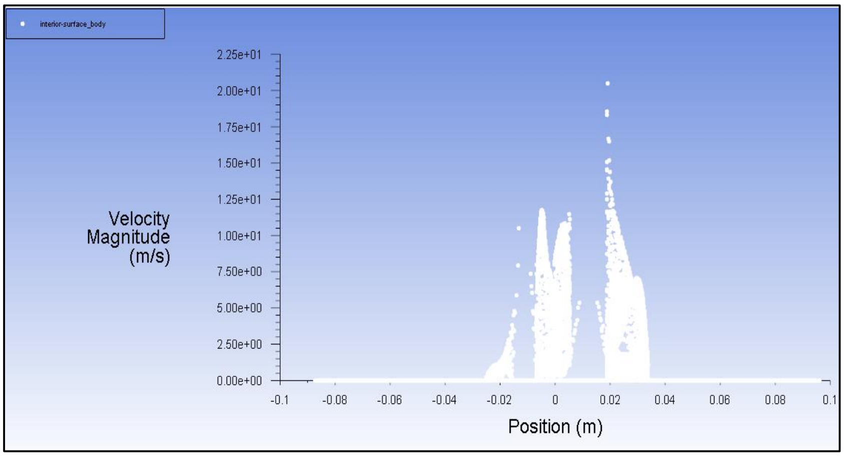


Fig. 8: Velocity graph inside and at the end of the channel for one rotation

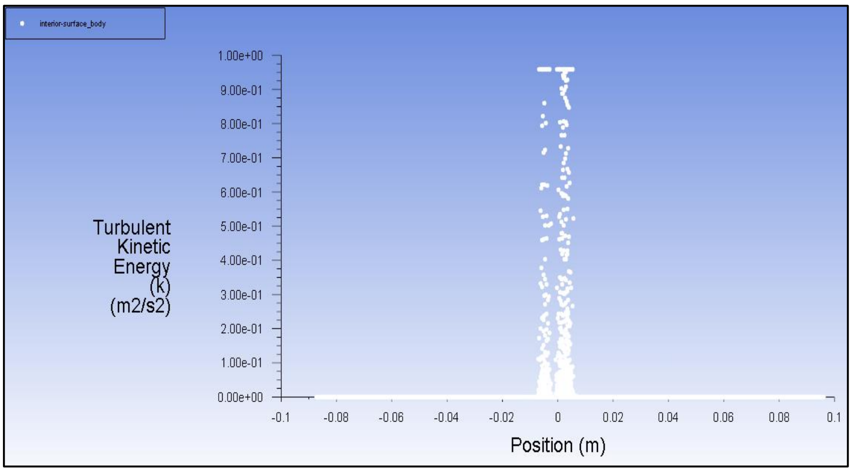
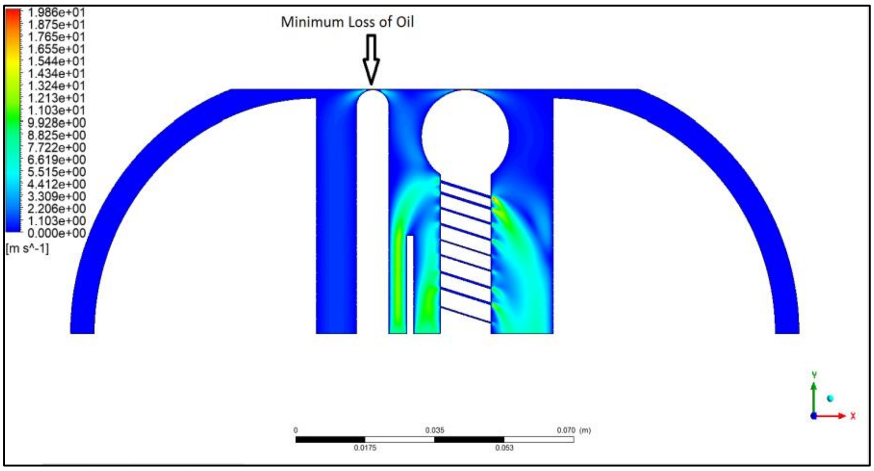
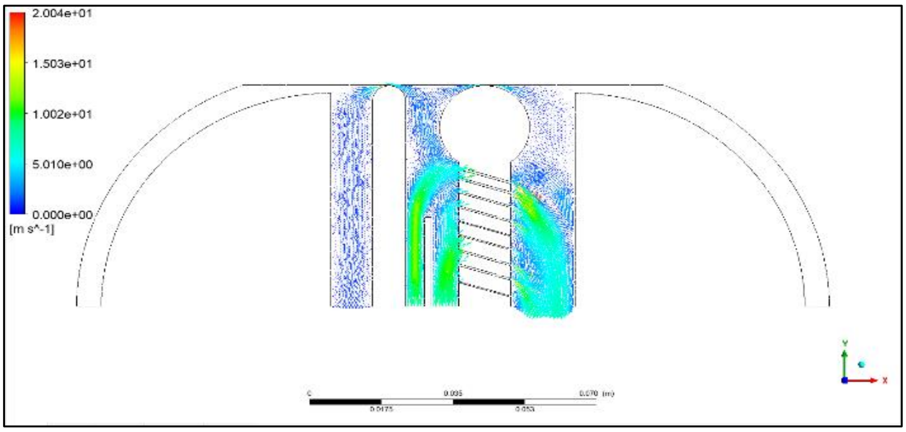


Fig. 9: Turbulent energy graph inside and at the end of the channel for one rotation



(a)



(b)

Fig. 10: (a), (b) Oil flow CFD analysis inside and at the end of the channel for one rotation

Here by using the ANSYS CFD software we did the 2D oil pressure, velocity and flow analysis. The hydrodynamic pressure generated by the oil is being considered here, due to hydrodynamic pressure there must be leakage loss will be there which can be observed from figure 10.

As shown in figure 3 in the oil galleries we have two holes at the bottom of the apex seal floor, so that the oil flow inside the oil channel will help to save the seals from being worn out, which increase the lifespan of the seal and also of the rotor. The different graphs also prove that this new design will be efficient for the rotor and can be satisfactorily used for real test experiments.

8. CONCLUSION

The seal inside the Wankel engine is very essential and responsible part for better fuel efficiency, proper utilization of fuel power and emission. This paper shows the possible improvement in the design of the seal and lubrication system for Wankel engine rotor which will serve better fuel efficiency with proper utilization of oil and thus it will help to reduce the emission of the rotary engine. Based on the frictional analysis, and lubricating oil flow analysis done on ANSYS 19.1 software, this design gives the following advantages:

- Due to improved roller seal design, we can reduce the friction up to a good extent compared to conventional friction bearing.
- We can reduce the oil loss in the cylinder due to combustion.
- Due to less oil burning loss inside the cylinder the consumption of oil will be less.
- Due to less oil burning the exhaust gas emissions will also get reduced.
- Due to centrifugal force distribution of oil in the oil rotor galleries will be even.
- The total cost of sealing and oil maintenance will get reduce.

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