Design and Modelling of a Rotor Pump used in A12 Engine

Soe Htet Ko, Myint Thein

***Abstract*— Oil pump is a kind of pump which contains gear wheel. Liquid is forced it through the discharge port into the system. It sucks the lubricant from oil pan and sends the high pressure oil into the moving components of engine and machine to lubricate all engine components. The main aims of this research are to design the inner and outer rotors used in rotor pump for A12 Engine and draw the model of rotors by using AutoCAD software. From the design calculations, the results of the inner and outer diameters of inner rotor are 15.4 mm and 30.8 mm respectively, and for the outer rotor design, the inner and outer diameters are 31m and 38.7mm. And, the required parameters (widths of inner and outer rotors and radii of inner and outer rotor chest curves and root curve) of rotor pump design are also calculated. After that, the design calculated results of rotor pump are compared with the existing design for the design confirmation. Finally, the inner and outer rotors of rotor pump design are modelled by using AutoCAD software.**

***Index Terms*— Oil Pump, A12 Engine, Inner Rotor, Outer Rotor, Rotor Pump.**

1) INTRODUCTION

The operation of oil pump is to pump the lubricant from the oil pan through a suction pipe with a strainer welded at the front. The lubricant passes through an oil filter which is distributed to the main and big end bearings and continues to flow in jets on the connecting rod [6, 7]. After the filter, one of the oil galleries turns vertically towards the middle area of the cylinder head. In the cylinder head, there are two main oil galleries for the lubrication of the cam bearings and hydraulic tappets on the intake and exhaust sides. First, the lubricant is supplied to the hydraulic tappets [3].

The lubricant is supplied to the rear cam bearing at the end of the cylinder head main oil gallery. In the middle of camshaft, there is a long oil bore for lubrication of other cam bearings. The lubricant passes through the valve train in the cylinder head before flowing down to the oil pan through the several vertical oil bores [9].

In a rotor pump, the teeth of one gear project outward from the gear hub, the teeth of the other gear project inward toward the center of the pump. Internal gear pumps may be either centered or off-centered. The rotor pump consists of housing, an inner rotor and outer rotor as shown in Fig. 1. The inner rotor is shaped in the form of a cross with rounded points that fit in the outer rotor star. It is driven by a shaft turned by the camshaft [1, 2]. When the inner rotor turns, the rounded points walk around in the star-shaped outer rotor because it is mounted off center.

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Soe Htet Ko, *Department of Workshop, Mandalay Technological University, Ministry of Education, Mandalay, Myanmar, Phone/ +959256037591*

Myint Thein, *Department of Mechanical Engineering, Mandalay Technological University, Ministry of Education, Mandalay, Myanmar, Phone/ +959402534024*

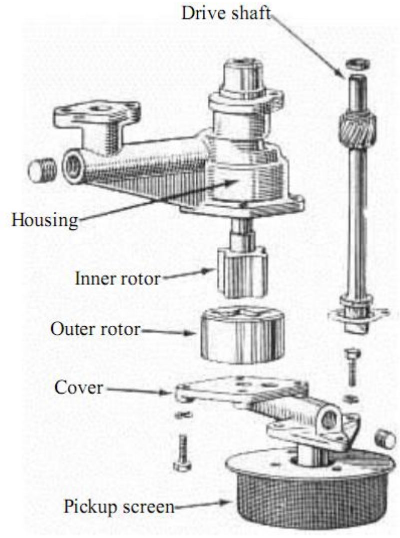


Fig. 1 Rotor Type of Oil Pump [4]

As the inner rotor walks the outer rotor around the outer rotor openings pick up oil at the inlet pipe and pull it around until it lines up with outlet. It is then forced out as the inner and outer rotor points close together. The outer rotor is cut away in the form of a star with rounded points [5].

The rotation of the center gear by the drive shaft causes the outside gear to rotate since the two gears are meshed. Everything in the chamber rotates except the crescent. This causes liquid to be trapped in the gear spaces as they pass the crescent. The liquid is carried from the suction port to the discharge port where it is forced out of the pump by the meshing gears [8]. The size of the crescent that separates the internal and external gears determines the volume delivered by the pump. Fig. 2 shows the inner and outer rotor oil pump.

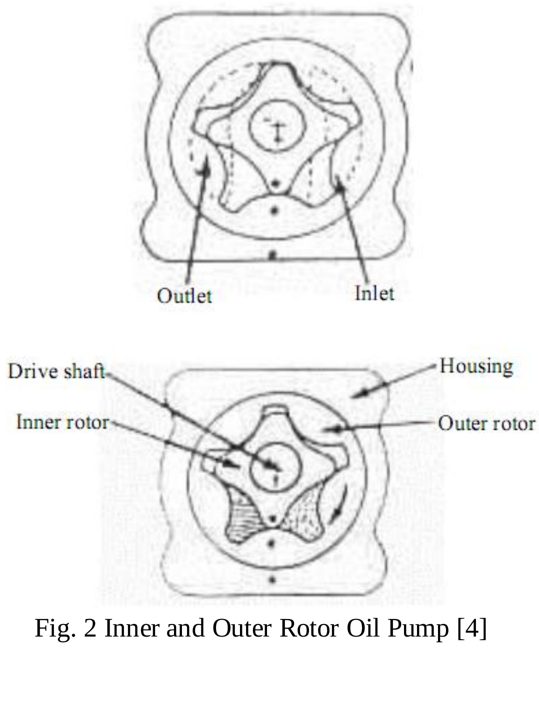


Fig. 2 Inner and Outer Rotor Oil Pump [4]

2) METHODOLOGY

Rotor pumps are arranged either inside or outside the engine and are rotated by a driving gear on the front end of the crankshaft or by the camshaft. In rotor pump case, the driving helical gear is made integral with the shaft and a pump is driven by the crankshaft [10]. In general, the crankshaft of an engine rotates at 1800~2200 rpm and the pump shaft rotates at 4000~5000 rpm. The gear ratios between the camshaft or crankshaft and the pump shaft range from 1.0 to 1.5. With the increased speed, the delivery coefficient of the pump decreases because of higher resistances in the suction line and the centrifugal effect which throws oil form the spaces between the teeth towards the inlet port. This effect can be prevented if the peripheral velocity of the working pump gears at the pitch circle radius does not simply exceed 10m/s.

A)Design Calculation of Rotor Pump

The amount of oil required to supply the bearing can be calculated by using the following Equation (1);

$$V_b = C n_r d^2 i_b \quad (1)$$

Where,

V_b = amount of oil required to supply the bearing, m³/hr
C = coefficient of speed
n_r= rated speed of crankshaft, rpm
d = diameter of shaft journals and crankpins, m
i_b = total number of crankpins and main bearings

The coefficient C is usually taken in the range of 0.01~0.05, if the engine speed is 1000 rpm or more.

B) Design Calculation of Inner Rotor

Amount of oil pumped to the bearings by the rotor pump can be calculated by the following Equation (2);

$$V_p = (1.7 \sim 2.5) V_b \quad (2)$$

For a pump with rotor,

$$V_{th} = 47(d_{ex}^2 - d_{in}^2) b_i n_p \quad (3)$$

$$V_p = \eta_p V_{th}$$

Where,

d_{ex}= external diameter of the inner rotor, m
d_{in}= internal diameter of the inner rotor, m
b_i = width of rotor, m
n_p = speed of the pump driving shaft, rpm
η_p = volumetric coefficient of delivery equal to 0.8~0.9

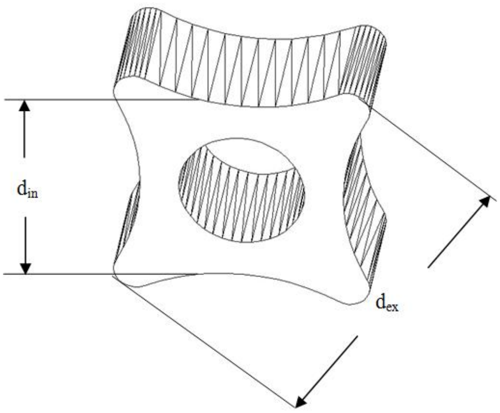


Fig. 3 Diameters of Inner Rotor

The width of the inner rotor can be taken 1.2~1.8 of the internal diameter of the inner rotor, so the width of the inner rotor is calculated by using the following Equation (4).

$$b_i = K_2 d_{ex} \quad (4)$$

The eccentricity e_p is half of the lobe height.

$$e_p = \frac{1}{2} h \quad (5)$$

The height of the lobe can be calculated from the relation of the external and internal diameter of inner rotor.

$$h = \frac{1}{2}(d_{ex} - d_{in}) \quad (6)$$

C) Design Calculation of Outer Rotor

Diameters of the outer rotor can be known by calculation from the external diameter of the inner rotor and the clearance values between them as the following equation. For the internal diameter of the outer rotor, the external diameter of the inner rotor and clearance are considered as the following Equation (7).

$$D_{in} = d_{ex} + 2(CR) \quad (7)$$

Where,

D_{in}= internal diameter of outer rotor, m
CR = clearance between inner rotor and outer rotor

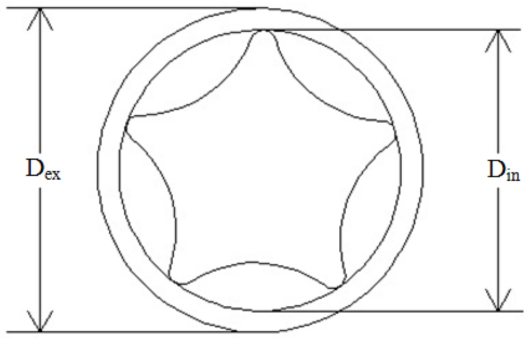


Fig. 4 Diameters of Outer Rotor

In the calculation of the external diameter of the outer rotor in Fig. 4, internal diameter known by the Equation (8) is used and the thickness of the outer rotor at the root is also applied.

$$D_{ex} = D_{in} + 2t \quad (8)$$

Width of the outer rotor is equal to the width of the inner rotor. Therefore, the width of outer rotor must be regarded as the same of that of the inner rotor.

$$b_o = b_i \quad (9)$$

Radius of the chest of the inner rotor shown in Fig. 4 is equal to the eccentricity.

$$r_{chest} = e_p = 0.5h \quad (10)$$

Where,

r_{chest} = radius of chest curve of the inner rotor, m

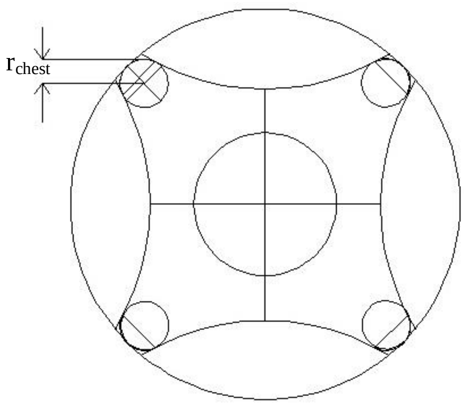


Fig. 4 Radius of the Inner Rotor Chest Curve

The radius of the outer rotor chest curve can be calculated by using the following Equation (11),

$$R_{chest} = \frac{1}{2} D_{in} \quad (11)$$

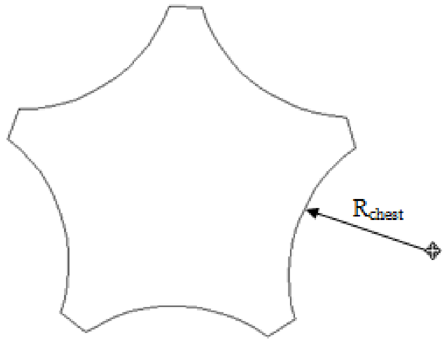


Fig. 5 Radius of the Outer Rotor Chest Curve

The location of the center point of the inner rotor chest curve can be calculated by using Equation (12),

$$L_1 = r_{in} + e_p \quad (12)$$

And, the location of the center point of the inner rotor root curve can be obtained from Equation (13),

$$L_2 = r_{in} + \frac{D_{in}}{2} \quad (13)$$

Finally, the location of the center point of the outer rotor root curve is computed form Equation (14),

$$L_3 = r_{in} + CR + \frac{D_{in}}{2} \quad (14)$$

3) Result And Discussion

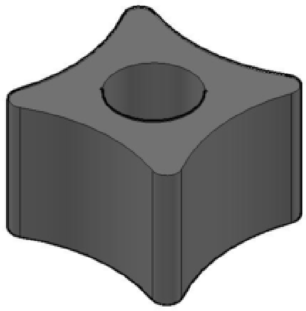
The design parameters of inner and outer rotor of rotor pump are calculated in this research. And then, the calculated result data of rotor pump are compared with the existing design data of rotor pump as shown in Table 1.

Table 1. Comparison between Calculated and Existing Design Data of Inner Rotor and Outer Rotor

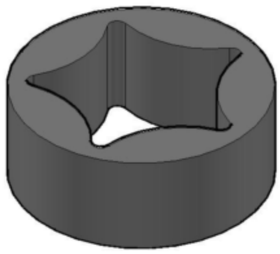
Dimension of the oil pump	Calculated Design Data (mm)	Existing Design Data (mm)	Error Percentage (%)
Internal diameter of the inner rotor	15.4	17.3	10.98
External diameter of the inner rotor	30.8	30	2.67
Internal diameter of the outer rotor	31	29	6.90
External diameter of the outer rotor	38.7	36.6	5.74
Width of the inner rotor	55.44	50	10.88
Width of the outer rotor	55.44	50	10.88
Eccentricity	3.85	3.65	5.48
Radius of the inner rotor chest curve	3.85	3.65	5.48
Radius of the inner rotor root curve	15.5	13.3	16.54
Radius of the outer rotor chest curve	15.5	13.3	16.54

From the comparison of Calculated Design Result Data and Actual Existing Design Result Data of inner and outer rotors of rotor pump design, the calculated design data are nearly the same as the existing design. The maximum error percentage is occurred at radii of inner and outer rotor root and chest curves because the maximum value of volumetric coefficient of delivery and diameter ratio are considered in the design calculation for this research. The maximum error percentage is 16.54%.Apart from this radius parameter design comparison, other results are less than 11% error between actual and calculated design. Therefore, the calculated design data of inner and outer rotors of rotor pump are satisfied.

Finally, 3D model of inner rotor, outer rotor and assemble of inner and outer rotors design are modeled by using AutoCAD software based on calculated design data which are shown in Figures 6 (a), (b), and (c).



(a)



(b)

(c)

Fig. 6. (a) Inner Rotor Design, (b) Outer Rotor Design, and (c) Assemble of Inner and Outer Rotors

4) Conclusions

In this research, the inner and outer rotors of rotor pump for A12 Engine designed by theoretically and compared with existing design result data. From the comparison result, the maximum error percentage is less than 20%. So, the design is safe. And, the calculated result data of inner rotor and outer rotor design modeled with AutoCAD software. In this research, structural steel is selected for the rotor design.

5) Recommendations

In this research, the author only conducted the design of inner and outer rotors of rotor pump and modelled the 3D view of inner rotor, outer rotor and combination of inner and outer rotors by using AutoCAD software. Therefore, in order to complete design of rotor pump for A12 Engine, the next researcher should be computed shaft design, gear design, and oil pump casing design. And, the researcher should consider the design of the oil filter, oil strainer, and relief valve.

Moreover, the author didn't analyze flow distribution of rotor pump. So, the next researcher should analyze velocity and pressure distribution of rotor pump by theoretically and numerically to obtain the optimum flow distribution.

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Soe Htet Ko received his BE (Mechanical) Degree and ME (Mechanical) from Mandalay Technological University, Mandalay, Myanmar in 2005 and 2007, respectively. He also finished ME (Nuclear Power Plant) from BMSTU, Russia in 2012. After that, he works at Department of Workshop, in MTU from August 2012 until now. Now he is currently a Lecturer at the Department of Workshop, MTU. His research work is in Production Technology and Workshop.

Myint Thein received his BE (Mechanical) Degree and ME (Mechanical) from Mandalay Technological University, Mandalay, Myanmar in 2005 and 2007, respectively. He also finished ME (Automation and Control) from SWSU, South-West State University, Kursk, Russia in 2011. And, he also finished his Ph.D degree from MTU, Mandalay Technological University, Mandalay, Myanmar in 2015. After that, he works at Department of Mechanical Engineering in MTU from February, 2015 until now. Now he is currently working as an Associate Professor at the Department of Mechanical Engineering, MTU. His research field is in solid and structural mechanics.