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LASER OPTICAL MICRO ACTUATION INDUCED BY EFFECTS OF RAREFIED GAS DYNAMICS

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KEY WORDS

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ABSTRACT

Laser optical micro actuators are proposed for micro machines. Optical energy is supplied by a laser beam to the actuators. The actuators are rotated by rarefied gas dynamics (RGD) effects such as thermal creep. The effects of gas pressures, actuator blade lengths, rotor materials, axis bearings and the molecular weights of gas species around the actuators on actuator performances are revealed by experiments and DSMC simulations.

System for Laser Optical Micro Actuator

Large scale research projects on micro machines have been carried out. One of the applied areas of the micro machines is Optical Micro-Electro-Mechanical Systems (OMEMS). Various kinds of energy supply methods are proposed for the OMEMS. One of the most important problems in the development of the OMEMS is how to supply a power to the OMEMS. Laser optical micro actuators (LOMA)^{[1] [2]} are proposed for the OMEMS. Temperature differences between the front and rear blade surfaces of the LOMA rotors can induce the rotation by RGD effects such as radiometric force and thermal creep.

. One of the purposes of the present research is the establishment of a method for supplying energy to the LOMA. The experimental facility is composed from a vacuum chamber, the device for measuring rotational rates and surface temperatures of the rotors, and a laser beam generation device. The LOMA are installed inside of the chamber. The rotors have four blades made of rectangular plates. The tips of the blades are a little bit far from the axis of the rotor by 1.25 mm. The blade length of the rotors is 1 mm. The blade thickness is 0.1 mm. The only one-side surface of each of the blades at first was coated with carbon-black powder. The four blades are connected with a bearing like a cap made of Pyrex glass, originally. An argon ion laser beam with 514.5 μ m wavelength is used for heating. The gas pressure in the chamber is reduced to a certain gas pressure using a vacuum pump system. At a pressure, the irradiation of the laser beam from the outside of the chamber heats the surfaces of the rotor blades. Immediately after the irradiation, the rotor begins to be rotated or to be twisted. The twisted torques were evaluated by the elastic theory in solid mechanics after measuring twisted angles.

Experimental results and discussion

Fig. 1 shows the results of the twisted torque measurement which the gas pressure in the chamber is converted into Kn. The Kn (Knudsen number), a non-dimensional parameter for RGD, is defined by

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the ratio of the mean free path length of the gas to the length of the blade. It is noted that the maximum torques between $Kn=0.1$ and $Kn=0.3$ are generated. Although the radiometric and the thermal forces^[3]^[4] are considered to be the sources of the optical-micro actuation, the flow condition around the actuators belongs to the intermediate region of rarefied gas dynamics. The radiometric force works in the free molecular flow region of rarefied gas dynamics. The tendency that the maximum torques increase with decreasing the molecular weight of the gas is observed in Fig.1. The molecular weight of the gas is of no concern of the radiometric force^[3]^[4], depending only on the pressure and the temperature of the gas. On the other hand, the thermal force is proportional to a gas constant, a temperature gradient, and the square of a viscosity. However, according to the experimental results on the maximum torques, the values of the torques by He (Helium) are larger than those of Xe (Xenon) by twice. The reason could be related to the effect of the accommodation coefficient on the blade surface. The experimental data measured by the device shown in Fig.2 on rotational rates of the actuators and comparisons with DSMC^[5] numerical results will be shown in the presentation.

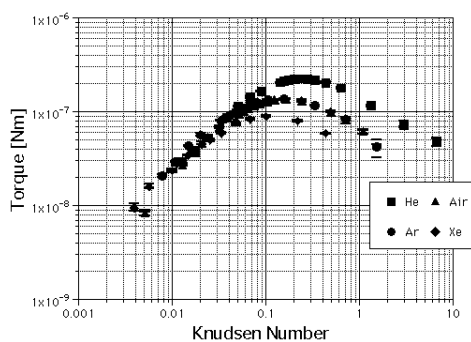
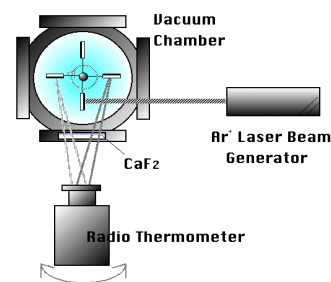


Figure 1: Dependence of twisted torques on Knudsen number



Plane view

Fig.2 Schematic drawing of device for measuring simultaneously rotational rate and surface temperature

Conclusion

Laser optical micro actuator are proposed for OMEMS. The actuators are twisted or rotated by rarefied gas dynamics effects, such as thermal creep. The effects of gas pressures, actuator blade lengths, rotor materials, axis bearings and the molecular weights of gas species are revealed on actuator performances, by the experimental data and DSMC numerical results.

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