Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 7-8, 2015

Preliminary Design for the Motor and Body of the IVTM in PGSFR

S. H. Kim [a*], G. H. Koo [a]
[a]*Korea Atomic Energy Research Institute, Daejeon 305-600, The Republic of Korea*
[*]*Corresponding author: shkim5@kaeri.re.kr*

1. Introduction

The purpose of this study is to determine the size of the motor installed in the upper motor driving part of an In-Vessel Transfer Machine (IVTM) and perform a kinematic analysis for the pantograph mechanism of the IVTM in a PGSFR. If the core assembly cannot be withdrawn from the reactor core due to a deformation or accident, a maximum load of 27 KN can be applied to the gripper finger. Thus, the motor size of the gripper driving part which can move up and down the core assembly is determined by considering the gear arrangement, the gear reduction ratio and the maximum torque between the gripper and the drive motor. In addition, the pantograph arm of the IVTM can be retracted and extended to handle the core assembly as shown in Fig. 1. In this mechanism, the relative geometrical positions for each joint are calculated using the Scott Russell Perfect Strait Line Mechanism [1].

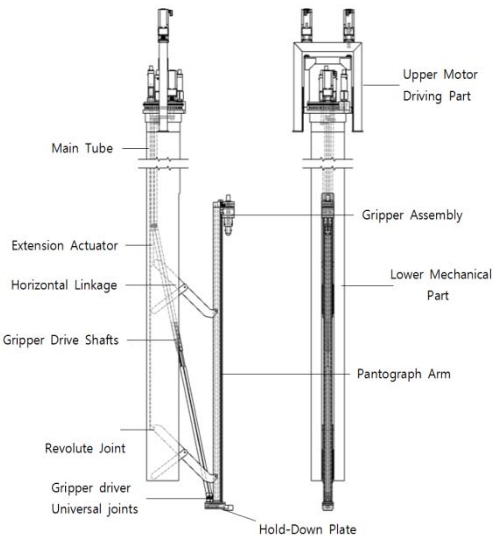

Fig. 1 Design configuration of the IVTM in PGSFR

2. **Motor and Body Design for the IVTM**

2.1 Max. Torque for the Gripper Vertical Movement

The IVTM in the PGSFR withdraw the core assembly from the reactor core by using the gripper to handle the core assembly inside the reactor during the refueling time. The gripper transforms the driving force transmitted from the motor into the vertical movement of the gripper using the ball screw shaft and nut installed inside the pantograph arm. By means of this movement, the gripper can move up and down inside the pantograph arm. During the operation, we can assume a condition that is impossible for a withdrawal due to the deformation of the core assembly and another malfunction. We define the load at this time as the maximum value of the refueling load and consider it as the design load. To calculate the torque when the core assembly is not withdrawn, we can assume that the refueling load of 27 KN is totally applied to one side of the gripper finger as shown in Fig. 2.

Under this loading condition, the bending moment in the ball screw shaft inside the gripper occurs due to the load applied to the gripper and the friction force on the contact surface is generated. On the basis of this working load, the maximum design torque is calculated based on the design formula of the ball screw. The friction coefficient on the contact surface and the efficiency in the ball screw are assumed to be 0.3 and 0.9, respectively. As a result of the calculation, the maximum torque required for this refueling load is calculated as 155.3 N.m.

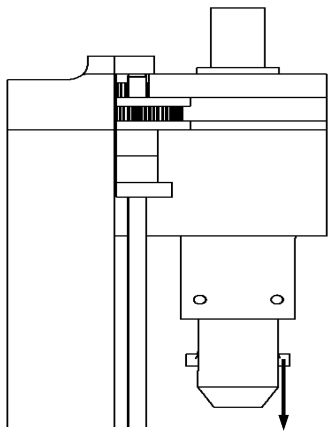

Fig. 2 Maximum refueling load applied by a “stuck” core assembly

2.2. Motor Sizing of the Driving Part

In this calculation, the refueling design load of 27 KN is considered in the lower part of the gripper finger to determine the motor size for the vertical movement part of the gripper. According to this, the motor size needed to move up and down the gripper is calculated. For the analysis data, it is considered that the movement speed of the gripper is 4.55 m/min and the ball screw shaft is 2 threaded screw with a 1 inch thread pitch. In addition, the torque needed to raise the gripper for the refueling design load was calculated as 155.3 N.m. Thus, the motor size of the driving part for this torque is determined by considering the gear reduction ratio. The calculation is performed using the MATHCAD program and the calculated motor torque and rotation speed for the vertical movement part of the gripper are 45.3 N.m and 1200 rpm, respectively.

2.3 Pantograph Mechanism Design Calculation

The IVTM has a pantograph movement to handle the core assembly inside the reactor during the refueling period. Here, the rotation force of the upper driving motor is changed into vertical movement which is transferred to the extension actuator using the ball screw drive elements, and the pantograph arm is then retracted and extended using the revolute joints. Thus, it is necessary to calculate the relative position and rotation angle of the pantograph mechanism. The dimension of the variation in the arm length on the pantograph mechanism calculated using the MATHCAD program is as shown in Fig. 3. This figure represents the dimensions for the retraction and extension of the pantograph arm designed using the INVENTOR 3D program. The left side figure represents the position of the pantograph arm when it retracts. From this figure, we can see that the distance between the pantograph arm and the main tube is 180 mm and the vertical distance between the revolute joints is 1388.4 mm. In the right side figure, we can see that the distance between the pantograph arm and the main tube is 1144.5 mm and the vertical distance between the revolute joints is 806.3 mm. For a kinematic analysis of the pantograph mechanism, because the upper and lower parts are symmetric, we can calculate the length variation of the pantograph arm for the lower part by using the Scott Russell Perfect Straight Line Mechanism theory as shown in Fig. 4. From the MATHCAD calculation results, the relative positions for the retraction and extension of the pantograph arm are calculated and indicated as a graph as shown in Fig. 5.

3. Conclusions

In this calculation, a motor sizing of the driving part which is located above the reactor head is performed. When the core assembly cannot be withdrawn due to a malfunction, the maximum torque is evaluated, and the motor driving torque by considering the gear reduction ratio is calculated. In addition, for the pantograph mechanism, the relative positions of the revolute joints and the trajectory for the retraction and extension of the pantograph arm are calculated.

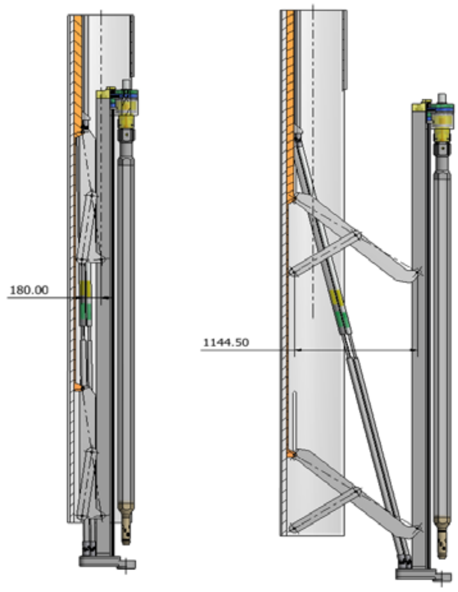

Fig. 3 Movement mechanism of the pantograph arm

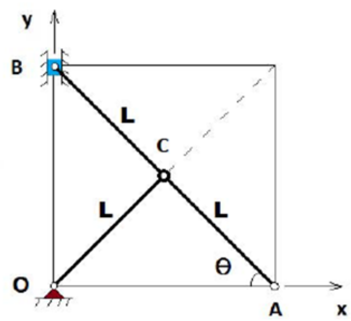

Fig. 4 Scott Russell Perfect Straight Line Mechanism

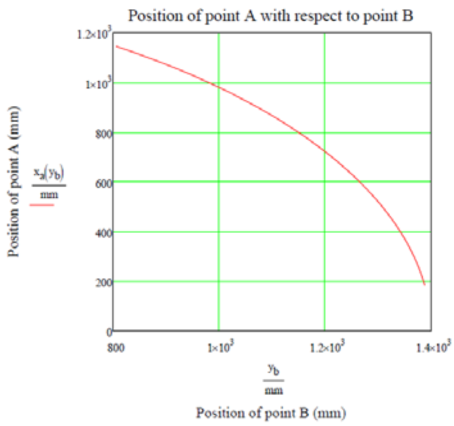

Fig. 5 Trajectory of the pantograph arm calculated using the Scott Russell Perfect Straight Line Mechanism

Acknowledgements

This study was supported by the MSIP through its National Nuclear Technology Program.

REFERENCES

[1] ANL, Preliminary Design Calculations for the PGSFR IVTM, ANL-KAERI-SFR-01, 2014.