§9. A Prototype Design of Replacement System of the Mirror for Measurement in the Fusion Reactor

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i) Introduction and aim of the study

In the steady operation of future fusion plasma device, some mirrors will be installed inside of the reactor in order to reflect laser beam which is used for "Interferometer / Polarimeter", "Thomson scattering measurement" or "spectroscopy". The surfaces of the mirrors are often subject to wear by plasma and covered by deposition substance. As a result, reflection rates of the mirrors might be deteriorated and mirrors should be replaced with new one on a regular schedule. However, in the practical point of view, it is inefficient to stop the operation of fusion reactor for the sake of mirror replacement. Therefore, the future goal of our study is to develop a mirror replacement system which does not require stop of operation of fusion reactor. In order to achieve the future goal, in this study, it is necessary to extract essential problems for development of a mechanical system which can drive precisely in the special circumstances of the inside of fusion reactor, i.e. "high radiation", "wide range of temperature change", "high vacuum" and "intense magnetic field". Furthermore, it is important to develop a prototype of the mirror replacement system which resolves the extracted problems.

ii) Countermeasure against special circumstances

At first, the wide range of temperature causes thermal deformation and such a deformation leads to configuration error of mechanical system. Especially, the system in the study has mirror for laser beam reflection which is sensitive to configuration error. However, it is difficult to implement thermal control system because of its size and complexity. Hence, compensation mechanism for thermal deformation is installed in the proposed system, and it can also absorb the error due to mechanical backlash. Next, high vacuum have an influence on the lubrication of the mechanical drive system[1)]. However, solid lubrication and kind of coating technologies, e.g. DLC coating, can reduce such an influence and, are applied to the proposed system. Next, intense magnetic field causes stress on ferromagnetic material which is generally key material for actuators, and leads to mechanical deformation of the system and consequently imprecise behavior of the system. In order to avoid the influence of intense magnetic field, the proposed system piezoelectric based actuator which does not need ferromagnetic material. Finally, it is reported that plastic part is decayed by radiation. However, such materials are used for harness etc. and various technologies are existing, and those are utilized in this study. Furthermore, radiation has influences on sensors which are made from transistor. The measurements of displacement are required in the study, and load cell based technology with piezoelectric is going to be employed in the study.

iii) Proposed system

Fig. 1 shows the proposed system which employs aforementioned countermeasure against special circumstances. In the system, validation of mechanical feasibility is focused on and actuators used in the system are not special one for simplicity.

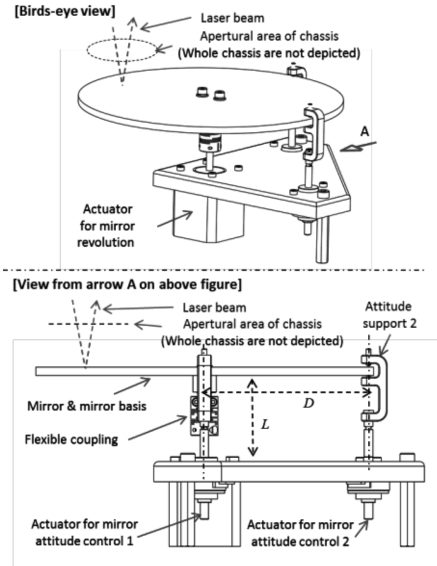

Fig. 1. Proposed system

As Fig.1 shows, mirror is mounted on the mirror connected to the actuator for mirror revolution, which enables the mirror to rotate around shaft of the actuator. Whole system is covered by chassis which has the apertural area. Area of the mirror under the apertural area is used for reflection of the laser beam. That is other area of mirror is protected from wear by plasm and deposit materials. In general, mechanical system has backlash and thermal deformation described above, the system absorb such a unexpected factor in order to achieve precise movement. In the system, attitude support 1 and 2 which can be moved vertically by actuator, adjust the tilt of the mirror. Furthermore, in order to give two degrees of freedom according to two tilt angle of the mirror, axis attached to mirror base include flexible coupling which give more reliability than the general mechanical joint for giving degree of freedom. In order to satisfy absorb the unexpected tilt angle of the mirror, appropriate stiffness of the flexible coupling should be designed for estimated worst title angle θ and given actuator force α. Supposing flexible coupling is uniform circle shape beam, diameter of the beam d is given as

$$d = \sqrt[4]{128DL\alpha / E\theta} \qquad (2)$$

where E is young's modulus of the uniform beam and other parameters are given in Fig.1. The stiffness of the coupling is set to the same value of the uniform beam with the diameter derived by Eq. (1).

1) Wertz J. R., Larson W. J.: Space Mission Analysis and Design (1999)