Load Analysis for Hinge Joint in Control Element Drive Mechanism of Integral Reactor

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1. Introduction

Integral Reactor needs CEDM which has the design characteristics of fine step control and high load capacity to satisfy soluble boron-free operation and lift heavy control element assembly. Ballscrew type CEDM shown in Figure 1 satisfies such requirements[1,2]. In this paper the load analysis for hinge joint which is the weakest part of the load carrying system of CEDM is carried out and a strength requirement for the hinge joint is provided. The hinge joint as shown in Fig.2 plays a role of minimizing the momentum transmitted to screw in case of misalignment of upper pressure housing.

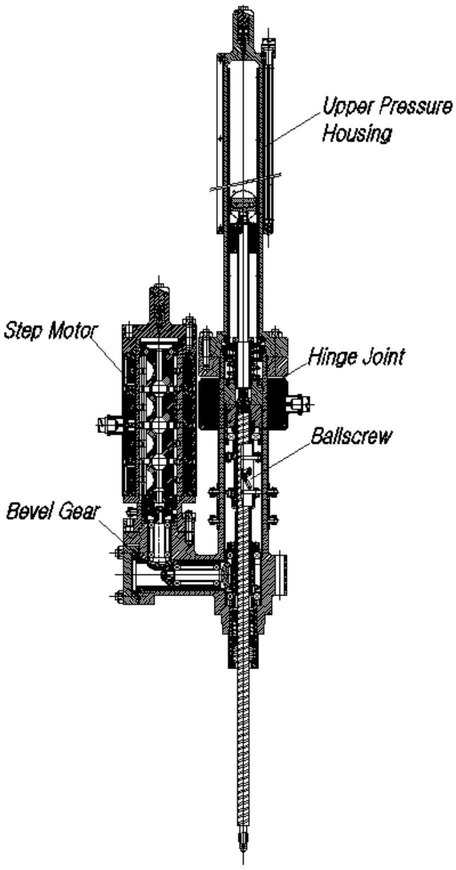

Figure 1. Ballscrew type CEDM

2. Load Analysis

2.1 Tensile loads

The maximum tensile load is applied to hinge joint when the moving parts of CEDM are rested on the upper damper casing with de-energized step motor and then the step motor is operated to the direction of screw insertion. This operation is not allowed but the load due to such malfunction should be considered in hinge joint design. The loads applied to the hinge joint for that case are divided into three items; release spring force, dead weight of moving parts, and tensile load by step motor torque.

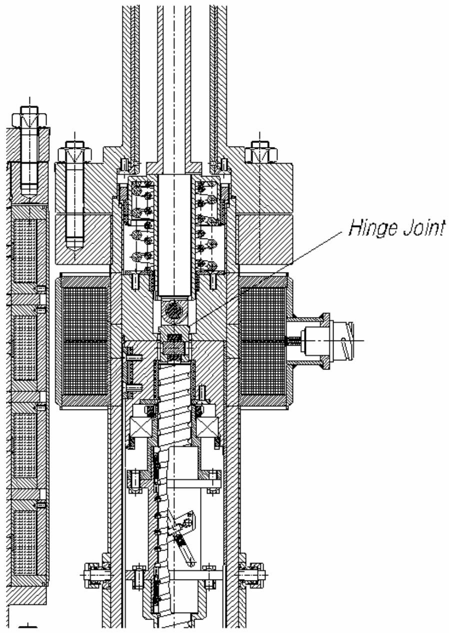

Figure 2. Details of Hinge Joint

Release spring assembly plays a role of improving the quick insertion of control element assembly into core on emergency. The design loads of release spring assembly are 800N on installation and 1,500N on full withdrawal of nominal stroke of 680mm. So, the maximum tensile load by release spring assemly, Q_r, is 1,500N.

Dead weight of moving parts, Q_w, that includes all vertically driven parts such as control element assembly, extension shaft assembly, and screw assembly is 1,100N for the biggest control element grouping plate.

Tensile load caused by the step motor torque is transmitted through the complicated load carrying parts such as ball bearings, bevel gears, and ballscrew. Load carrying mechanism of ballscrew can be modeled as shown in Fig.3.

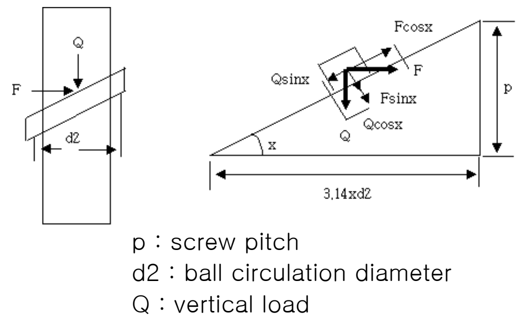

Figure 3. Ballscrew load carrying model

Therefore the vertical tensile load by step motor torque is given by

$$Q_{sm} = \frac{2T_{SM}\eta_t}{d_2 G_r \tan(x+\rho)} \qquad (1)$$

where T_{SM} is step motor torque, G_r is bevel gear ratio, and η_t is a total efficiency considering the friction of all ball bearings, bevel gears, splines, and ball screw.

Step motor torque, T_{SM}, can be obtained from step motor performance test result shown in Figure 4[3].

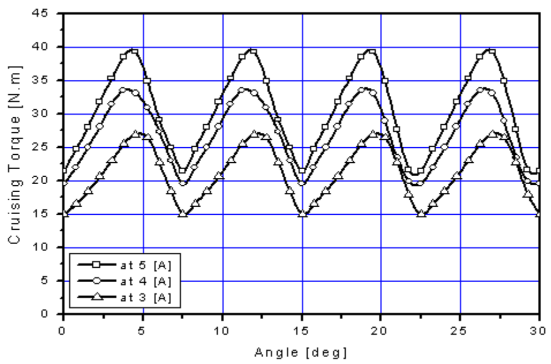

Figure 4. Step motor performance test result

Since the nominal design current for the step motor is 3.4A, the step motor torque at design current is about 30Nm from the test result of Figure 4. From equation (1) the tensile load due to step motor torque is 10,800N.

Therefore the total tensile load, Q, applied to hinge joint is

$$Q = Q_r + Q_w + Q_{sm} = 13{,}400N \qquad (2)$$

2.2 Torques

Torque is also applied to hinge joint by the release spring force, dead weight, and step motor torque. During normal operation the torque applied to hinge joint by release spring force and dead weight is

$$T_{rw} = 0.0027(Q_r + Q_w) = 11Nm \qquad (3)$$

And the step motor torque of 30Nm is directly applied to the hinge joint. So the total torque applied to hinge joint is 41 Nm.

3. Requirement for strength

The minimum sectional area of hinge joint is 108.0mm^2. If only the tensile load is considered for hinge joint strength assessment because torque is very small compared to tensile load, the yield strength should be more than 124MPa. This value is not taken account of safety factor. If dynamic load of 2g is applied the yield strength should be more than 144MPa. In addition if design current is increased up to 5A(maximum step motor torque is 40Nm at this current), the yield strength should be more than 177MPa.

4. Conclusions

The load analysis for hinge joint of CEDM was carried out to provide a strength requirement.

The maximum tensile load applied to hinge joint is 13,400N and the torque is 41Nm. The yield strength of hinge joint should be more than 124MPa at static condition and design current 3.4A. If dynamic load of 2g is applied and design current is increased up to 5A, the yield strength should be more than 177MPa.

Acknowledgement

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