Development of One-Way Clutch with Built-in Ball Bearing

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A one-way clutch with built-in ball bearing for fully automatic washing machines has been developed at Koyo. This new product has the function of a one-way clutch in addition to that of a ball bearing and contributes to the downsizing of mechanical parts, assembly simplification, and higher torque capacity. This paper presents the structure, features, and performance characteristics of this product along with the results of evaluation testing.

***Key Words**: one-way clutch, ball bearing, washing machine*

1. Introduction

The performance of electrical appliances has continued to be improved in order to meet users' needs. Electric washing machines are no exception to this trend. Washing machines have been improved from the two-tank system to a fully automatic system. Furthermore, larger capacities and more silent operation have been achieved. There have also been striking improvements in performance, such as the adoption of inclined drum mechanisms and DD inverter motors, and new washing systems that use ultrasonic waves or centrifugal force can be seen in recent years.

In order to cope with these trends, a bearing had to be designed to withstand high loaded torque have a low rotation torque in the free spinning direction and operate as quietly as a standard bearing. Additionally, the bearing had to fit the envelope dimensions of a standard bearing while reducing the total number of parts used in washing machines.

In this paper, fundamental and endurance performance of the new one-way clutch with built-in ball bearing which was developed in Koyo and adopted for fully automatic washing machines is introduced.

2. Washing Machine Market and Structure of Fully Automatic Washing Machine

Currently, the global washing machine market is said to be in excess of 40 million units per year, and the washing systems of the machines are roughly divided into the following three systems :

1. Drum system (horizontal rotation shaft, popular in Europe)
2. Agitator system (vertical rotation shaft, popular in North America)
3. Pulsator system (vertical rotation shaft, popular in Japan, Southeast Asia)

Types of (2) and (3) are structurally very similar. The agitator system has a short reverse cycle and washes through agitating the water, while the pulsator system has a long reverse cycle and washes by creating a whirlpool through rotation over a fixed period of time.

The latter type is popular in Japan, and includes a two-tank system where washing and spin-drying are done in separate tanks, and a fully automatic system where washing and spin-drying are done in the same tank. The entire Japanese domestic market is a demand-based stable market where approximately 4.5 million old units are replaced with new ones each year. The percentage accounted for by fully automatic system machines is increasing year by year, and recently approximately 3.8 million units a year (1997, 1998) are fully automatic (according to Japan Electrical Manufacturers' Association). The structure of a fully automatic washing machine is shown in **Fig. 1**.

In the fully automatic system (including the agitator system), because washing and spin-drying should be done in the same tank, the washing tank is a double structure. When spin-drying, the inside tank and agitator are spun in synchronization, and when washing, only the agitator needs to be run (or reciprocated) intermittently. For this reason, a double structure driving shaft is adopted, and a one-way clutch is used so that tank does not turn during reverse rotation of the agitator.

In the past, spring clutches or roller clutches were used as these one-way clutches, but recently, for the purpose of saving space in the mechanism section and simplifying assembly, the need of integration for a ball bearing and an one-way clutch has increased. For this application, therefore, Koyo developed a one-way clutch with built-in ball bearing that has the function of both a bearing and a one-way clutch in the main dimensions of a standard deep-groove ball bearing.

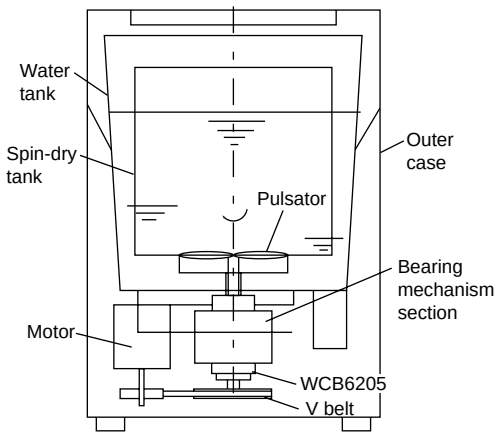

Fig. 1 General structure of fully automatic washing machine

3. Product Structure and Features

The one-way clutch with built-in ball bearing contains a built-in part with a cam shaped component called "sprag" between the inner ring and outer ring of a conventional deep-groove ball bearing, and is a product that has the combined functions of a bearing and a one-way clutch. The specifications and fundamental performance of the developed product are given in **Table 1**, and the structure is shown in **Figs. 2, 3** and **4**. The size is the same as 6205 (deep-groove ball bearing) for fully automatic washing machines. There are two types, a double row and a single row, according to the required torque.

Fig. 2 One-way clutch with built-in ball bearing

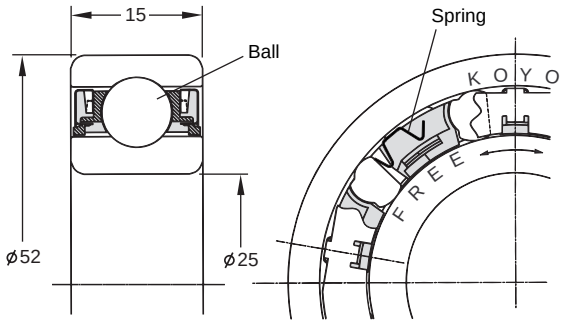

Fig. 3 Structure of one-way clutch with built-in ball bearing WCB6205

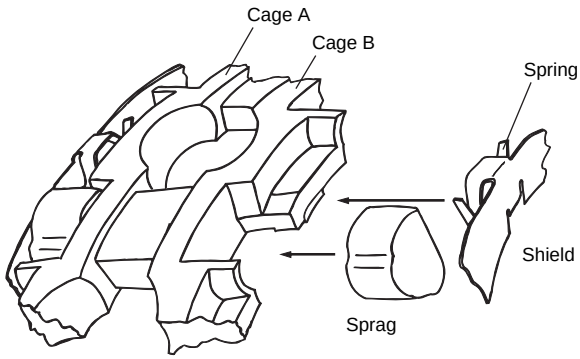

Fig. 4 Internal structure of one-way clutch with built-in ball bearing WCB6205

Table 1 Specifications and basic performance characteristics

Bearing			WCB6205	WCB6205-S
Main dimensions, mm			(ID) ϕ25 × (OD) ϕ52 × (W) 15	
Parts		Inner ring	The size is the same as 6205	
		Outer ring		
		Balls		
		Cage	Molded resin part	
		Sprags	Two rows	One row
		Side plates	2 (all in one)	1 (all in one)
		Springs		
		Lubrication	Grease	
Measurement values	Weight		Approx. 132 g	Approx. 126 g
	Starting torque		12.7 mN·m	10.8 mN·m
	Rotating torque (at 900 min^{-1})		15.3 mN·m	13.7 mN·m
Calculated values	Basic dynamic load rating C (JIS)		14.00 kN	
	Basic static load rating C_0 (JIS)		7.85 kN	
	Torque capacity (one-way clutch)		74.7 N·m	37.3 N·m

The rated load is the same as the standard deep-groove ball bearing 6205, and rated torque capacity of the one-way clutch is 74.7 N·m for the double row product, and half of that, 37.3 N·m for the single row product.

The advantages of using the one-way clutch with built-in ball bearing are as follows :

①By having the working of a spring clutch or one-way clutch function in a bearing, space can be saved and the number of parts in an assembly can be reduced and the overall assembly process can be simplified.

②The torque capacity is large compared to conventional spring and roller clutches, and durability is improved.

③Compared to a spring clutch, rapid cycling can be employed.

At the beginning of the development, products that combined a bearing and a one-way clutch all in one already existed, but they were much larger than a standard size bearing, and their cages and spring mechanisms were complicated, so they were not suitable for mass production. Therefore, in order to cope with these problems, the structure and shape were throughly investigated. The features of the developed product are as follows :

①Size reduction was aimed for by making main dimensions the same as that of a standard 6205 deep-groove ball bearing.

②By adopting a combined cage and locating the sprags in the shoulder section on both sides of the raceways, the cage could be used to retain both balls and sprags.

③By locating sprags in the shoulder section of both sides of the raceway a high level of torque could be accommodated. However if the required torque is small, single row sprags could be used to reduce cost.

④Sprag control was made to be handled by leaf spring designed into the side plate, and a system for mounting the side plate to the cage was adopted (patent pending). This contributed to improved ease of mounting, parts number reduction, and a realized lower cost.

⑤Cold forging was used as the sprag manufacturing method, because it is more capable of mass production than conventional drawing methods (patent pending).

4. Performance Test Results

In order to confirm performances of the developed product, the following three tests were conducted.

4. 1 Stroking Endurance Test

In order to confirm endurance performance by cycling the free/lock operation of the clutch, a stroking endurance test was conducted using the test machine of **Fig. 5** under the conditions of **Table 2**. The results are shown in **Fig. 6**. The results confirmed that performance exceeded the calculated life.

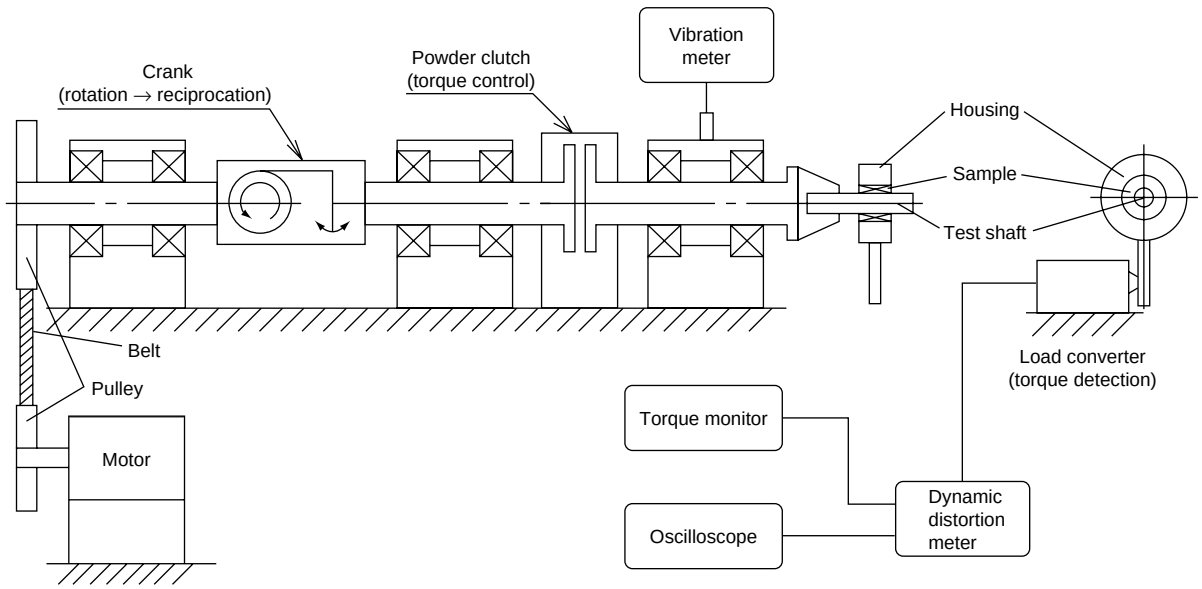

Fig. 5 Stroking endurance test machine

Table 2 Conditions of stroking endurance test

	WCB6205	WCB6205-S
Loaded torque	68.6~98.0 N·m	34.3~49.0 N·m
Axial load	1 764 N	
Load cycle	5 Hz	
Reciprocating angle	Approx. 30°	
Temperature	Room temperature	

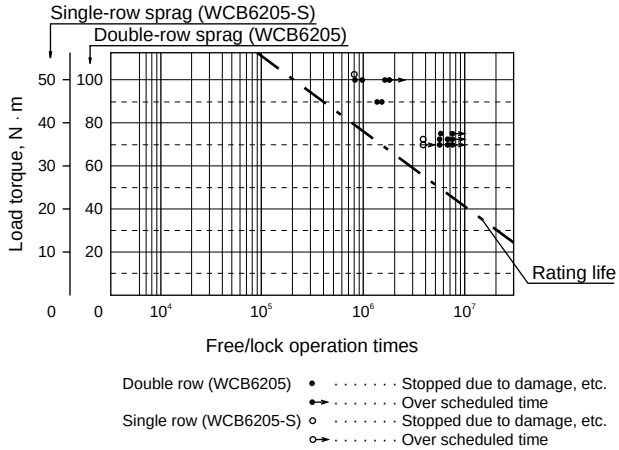

Fig. 6 Results of stroking endurance test

4. 2 Rotating Endurance Test

In order to confirm endurance performance when rotating, the rotating endurance test was conducted using the test machine of **Fig. 7** under the conditions of **Table 3**. The results are shown in **Fig. 8**. It was confirmed that there was no abnormality even after continuous rotation for 3 000 hours (= approx. 5 minutes of spin-drying 36 000 loading) at 1 000 min^{-1}.

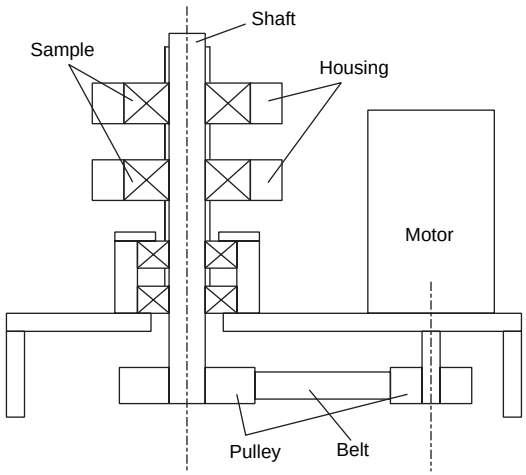

Fig. 7 Rotating endurance test machine

Table 3 Conditions of rotating endurance test

	WCB6205/WCB6205-S
Rotation ring	Inner ring
Shaft rotation speed	1 000 min^{-1}
Axial load	20 N
Rotating time	3 000 h
Temperature	Room temperature

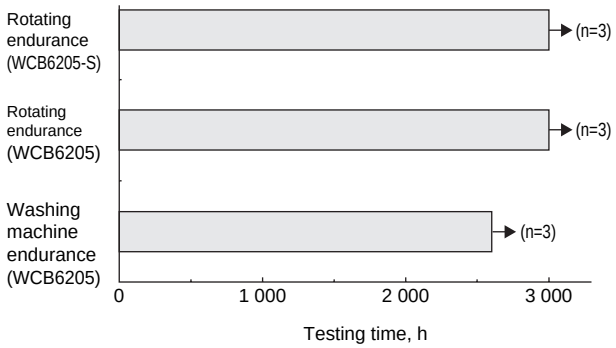

Fig. 8 Results of rotating endurance tests and cycle test with a washing machine

4. 3 Cycle Test in Washing Machine

In order to confirm endurance performance in an actual washing machine, the endurance test with actual machine was conducted using a fully automatic washing machine (agitator system) under the conditions of **Table 4**. The results are shown in **Fig. 8**. Under the condition of actual machine, it was confirmed that there was no abnormality even for continuous cycle operation of 2 600 hours (= washing 5 200 times, the equivalent of 14 years if washing once a day), and that there was sufficient endurance.

Table 4 Conditions of cycle test in washing machine

Machine	Fully automatic washing machine (agitator system)
Load	Water + objects (rags, etc.), approx. 6 kg (load torque 67.7 N·m equivalent)
Washing cycle	Washing (15 min) → rinse → spin-dry (5 min) (1 cycle approx. 30 min)
Testing time	Repeat above cycle continuously for 2 600 h

5. Conclusion

A one-way clutch with built-in ball bearing having the characteristics of both a ball bearing and a one-way clutch mechanism in one was designed and developed within the same size as 6205 for fully automatic washing machines.

In order to cope with wide market needs of the future, Koyo plans to create a series of one-way clutches with built-in ball bearing and expand to washing machines and other applications.