Specimen Tests for Candidate Materials of Ball Screw Assembly

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1. Introduction

A control element drive mechanism (CEDM) is one of essential parts of the reactor regulating system, and its function is to insert, withdraw or maintain a control rod including a neutron absorbing material at any required position within the reactor core. Korea Atomic Energy Research Institute (KAERI) has been developed a ball-screw type CEDM driven by the stepping motor for the integral reactor [1]. This integral reactor requires the CEDM to have fine movement as well as high reliability for the fine reactivity control. The project includes also a commitment to performance improvement for the CEDM main components such as ball bearing and ball screw assembly [2-4].

This paper describes the specimen test results to select the good combination of materials for the ball screw assembly. Five candidate materials with good mechanical and chemical characteristics are selected, and total 36 test specimens with the combination of materials are tested by using wear test equipment. The ball diameter and plate groove radius due to wear are measured and evaluated.

2. Specimen Test

A ball screw assembly of integral reactor CEDM changes the rotation of stepping motor to the vertical movement of control element assembly through the ball nut. Thus, the ball screw and nut are subjected to large load due to the weight of moving parts such as control elements and extension shaft in water. In general, a ball screw assembly is composed of a ball screw shaft, a ball nut, balls and a transferring tube as shown in Fig. 1.

2.1 Candidate materials and specimens

The preliminary candidate materials to be used the ball screw assembly of CEDM are selected by considering mechanical properties and chemical characteristics. These materials for the specimen are heat or surface treated such as hardening, tempering, Cr-plating and peening to enhance the corrosion, hardness and wear characteristics.

○ Ball screw shaft and nut: Cronidur30, Incoloy925, ASTM A564-XM16
○ Ball: Si_3N_4, WC(Ni), Cronidur30

One test specimen is composed of 42 balls, the top plate and the bottom plate as shown in Fig. 2. The top and bottom plates have the same groove size as actual ball screw assembly. The specimens of total 36 cases according to the materials and heat treatment are prepared and tested by using the wear test equipment.

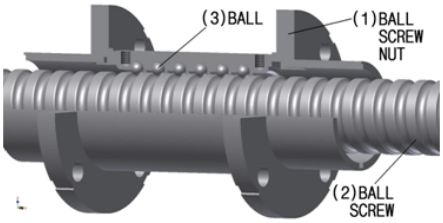


Fig. 1 Configuration of ball screw assembly

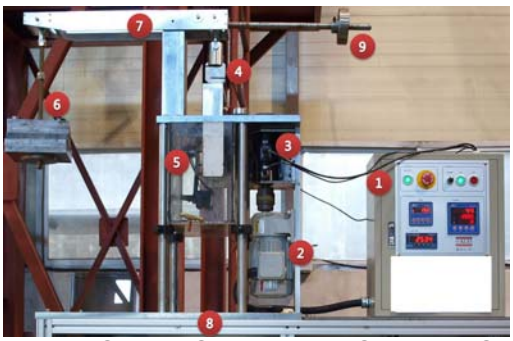

Fig. 2 Typical specimen set

2.2 Test equipment and methods

Fig.3 shows the test equipment which is fabricated to test the endurance of ball bearing and the specimen test of ball screw assembly [2-3]. One set of specimen is installed on the specimen assembling part inside the water tank. The load is applied to the bottom plate through the lever with load ratio of 10 to 1. The test equipment has also the load cell and the torque sensor to check the test conditions and results. The tests are carried out under the following test conditions.

○ Environment: water
○ Applied loads: 250 kgf at bottom plate
○ Rotation: Total 340,000 rotations at top plate
○ Rotating speed: 150 rpm

A diameter of ball and a radius of curvature for the groove of top and bottom plates are measured after the test to estimate the wear.



① Controller, ② Motor, ③ Torque sensor, ④ Load cell, ⑤ Water tank including specimen, ⑥ Weight, ⑦ Lever(10:1), ⑧ Support frame, ⑨ Fine load controller
Fig. 3 Specimen test equipment

3. Results and Discussion

3.1 The first test

The first test for all 36 specimens is performed under the same test conditions for 170,000 rotations. The primary selection of specimen materials is done based on the measured results. As a result, Incoloy925 plate (Fig. 4) and Cronidur30 ball show the larger wear than other materials. The wear of Incoloy925 is also large regardless of surface or heat treatment. Therefore, we decided to exclude Incoloy925 from the candidate materials of ball screw after the first test.

(a) Top plate (b) Bottom plate

Fig. 4 Typical shape of Incoloy925 specimen after test

3.2 The second test

The second test for 18 specimens with the combination of Cronidur30 and XM16 excluding Incoloy925 is continued under the same conditions until total 340,000 rotations.

Fig. 5 shows the typical measurement result of the radius of curvature for test No. 1 specimen (Cronidur30, bottom plate). Table 1 presents the measured results for the change of ball diameter and plate groove radius after the second test. The diameter of balls made of Si_3N_4 and WC(Ni) is changed in the range of 11 to 19μm. The wear of Si_3N_4 balls is the smaller than that of WC(Ni) although the quantity of wear is very small.

The radius of curvature for grooves of top and bottom plates is increased with 15～31μm after the test. When evaluated as a whole, the wear of bottom plate is slightly larger than top plate. Peened Cronidur30 and heat-treated XM16 have relatively good wear resistant characteristics. Actually, it is difficult to find the best material because the wear for specimens is similarly small for all cases. However, if we need to choose, it is found that Si_3N_4 for ball and Cronidur30 for ball screw/nut are good.

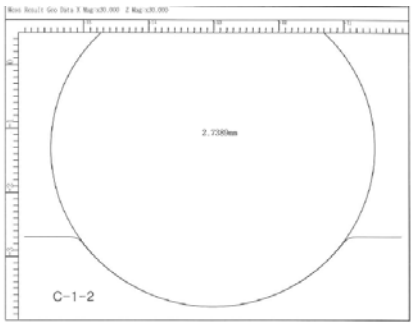


Fig. 5 Groove measurement result (Test No.1)

Table 1 Summary of test results

Test No.	Heat Treat.	Material			Dimension change (μm)		
		Top Plate	Bot. Plate	Ball	Ball Dia.	Radius of curvature (top plate)	Radius of curvature (bot. plate)
1	H[1)]	C2[2)]	C5	Si_3N_4	12.0	21.80	15.20
3		C7	C8	WC	12.0	31.20	27.80
4	P[1)]	C9	C10	Si_3N_4	17.0	18.40	18.20
6		C13	C14	WC	11.0	23.20	25.20
7	QT[1)] (XM16)	X6[2)]	C3	Si_3N_4	14.0	21.00	28.40
9		X9	C27	WC	17.0	24.40	24.10
10		X3	X4	Si_3N_4	12.0	16.20	28.30
12		X7	X8	WC	18.0	20.20	28.10
13	P (XM16)	X18	C15	Si_3N_4	13.0	19.10	28.00
15		X11	C17	WC	17.0	20.50	29.80
16		X12	X15	Si_3N_4	14.0	21.70	29.20
18		X14	X17	WC	19.0	22.50	24.70

Note : 1. H- hardening, P-Peening, QT-Quenching and tempering
2. C-Cronidur30, X-XM16

4. Conclusions

A wear test for total 36 specimens with the combination of materials is performed to select the good candidate material of the ball screw assembly. The first test results show that Incoloy925 plates and Cronidur30 balls have relatively large wear. From the results of the second test excluding Incoloy925, it is found that Cronidur30 and ASTM A564-XM16 have good wear resistant for the screw/nut and Si_3N_4 for the ball. In conclusion, Cronidur30, XM16 and Si_3N_4 are selected as the final candidate materials, and will be manufactured and tested for the performance verification of ball screw assembly.

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