

Assessment of Durability of Needle Roller Bearing on Crankshaft of Internal Combustion Engine on Basis of Slip Ratio

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ABSTRACT

In the designing of bearing to use in internal combustion engines, the author has established an assessment method for needle roller bearing considering the slip ratio of needle rollers when operating. Damages sometimes occur in a bearing when continuously operating the engine although the bearing has a basic dynamic load rating. For an example, flaking occurred in the needle rollers during the continuous operation of the engine when a roller bearing was applied to the bearing that supported the gear which transmitted the driving force from the starter motor to the crankshaft when starting the engine. While the bearing is located on the crankshaft, the bearing is not directly subjected to the loads from engine combustion pressures. We therefore focused our attention on the bearing slip ratio as a factor that affects the bearing rather than the loads.

After researching the factors that affect bearing slip ratio of the concerned part, it has been clarified through the studies reported in this paper that the slip ratio can be reduced by applying the following three measures.

1. Control of crankshaft whirling
2. Reduction of radial clearance
3. Application of crowning on needle rollers

The actual reduction of slip ratio enabled prevention of flaking when continuously operating the engine. As the result, an optimum designing of bearing is possible by the bearing life assessment considering the slip ratio of needle rollers during engine operations.

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INTRODUCTION

In motorcycle engines, there are increasing applications of roller bearings instead of plane bearings to fill the recent needs of friction reduction for fuel economy. An example is the application of rollers to the bearing that supports the gear which transmits the driving force from the starter motor to the crankshaft when starting the engine. The concerned bearing is designed upon calculations taking into considerations the loads when starting the engine. There was such a case in that flaking occurred in the needle rollers in the continuous running test although there was no load in the radial direction from the combustion pressure during engine operations. As the bearing had an adequate capacity for the loads from engine operations, we supposed that the flaking occurred due

to improper rolling of needle rollers. The rolling performance of needle rollers is assessed by measuring the slip ratio of needle rollers using the unit test equipment.¹⁾ In this paper, the slip ratio was measured during engine operations, the factors that affect the slip ratio were identified, eventually enabling an assessment of bearing design.

TEST ENGINE AND CONSTRUCTION OF PART SUBJECTED TO ANALYSIS

The single cylinder engine for small class motorcycles was used for the tests. Fig. 1 shows the crankshaft of the test engine and the construction of the bearing subjected to the analysis. The concerned bearing holds the gear that transmits the driving force from the starter motor to the crankshaft

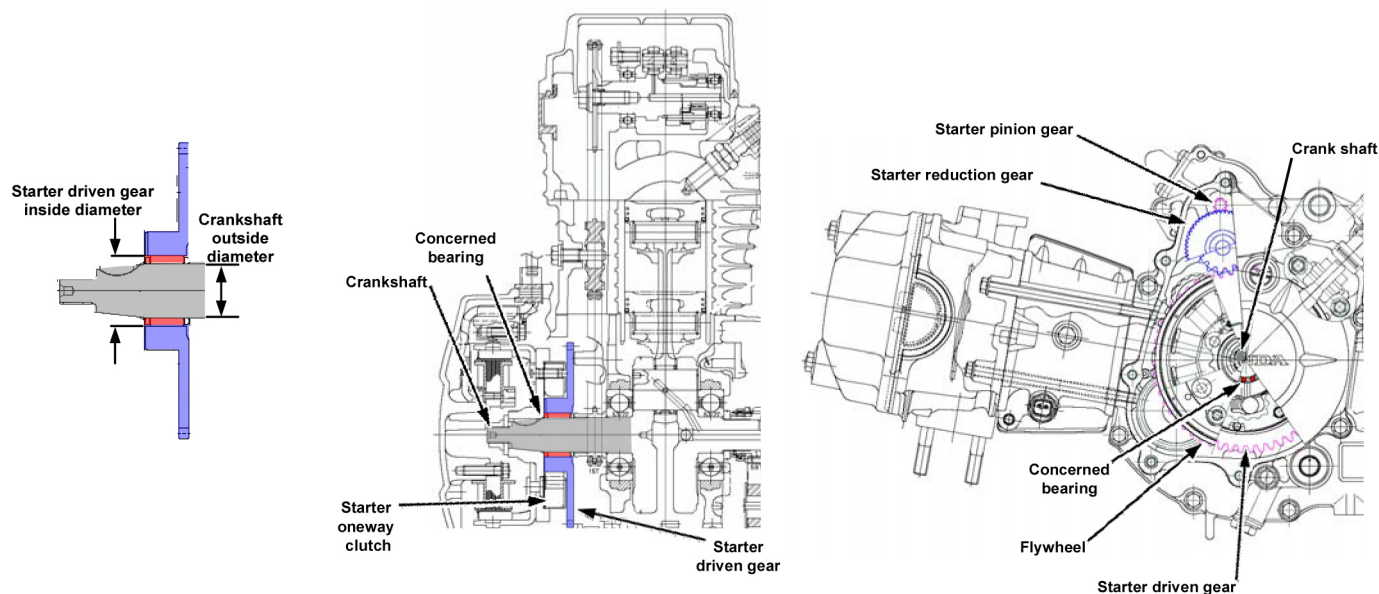


Fig. 1. Construction of bearing subjected to analysis and nearby parts

Table 1. Table.1 Specifications of test engine, concerned bearing and nearby parts

		Test	Test engine 2
Engine	Cooling method	Air cooling	Air cooling
	Bore (mm)	50.0	52.4
	Stroke (mm)	55.6	57.8
	Displacement (cm ³)	109.2	124.6
	Maximum output (kW / rpm)	6.25 / 7500	6.75 / 7500
	Maximum torque (Nm / rpm)	8.62 / 5000	9.69 / 5500
	Crankshaft outside diameter (mm)	19	21
	Starter driven gear inside diameter (mm)	23	25
Concerned bearing	Needle roller outside diameter (mm) × Number	2×18pcs	2×20pcs
	Needle roller length (mm)	13.8	13.8
	Radial clearance (μm)	20—74	20—74
	Basic dynamic load rating (kN)	11.0	11.6

when starting the engine via the one-way clutch. The construction is such that when the engine is running normally, the starter driven gear having internal contacts with the bearing does not rotate. The bearing having internal contacts with the crankshaft is driven by the rotating crankshaft and makes orbital motions. The lubricated condition of the concerned bearing is not under forced feed lubrication. The bearing is lubricated with the splashed engine oil which flows into the clearance between the crankshaft and the starter driven gear. Table 1 shows the specifications of the test engine, the concerned bearing and the nearby parts. Differences between two engines are not only displacement but also crankshaft outside diameter and starter driven gear inside diameter. Basic dynamic load ratings of the concerned bearing are almost same value. In the test engine 1, flaking occurred in the needle rollers located in

the concerned part. In the test engine 2, no flaking occurred in the same part. The cause of flaking was analyzed by comparing the engine having a long bearing life to another having a short bearing life although the basic construction is virtually identical.

MEASUREMENT OF SLIP RATIO

Definition of Slip Ratio

The slip ratio C_s of needle roller refers to an actual rate of lowering of orbital speed of the bearing compared to the theoretical orbital speed of the bearing. The variance between the theoretical value and the actually-measured value means that the needle roller slips on the contact surface rather than rolling. It is reported that the higher the slip ratio, the lower the bearing life becomes.^{(1), (2)}

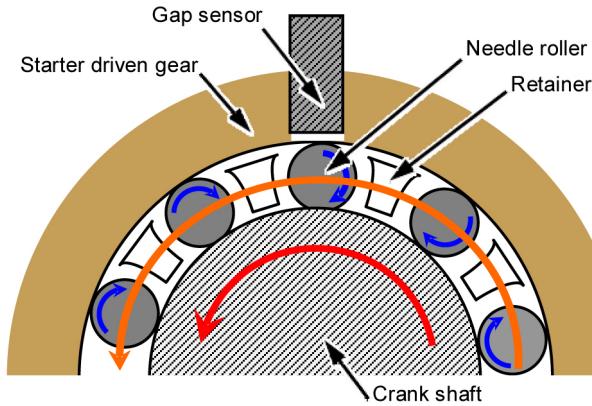


Fig. 2. Gap sensor installation method

$$Cs = \left(1 - \frac{Nc}{Ntc}\right) \times 100 \quad (\%) \quad (1)$$

Cs : Slip ratio (%)

Nc : Actually-measured orbital speed of bearing (rpm)

Ntc : Theoretical orbital speed of bearing (rpm)

$$Ntc = Ns \times \left(\frac{D_1}{D_1 + D_2}\right) \quad (2)$$

Ns : Main spindle revolution speed (rpm)

D_1 : Diameter of the main spindle making internal contact with the bearing

D_2 : Diameter of the rolling object making external contact with the bearing

Here, the main spindle revolution speed Ns shows crankshaft revolution speed, D_1 refers to the crankshaft diameter, D_2 refers to the inside diameter of starter driven gear.

Method of Measurement of Bearing Orbital Speed N_c

The orbital speed of bearing is measured by the motions of spinning retainer. The gap sensor is attached to the starter driven gear which makes an external contact with the bearing as Fig. 2 shows. When the needle roller part of the retainer passes in front of the gap sensor, pulses of voltage fluctuations occur as shown by Fig. 3 and Fig. 4. The pulse waves are frequency-analyzed, and converted to a speed from the peak frequency. Fig. 5 shows the flow of measurement. As the gap sensor is located inside of engine, it has to be heat-resistant and compact. The gap sensor used at this time is a product of Applied Electronics Corporation shown by Fig. 6. Table 2 shows specifications of the sensor. The sensor

can be used in high-temperatures conditions as high as 180°C. The compactness of sensor head, $\phi 2.7 \times 7$ mm is another feature. The measurements were performed under the conditions that engine oil temperature around the drain bolt was kept 60°C.

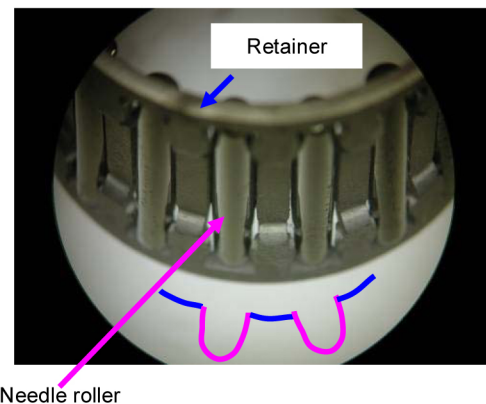
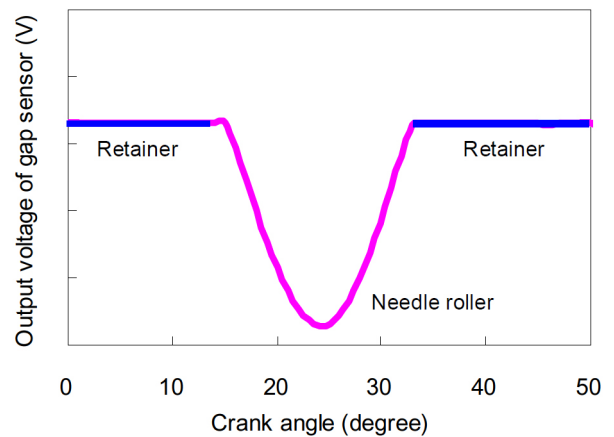


Fig. 3. Voltage fluctuation from orbital motions of bearing