Development of High Efficiency P/M Internal Gear Pump Rotor (Megafloid Rotor)

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Powder metallurgy (P/M) internal gear pump rotors are widely used in automobiles, especially for oil pumps. In recent years, because the automotive market demands low fuel consumption and more use of hydraulic power, oil pumps are demanded to have higher volumetric efficiency and smaller sizes. To meet these demands, Sumitomo Electric has developed P/M internal gear pump rotors with a new tooth profile. The theoretical discharge volumes of pumps that use the new internal gear rotors are higher by 10% or more than those of pumps using conventional rotors of the same size and volumetric efficiency. This means that compared with conventional rotors, the newly developed rotors can be made smaller in size and can achieve lower torque and better fuel efficiency. The new rotors are being used for automotive engine oil pumps since April 2007.

1. Introduction

Powder metallurgy (P/M) internal gear pump rotors are widely used for automotive oil pumps. They are mainly used for lubricating engines, generating hydraulic pressure for AT or CVT units and supplying diesel engine fuel. The energy loss of the oil pump in each unit is large. For example, the loss in engine lubrication oil pump makes up 10% of the loss in the entire engine, and the loss in AT makes up 20% to 30%. With this as background, recently the automotive market strongly demands reduction of oil pump loss for the purpose of achieving low fuel consumption. In order to cut down the loss in oil pumps, it is effective that the size of oil pump rotors is made smaller and friction is cut down.

However, smaller oil pump means less discharge volume. Therefore, manufacturers have been required to develop new oil pump rotors that have smaller size but are equivalent in discharge volume compared with conventional rotors.

To meet this requirement, Sumitomo Electric has developed a new gear tooth profile named "Megafloid" for P/M internal gear pump rotors. The discharge volume of oil pump rotors using Megafloid gears is 10% or higher than that of the rotors of the same size that use Sumitomo Electric's conventional Parachoid gears.

Hereinafter, the features of Megafloid rotors will be described in comparison with conventional "Parachoid" rotors.

2. Development approach for high-efficiency pump rotor

2-1 Oil pump mechanism

The mechanism of an oil pump having internal gear pump rotors is shown in **Fig. 1**. The inner and outer rotors are set eccentrically, and the number of teeth of the outer rotor is larger by one than that of the inner rotor. Therefore, there exist spaces enclosed by the outer and inner rotors. When the inner rotor is rotary driven by a shaft inserted in its inner bore, the outer rotor is rotary driven in the same direction, because the outer rotor is forced into rotary motion by contacts with the teeth surfaces of the inner rotor. At each enclosed space, the volume of space gradually becomes larger with rotation and after reaching its maximum it gradually becomes smaller. This change in volume is repeated again and again. The pump draws oil while the volume becomes larger. The enclosed space is separated from the input or output port when the volume reaches its maximum. The pump discharges oil while the volume becomes smaller. This is the mechanism of how an oil pump works.

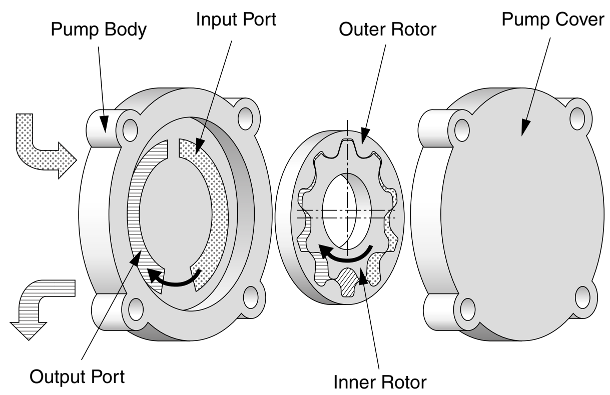


Fig. 1. Mechanism of oil pump with internal gear pump rotors

2-2 Development policy

Table 1 shows an example of the theoretically calculated breakdown by factors of friction-induced oil pump loss. This table indicates that making pump rotors thinner in thickness and smaller in outer diameter is effective for reducing pump loss. The newly developed tooth profile allows rotors to be smaller in size while ensuring

Table 1. Theoretical analysis result of friction loss in oil pump

End face(inner)	End face(outer)	Tooth top	Circumference(outer)
35%	50%	1%	14%

*In the case of a ø 94 x 10.8 mm rotor.

the same discharge volume as conventional rotors, and thus reduces friction loss. In other words, the new tooth profile provides a larger theoretical discharge volume with the same rotor size as conventional rotors.

For providing a larger theoretical discharge volume with the same pump rotor size, the height of tooth must be made taller. The new tooth profile adopts two base circles, and an involute curve connects the top and bottom curves for the purpose of enabling arbitrary modification of tooth height. Sumitomo Electric's conventional Parachoid tooth profile is shown in **Fig. 2**, and the new Megafloid tooth profile is shown in **Fig. 3**.

The Megafloid tooth profile allows tooth height to be changed arbitrarily, meaning that tooth height and theoretical discharge volume can be made larger. (In the case shown in **Fig. 4**, the theoretical discharge volume is 12.4% larger than that of Parachoid.). Contrary to Megafloid, the tooth height of Parachoid is determined depending on the number of teeth and the diameter of base circle that depends on the rotor size.

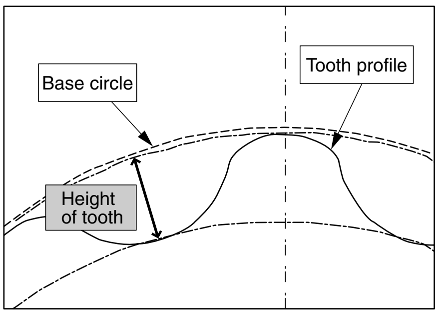


Fig. 2. Parachoid tooth profile

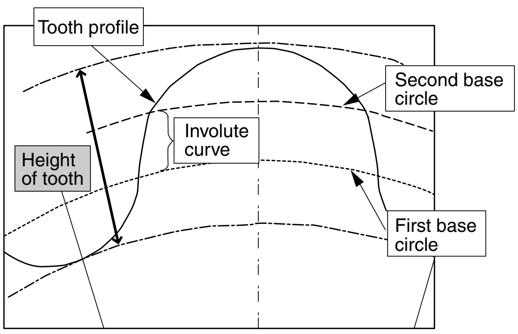


Fig. 3. Megafloid tooth profile

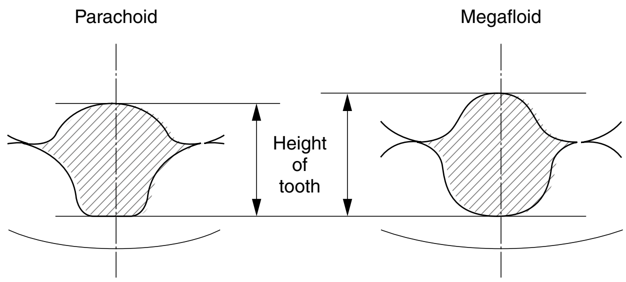


Fig. 4. Comparison of tooth heights and pumping clearances

3. Megafloid rotor performance

3-1 Megafloid rotor features

The theoretical discharge volume of Megafloid was discussed in Section 2-2. Other features related to oil pump performance is reported in this section.

(1) High volumetric efficiency

The area of clearance for pumping in Megafloid is equivalent to that in Parachoid rotor that is known for its high volumetric efficiency. This equivalence in clearance areas is enabled by the use of the envelope curve of inner rotor in designing outer rotor, as in the case of Parachoid. (Shown in **Fig. 5**.)

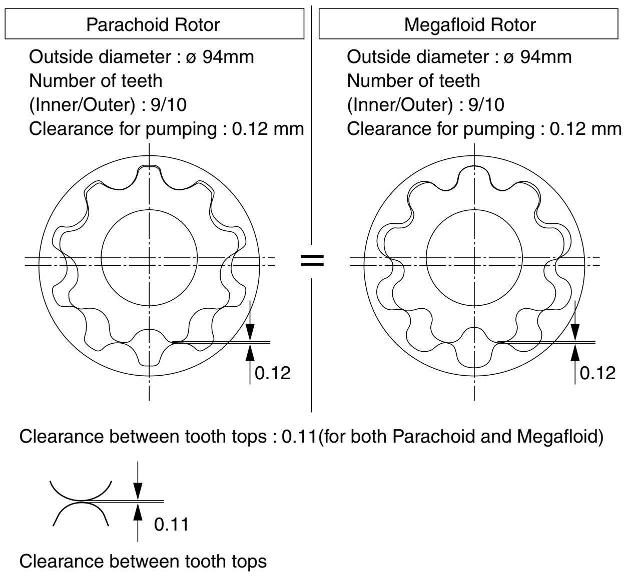


Fig. 5. Comparison of clearances for pumping

The clearance for pumping in Parachoid is narrower than that in conventional G-rotors. Parachoid has a higher volumetric efficiency than conventional rotors when the clearance area between tooth tops is the same for both types of rotors. This result is derived from using the envelope curve of inner rotor in designing outer rotor. The outer rotor profile of Megafloid is designed in the same way so as to ensure high volumetric efficiency.

(2) Torque

Megafloid has a smaller pressure angle than Parachoid because it uses an involute curve for establishing its contact area profile. This reduces unnecessary stress that works in a radial direction, and allows the torque to be changed smoothly to rotational power. (Shown in **Fig. 6**.) In other words, the torque decreases.

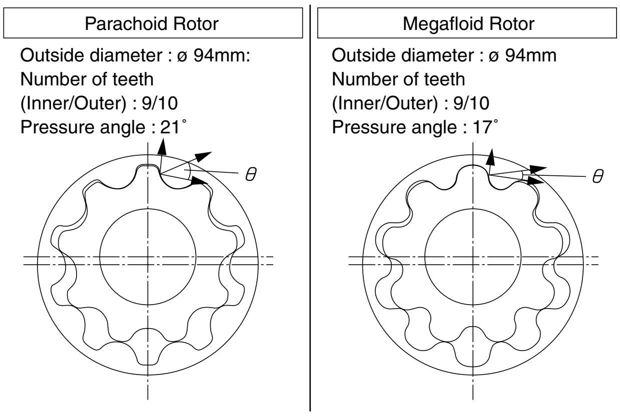


Fig. 6. Comparison of pressure angles

Table 2. Test conditions (for rotors of same size)

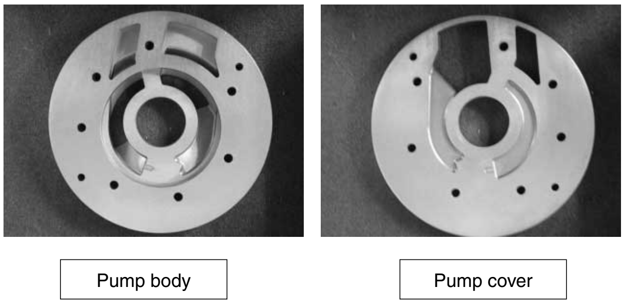
Item		Parachoid Rotor	Megafloid Rotor
Size	Thickness	10.80mm	10.80mm
	Outside diameter	ø 94mm	ø 94mm
	Theoretical discharge volume	17.28cm^3/rev	19.44cm^3/rev
Clearance	Side clearance(Inner)	0.037~0.041mm	0.038~0.043mm
	Side clearance(Outer)	0.037~0.043mm	0.040~0.045mm
	Body clearance	0.118~0.128mm	0.113~0.122mm
	Tip clearance(at Top)	0.11~0.14mm	0.10~0.12mm
Condition	Oil type	Normal ATF	
	Oil temperature	120˚C	
	Discharge pressure	0.5MPa	
	Revolution speed	500rpm~7,500rpm	

Side clearance : A clearance between a rotor face and a pump body.
Body clearance : A clearance between an outer rotor periphery and a pump body.
Tip clearance : A clearance between the tooth tops of outer and inner rotors.

3-2 Performance test No. 1(for rotors of same size)

The Megafloid and Parachoid rotors having the same rotor size were tested by using a simulated AT oil pump. The test conditions are shown in **Table 2**, the external views of the pump case is shown in **Fig. 7**, and test equipment is shown in **Fig. 8**.

The graph of volumetric efficiency is shown in **Fig. 9** and the graph of actual discharge volume is shown in **Fig. 10**. The test result shows that because Megafloid exhibits a high volumetric efficiency equivalent to that of Parachoid, the actual discharge volume increase d by an amount equal to the increase of theoretical discharge volume.



· A pump for simulating an actual AT oil pump.
· The rotor is placed in a pump body and covered by a pump cover.

Fig. 7. Pump case

Fig. 8. Test equipment

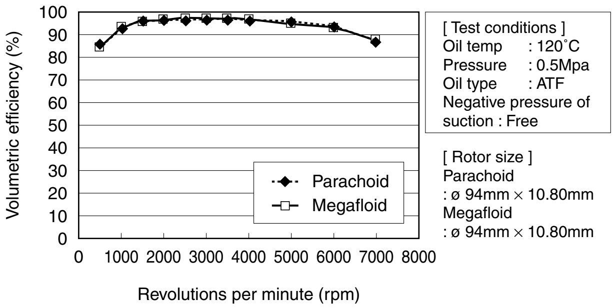


Fig. 9. Volumetric efficiency (No. 1)

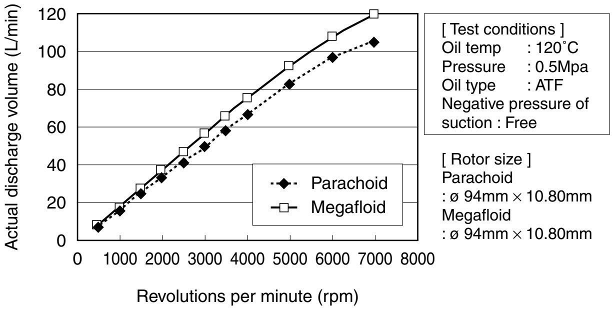
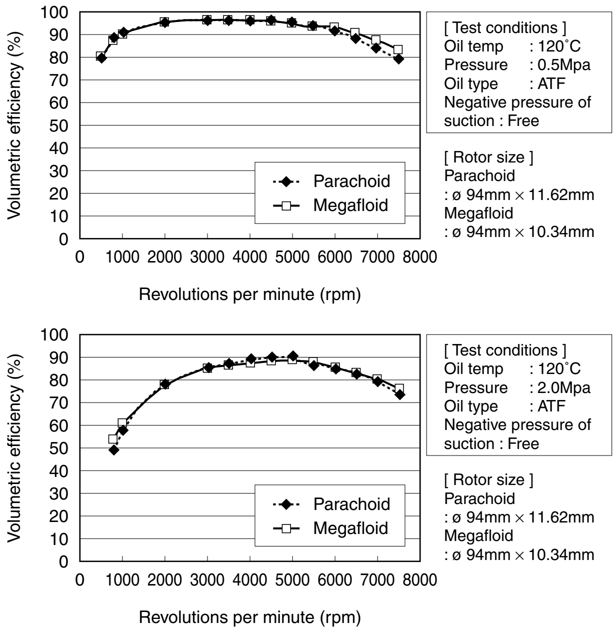


Fig. 10. Actual discharge volume (No. 1)

Table 3. Test conditions (for rotors with same theoretical discharge volume)

Item		Parachoid Rotor	Megafloid Rotor
Size	Thickness	11.62mm	10.34mm
	Outside diameter	ø 94mm	ø 94mm
	Theoretical discharge volume	18.6cm^3/rev	18.6cm^3/rev
Clearance	Side clearance(Inner)	0.050~0.054mm	0.049~0.055mm
	Side clearance(Outer)	0.049~0.053mm	0.047~0.053mm
	Body clearance	0.155~0.162mm	0.145~0.151mm
	Tip clearance(at Top)	0.11~0.12mm	0.10~0.13mm
Condition	Oil type	Normal ATF	
	Oil temperature	40˚C, 80˚C, 120˚C	
	Discharge pressure	0.5MPa, 1.0MPa, 2.0MPa	
	Revolution speed	500rpm~7,500rpm	



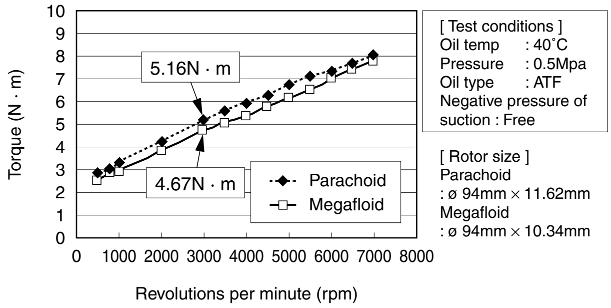
The volumetric efficiency of Megafloid is the same or higher than that of Parahoid for both cases of high and low oil discharge pressures.

Fig. 11. Volumetric efficiency (No. 2)

3-3 Performance test No. 2 (for rotors with same theoretical discharge volume)

The Megafloid and Parachoid rotors having the same theoretical discharge volume were tested. In order to ensure the same theoretical discharge volume, the two rotors have the same outside diameter and different overall lengths.

The test conditions are shown in **Table 3**. The graph of volumetric efficiency is shown in **Fig. 11**, and the graph of torque is shown in **Fig. 12**. The graph of actual discharge volume is not shown because both types of rotors have the same theoretical discharge volume in this test. The test result shows that Megafloid exhibits a high volumetric efficiency and a high actual discharge volume that are equivalent to those of Parachoid, and a torque 10% lower than that of Parachoid.



The torque of Megafloid is 10% less than that of Parachoid at 3,000 rpm.

Fig. 12. Torque

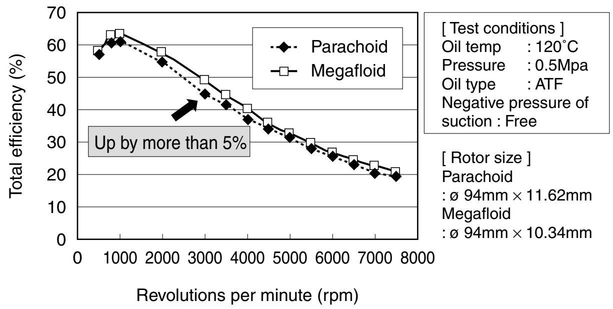


Fig. 13. Total efficiency

The graph of total efficiency (the product of mechanical efficiency times volumetric efficiency) is shown in **Fig. 13**. The graph indicates that the total efficiency of Megafloid increased by more than 5% compared with Parachoid.

4. Conclusion

Compared with Sumitomo Electric's conventional Parachoid rotors of the same sizes, the newly developed Megafloid rotors allow the theoretical discharge volumes of pumps to be larger by 10% or more. By using Megafloid, it has become possible to fabricate the pumps whose torque requirements are lower by 10% or more and oil discharge performances are as high as those using Parachoid.

The excellent performance of Megafloid is gradually being known and used in the automotive market.

It is expected that Megafloid rotor pumps will contribute to lower fuel consumption and higher performance of automobiles.

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