# Durability Tests of Ball Screw Assembly for the CEDM

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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 control elements within the reactor core. A ball-screw type CEDM driven by the stepping motor for the integral reactor has been developed, and efforts to improve the performance for the CEDM main components including a ball screw assembly has been continuously made[1~2].

This paper describes the test results to evaluate the durability performance of the ball screw assembly made of Cronidur 30(Cro30) and ASTM A564-XM16(XM16) materials which were selected by specimen tests[3]. Six ball screw assemblies are fabricated and tested by using a durability test device. All specimens satisfied the lifespan requirement for the research reactor.

## 2. Durability Tests

### *2.1 Test Specimens*

The ball screw assembly of integral reactor CEDM changes the rotation of stepping motor to the vertical movement of control elements through the ball nut. Thus, the ball screw and nut are subjected to high load due to the weight of moving parts in water.

In general, a ball screw assembly is composed of a shaft, a ball nut, balls and a transferring tube. Fig. 1 shows the test specimen of single-row and double-row ball screw assemblies. A total of six specimens are fabricated based on the combination of materials(Cro30, XM16, $Si_3N_4$(ball)), screw types(single-row, double-row) and heat treatment conditions(Hardening, Peening, Quenching/Tempering) as shown in Test ID of Table 1.

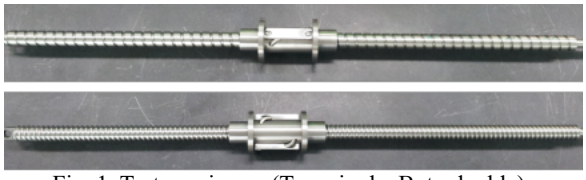


Fig. 1. Test specimens (Top: single, Bot.: double).

### *2.2 Test Device*

Fig. 2 shows the test device for a durability testing of ball screw assemblies. The device is composed of two specimens, a support frame, a drive motor, a torque transducer, a dummy weight, an acrylic cylinder, a linear guide, a control and measurement device, and a data storage PC. It is designed to test two ball screw assemblies simultaneously. In addition, the test device is capable of applying a large load to the ball nut and allows for the adjustment of rotational speed and direction of 60 rpm or more using a servo motor.



Fig. 2. Durability test device.

### *2.3 Test Requirements and Method*

The durability test is performed by the continuous up-and-down driving of the ball nut under the following requirements and conditions.

- ○ Applied load: 250 kgf upward on the ball nut
- ○ Cumulative travel distance of the ball nut: 10 km or more (670,000 rotations of the ball screw shaft)
- ○ Test environment: Ordinary fresh water at RT
- ○ Motor driving speed: 60 rpm

During the test, torque change and noise are measured periodically to determine if there are any abnormalities in the test process. A diameter of ball, a pre-load and a ball center diameter(BCD) of groove are also measured before and after the test to compare the amount of wear.

## 3. Results and Discussion

The results for all specimens after performing the durability test are shown in Table 1. The torque and noise measurement results show nearly constant values during the test, indicating that there are no significant changes in the test conditions. When evaluate based on quantitatively measured values, the ball diameter is changed in the range of 22–63μm, and the BCD of the shaft groove is decreased by 2–9μm. The heat-treated

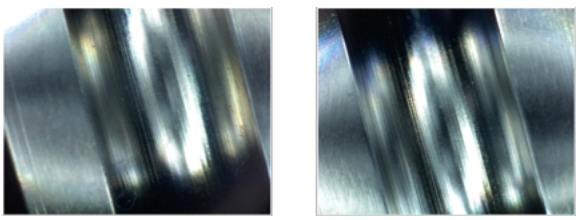
Cro30(CroD-H-2) specimen shows the smallest change in the ball at -22μm, while the peened Cro30(CroD-P-1) specimen presents the smallest change in BCD at -2μm. Overall, the wear on the balls and BCDs is slightly greater in the single-row ball screw assemblies(CroS) than in the double-row those(CroD). Additionally, after the test, the pre-load remaines at a reduced value in the double-row ball screws, whereas the single-row ball screws lose completely pre-load and presents a value of zero.

Table 1 : Summary of durability test results

| Test ID | Ball dia. change (μm) | BCD change (μm) | Avg. torque (kgf.cm) | Pre-load (kgf.cm) | Sound (db) |
|---|---|---|---|---|---|
| CroS-H-1* | -63 | -9 | 7.50 | 0 | 69.8 |
| CroS-H-2 | -58 | -8 | 7.99 | 0 | 68.6 |
| CroD-H-1 | -36 | -4 | 9.60 | 0~0.3 | 69.8 |
| CroD-H-2 | -22 | -7 | 8.98 | 0.5~0.8 | 68.9 |
| CroD-P-1 | -34 | -2 | 8.98 | 0.4~1.1 | 68.9 |
| XMD-QT-1 | -41 | -4 | 5.43 | 0~0.3 | 68.5 |
| Note : * CroS-H-1(Cronidur30 Single-Hardening-No.), Ball material : $Si_3N_4$ , Initial pre-load : 1.0~3.0 kgf.cm | | | | | |

Figs. 3 and 4 show the magnified groove of the shaft and nut for the peened Cro30 double-row specimen(CroD-P-1), respectively. There are no notable signs of wear before and after the test for the ball screw shaft. However, the ball nut groove shows signs of wear (light-colored line) on the lower surface as shown in Fig 3(b). This is because the load in the test device acts upward on the ball nut. In other words, the lower part of the nut groove comes into contact with the balls and receives the load during the test. In addition, the ball nut, which moves more during the test, is one of the causes of greater groove wear than the shaft.

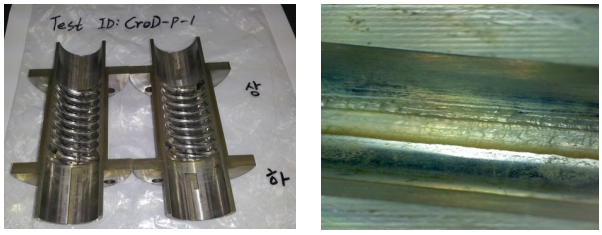
Generally, operating conditions such as wear, heat generation, eccentric loading affect the lifespan of ball screw assemblies, and flaking occurs in the groove at the end of their life. In this study, although there are minor wears on the ball screw shaft and nut such as changes in ball size or BCD, no flaking occurs in the groove even after 10 km operation. Fig. 5 shows an example of the result of measuring the groove of the ball nut.



(a) Before (b) After

Fig. 3 Shaft groove (peened Cro30)

Although not shown in this paper, inspections are performed for all specimens not only on other ball nuts but also on the shafts, and it is confirmed that the condition is good with no flaking in the groove.




(a) Section view (b) Groove

Fig. 4 Ball nut after the test (peened Cro 30)

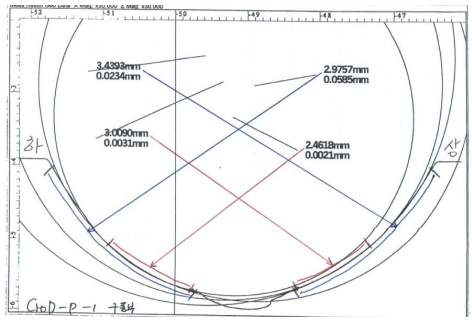



Fig. 5 Measured result of the ball nut groove

## 4. Conclusions

The durability tests for six ball screw assemblies are performed using a test device. All specimens meet the driving requirement of 10 km under the test conditions. For the same material, the amount of wear for the double-row ball screw assembly is lower than the single-row one, and the results for Cro30 specimens are similar to or slightly better than those of XM16. Therefore, it is determined that it would be good to use the peened Cro30 double-row ball screw assembly in the research reactor.

## REFERENCES

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