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RESEARCH ARTICLE

Design and Experimental Analysis of Eliptor Rotor

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ABSTRACT

Lubrication of IC engine is mostly done using a generated rotor (gerotor) pumps. The inner and outer gear tooth profiles are described by epitrochoidal (Conventional Gerotor) profile. Due to their compact design, low cost and robustness, gerotor pumps are commonly used for lubrication systems for pumping liquids such as oil, transmission fluid, and fuel. Higher demand of automotive research needs higher efficiency gerotor oil pump. Efficiency of gerotor oil pump can be increased by increasing the pocket volume of gerotor, where increasing the pocket volume can be achieved only by deriving a new gerotor profile. Such an attempt is made here and derived a new gerotor profile using a maximum ellipse inscribed inside the root circle of both internal and external gears while ensuring the smoothness of profile to reduce the friction on rotation. Adopting a maximum ellipse profile and changing the number of tooths with conventional epitrochoidal gerotor boundary gives a minimum of 9% pocket volume raise (pocket volume raise will differ from each and every rotor set since the number of tooth has a major impact on pocket volume) in the new eliptor rotor.
Keywords: CFD, Gerotor, Eliptor rotor, Gear pumps, Trochoidal rotor.

1. INTRODUCTION

[1, 2] A gerotor is normally a positive displacement pumping device consisting of two rotors. The teeth of inner and outer include N and N+1, where N is greater than 2. While rotating the rotors during their cycle, both the rotor's volume vary, where it increases and then return to initial position. A vacuum is developed due to this volume increase which in turn forms suction, where intake occurs. In the same way, compression occurs due to the decrease in volume and as a result, fluids are pumped and gaseous types are compressed. In consideration of gerotor pumps, its inner rotor including suction and delivery is trochoidal based and the outer one is created on the basis of circular arcs using gearing mechanism. [3] Calculation of rotor speed using fluid dynamics was done. It stated that the impulse torque and frictional resistance determine its speed. [4, 5] Unusual vibration that occurs during the design of rotor was specified, where investigations are made in relation with the stability and bifurcation of such unsteady state using shooting mode. [6, 7, 8] The parameters such as overlap/aspect ratio, power coefficients and number of stages/blades impact would have impact over rotor performance and its optimization. [9, 10] Balancing of rotor has to be maintained for its normal functioning and to find out whether the rotor is in balanced state or not, measurement point vector method was used. [11] The applications of internal gear pump rotors are common in automobiles and oil pumps. Since the demand of fuel consumption is less and the need of hydraulic power is more, volumetric efficiency is expected much, whereas, the size must be lowered. In order to satisfy all these, P/M internal gear rotors were designed using new tooth profile. In terms of efficiency, the newly designed pumps show 10%, increase in discharge volumes compared to the typical pumps of same size.

Similarly, an attempt is initialized in this work that alters the rotor profile and teeth thus to enhance its discharge volume. Figure 1 and figure 2 describes the gerotor oil pump

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with its body, cover plate, ports, inner and outer rotor and PRV settings.

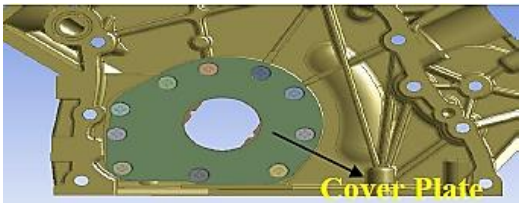

Figure 1.Oil pump with cover plate

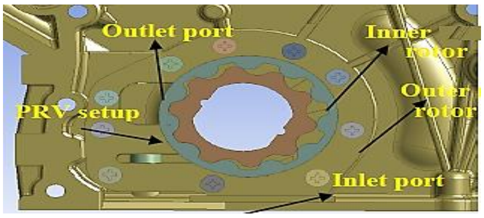

Figure 2.Parts of oil pump

1.1. Conventional epitrochoidal profile

[12] An epitrochoid is a curve outside of a circle, where the radius of the inner and outer (epitrochoid) circles are r and R respectively, where the distance between the curve point and the centre of the outer circle is d. The epitrochoid with R=3, r = 1 and d=1/2 is shown in figure 3.

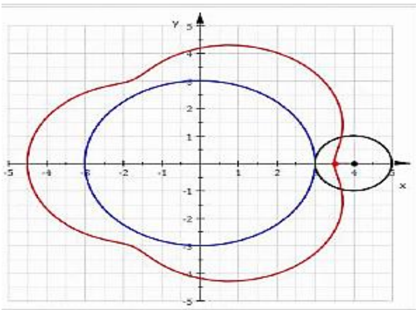

Figure 3.Epitrochoid profile

The following are the parametric equations of figure 1.

$$x(\theta) = (R + r)\cos\theta - d\cos\left(\frac{R + r}{r}\theta\right)$$

$$y(\theta) = (R + r)\sin\theta - d\sin\left(\frac{R + r}{r}\theta\right)$$

where, R and r denote base (blue) and rolling (red) circle radius, d refers to the distance between the rolling circle centre and the curve plotting point, θ is a parameter and X (θ) and Y (θ) are the points on X and Y axis in Cartesian co-ordinate system.

Epitrochoid profile points are obtained by the points X (θ) and Y (θ). The tooth of outer rotor is more than that of the inner rotor and the outer one is formed by the conjugate of the inner rotor. Derivation of different epitrochoid profile can be made by varying boundary condition and the radius of the base and rolling circle and distance, d. This type of epitrochoid profile with pocket volume is shown in figure 4.

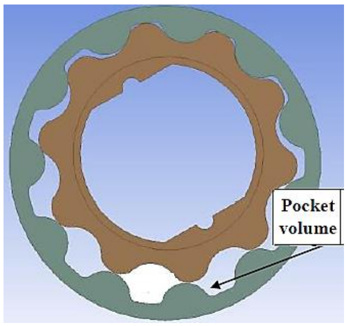

Figure 4.Conventional epitrochoid rotor set

1.2. Limitation of epitrochoid profile

The highest volume between the rotor teeth is the pocket volume. The role of Gerotor's pocket volume is noted in relation with oil pumping ability. In case of epitrochoidal model, the pocket volume is not variable if the boundary condition is fixed due to the categorization of equation. Changes in pocket volume is achieved by varying r, R and d. Oil pumping efficiency tends to degrade since the pressure angle of the epitrochoid profile is high.

2. Eliptor rotor design

Eliptor rotor is described based on epitrochoid profile and the performance between both the eliptor and epitrochoid rotor is compared. The parameters of the typical rotor are represented in figure 5.

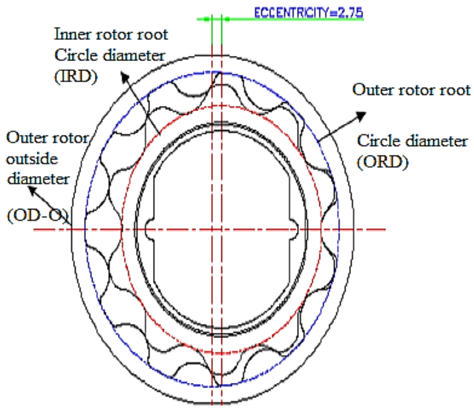

Figure 5.Critical parameters of conventional rotor unit

2.1. Parameters of epitrochoid rotor set

- Outer rotor outside Diameter =84.95mm
- Outer rotor Inside Diameter =65.6mm
- Outer Rotor Root Circle Diameter =76.5mm
- No of tooth's in Outer rotor =14
- Inner Rotor Outside diameter =70.8 mm
- Inner Rotor Root Circle diameter =60 mm
- No of tooth's in inner rotor =13
- Eccentricity =x-2.62272mm, y-0.82694mm

The parameters do not consider the number of teeth present and all these are employed in the design of eliptor rotor. These parameters aid in dealing with the performance criteria of the eliptor and epitrochoid rotors. In the design process, the inputs of eliptor rotor are obained from epitrochoid rotor and the development of a novel eliptor rotor is based on the following steps.

Step 1: Input from Epitrochoid rotor is used to develop a base profile as shown in figure 6.
OD of outer Rotor = 84.95mm
Root Circle diameter of Outer Rotor =76.5mm
Root circle diameter of inner rotor=60 mm
Eccentricity = x-2.62272mm, y-0.82694mm

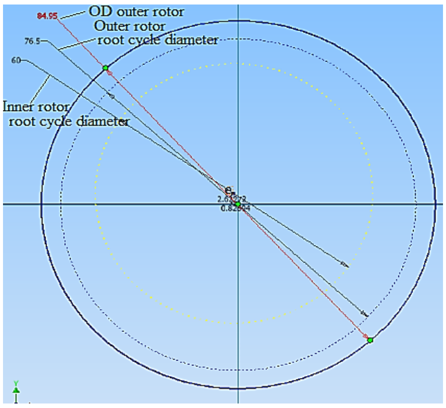

Figure 6.Base Rotor Profile

Step 2: Angle split up for an outer rotor tooth and tooth height from the existing epitrochoid rotor is plotted as shown in figure 7.

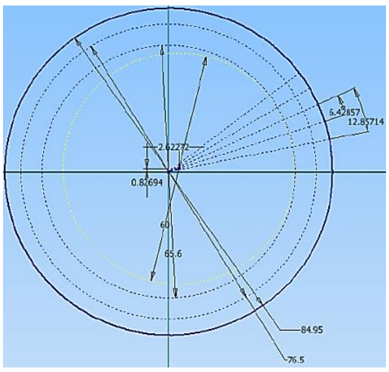

Figure 7.Angle split up & rotor tooth height

Step 3: Elipse formation with elipse center circle and various name plot is shown in figure 8.

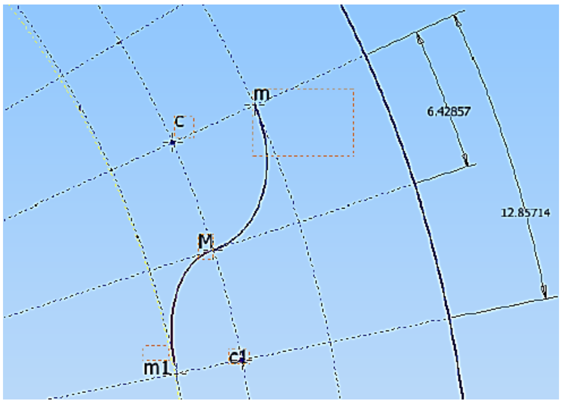

Figure 8.Ellipse Formation

Step 4: Total Profile development by mirroring and arraying is given in figure 9.

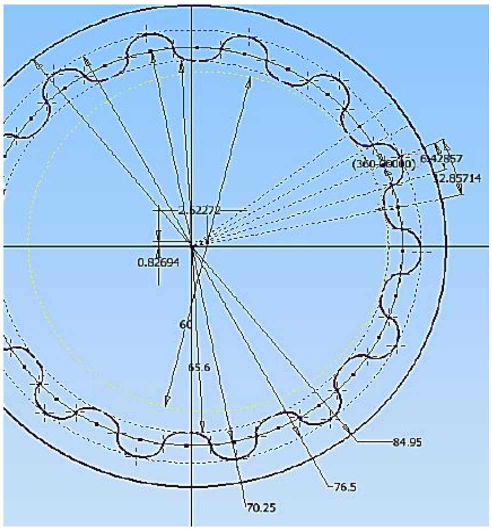

Figure 9.Outer rotor

Step 5: Development of total rotor set using conjugate method by commercial CADD software using sketch tool is represented in figure 10.

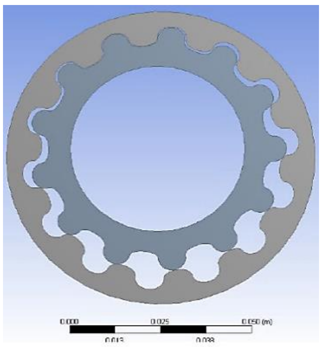
Figure 10.Total rotor set

3. Experimental test results and Comparison

3.1. Test rig

[13] TVS Sundram Fasteners Limited-Autolec division has its own test rig to evaluate the performance of oil pump, which consists of pressure gauges with inlet and outlet, flow meter with outlet and temperature gauge at oil tank with heater facility to heat oil with specific temperature up to 150°C. Speed meter such as digital tachometer of speed gauge has been coupled with digital display in RPM with 5± tolerance deviation.

Separate fixture is made to simulate the real condition of oil pump over the test rig to evaluate the performance of oil pump with different combination of inlet, outlet and RPM with temperature as variable parameters.

Figure 11.Test rig

Table 1.Four different RPM at different back pressure at outlet

No.	Speed in RPM Back	Pressure in bar
1 2 3 4	750 1000 1200 4000	1.6 2.8 2.8 5

Table 2.Epitrochoid rotor results

RPM	Back Pressure In bar	Epitrochoid Rotor	
		Flow in LPM	Power in kW
750 1000 1200 4000	1.6 2.8 2.8 5	4.0 4.2 6.2 10.3	0.32 0.38 0.43 1.75

Digital display meter is attached to the test rig that displays the variable parameters including flow in LPM, inlet pressure in kPa, outlet pressure in kPa, temperature in °C and pump speed in RPM. These parameters are used to plot the curve test rig with attached fixture. The digital display of the integrated circuit with oil pump mounted for testing is shown in figure 11.

Table 3.Eliptor rotor results

RPM	Back Pressure In bar	Eliptor Rotor	
		Flow in LPM	Power in kW
750 1000 1200 4000	1.6 2.8 2.8 5	4.7 4.8 6.8 12.1	0.3 0.36 0.42 1.65

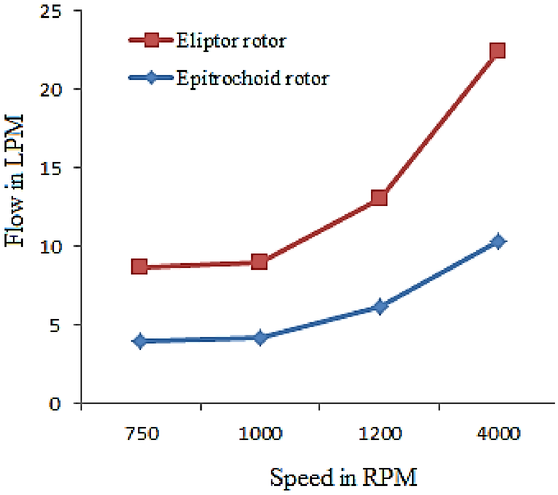

Figure 12.Flow comparison

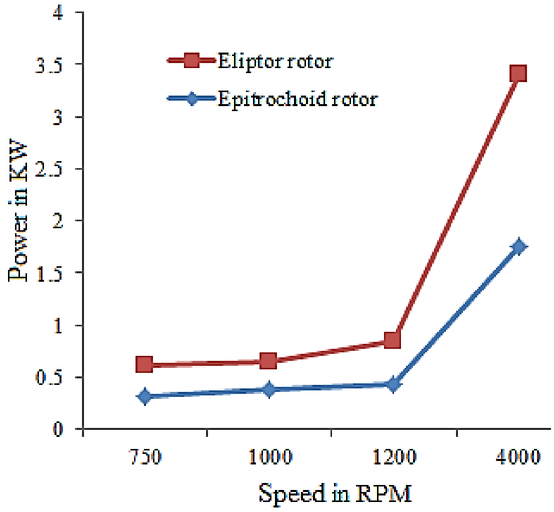

Figure 13.Power Comparison

In our case we have chosen four different RPM with different back pressure at outlet as shown in table 1.

Flow mapping for both epitrochoid and eliptor rotors are made out with different RPM and back pressure as listed in table 1 and the test results are given in table 2 and table 3.

Comparison of flow and power for epitrochoid and eliptor rotor sets are shown in figure 12 and 13.

3.2. Comparison result

On comparing the new eliptor rotor and epitrochoid rotor we found a minimum of 9% flow raise and a minimum of 2% power saving in all given specifications as listed in table 4.

Table 4.Flow raise and power saving %

S.no	RPM	Flow raise in %	Power saving in %
1	750	17.5 %	6.25 %
2	1000	14.2 %	5.26 %
3	1200	9.7 %	2.33 %
4	4000	17.5 %	5.71 %

4. CONCLUSION AND FUTURE RECOMMENDATIONS

In this study, we have developed a new rotor profile named "Eliptor" with varying number of tooth and rotor profile to achieve the higher theoretical volume of higher flow rate and less power consumption. These two parameters save the power consumption of IC engine. A new rotor is developed with a new profile methodology of ellipse approach. Both epitirchoid rotor and eliptor rotor sets are tested using same oil pump with different specification of RPM and back pressure. We observed a minimum of 9 % flow raise and 2% power saving with all specifications which is highly desirable for meeting out the current expectation of engine makers. As tip clearance of the rotor and porting design of oil pump has a vital role in oil pump efficiency, future study of this new eliptor rotor set with tip clearance and porting design is therefore to be carried out.

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This Eliptor concept is applied for patent (Patent application No : 201641035681) at the Indian Patent office

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