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Article / Book Information

題目(和文)	機能性流体を用いた超音波モータにおける摩擦制御に関する研究
Title(English)	Efficient Modulation of Friction in Ultrasonic Motors Using Functional Fluids
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Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
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論 文 要 旨

THESIS SUMMARY

専攻： Department of	物理情報システム 専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of	(Engineering)
学生氏名： Student's Name	Wei QIU (邱 惟)	指導教員（主）： Academic Advisor(main)	中村 健太郎 教授	
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

This thesis describes the efficient modulation of friction in ultrasonic motors (USMs) using functional fluids, i.e. lubricants and giant electrorheological (GER) fluids, which relate to the following areas of work.

In Chapter 2, the concept of friction modulation and proposed lubrication mechanisms in USMs were introduced. We also numerically analyzed the lubricating effect in hybrid transducer-type ultrasonic motors (HTUSMs) using an equivalent circuit. The dependence of the motor characteristics on the contact durations in dry and lubricated conditions was examined, and the reason of limited efficiency for HTUSMs in dry condition was clarified. The motor performance at various static preloads and applied voltages were also investigated, and the HTUSM characteristics, i.e. motor efficiency, no-load speed, and maximum torque, were shown to be more desirable at high static preloads in lubricated condition than in dry condition.

In Chapter 3, the lubricating effect in standing-wave type USMs was experimentally investigated. The dependence of the motor characteristics on the contact pressure was in good agreement with the simulation results. With lubrication, the motor performance at low static preloads, including the motor efficiency, the no-load speed and the maximum torque, was lower than that without lubrication. However, it was drastically improved at high static preloads, which indicates that high pressure is required to keep sufficient friction force if lubricant is applied. The transduction efficiency of the motor was enhanced from 28% in dry condition to 68% in lubricated condition. We also examined the torque of USMs in lubricated condition, and significant improvement in motor output torque was observed. The maximum torque as high as 1.01 Nm was obtained in a 25-mm-diameter HTUSM, which was 2.6 times higher than that in dry condition. The torque enhancement was attributed to the fact that the motor with lubrication can withstand much higher static preload than that without lubrication. Both high efficiency and high torque were achieved under high static preloads, which solved the dilemma in dry condition. By employing a stroboscopic optical interferometry, the transient variation in lubricant film thickness was measured at an oscillating frequency >50 kHz. This is the first measurement of film thickness at such a high frequency. Current results provide preliminary information on the lubrication mechanisms in USMs, though direct connection with the results obtained in high-efficiency USMs is difficult due to different experimental conditions. This technique will be useful to measure the film thickness change in various mechanical systems.

In Chapter 4, the tribological performance of four types of advanced engineering ceramics was investigated in USMs with the lubrication of high traction fluid. Mechanical fracture was found to be the main wear mechanisms of the tested ceramics in lubricated USMs. ZrO_2 showed the mildest wear of all the tested ceramics, indicating that the ceramics possessing high fracture toughness are desirable for lubricated USMs. In contrast, the hardness of ceramics plays a less important role than the fracture toughness, since SiC exhibited the most severe wear.

In Chapter 5, the lubricating effect in traveling wave ultrasonic motors was experimentally studied. Unlike the situation in standing wave ultrasonic motors, lubricant significantly lowered the mechanical characteristics of motor, including motor efficiency, no-load speed, and maximum torque. This phenomenon was attributed to that the quality factor of the stator was largely reduced due to the presence of lubricant, resulting in high vibration loss and poor motor performance. A bending vibrator with higher vibration energy might be the solution for lubricated traveling-wave type USMs.

In Chapter 6, we developed a non-contact rotary motor using a piezoelectric torsional vibrator and the GER fluid. By comparing with the motor using the conventional dielectric electrorheological (ER) fluid, drastic improvement in the motor characteristics was observed because of the short response time and high yield stress of the GER fluid. Ideal motor performance was obtained under 2 kV/mm electric field strength with 30% duty cycle, and 1.04 mN m torque at the rotational speed of up to 6.98 rad/s was achieved, offering force at least two orders of magnitude larger than that of conventional non-contact USMs. Several similarities and differences between this motor and contact-type standing-wave type USMs were discussed, verifying the operating principle of this type of non-contact motor. The torque transmission mechanism of this motor was simulated by an equivalent circuit model. The simulation results had a good agreement with the experimental ones except the value of output torque. The discrepancy in torque might be attributed to the reduced contact area due to the centrifugal force and the slip between the GER fluid and the rotor surface. Simulated dependence of the rotational speed on the phase difference indicates that the actual response time of the GER fluid might be even smaller than 1 ms.