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STUDY ON MOTORS USING LIQUID CRYSTAL FLOW INDUCED BY ELECTRIC FIELD

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ABSTRACT

It is well-known from our previous study that LC(liquid crystal) circumrotates in a mini cylinder by a rotating electrical field. The possibility of the development for a motor based on the above idea is investigated in this study. In the experiments, electrodes are located both at the bottom and on the side wall of the cylinder, in which the LC and the rotor are placed. The influence of the viscosity on rotation speed of the rotor is investigated. Moreover, the theoretical study on torque generation is expected too.

KEY WORDS

Liquid Crystal, Relative Permittivity, Functional Fluid, Motor, Unsteady Electric Field

INTRODUCTION

It is known from our previous work that Liquid crystal (LC) flows in a mini cylinder by rotating electric field[1]. The possibility for designing motors driven by the flowing based on the above mechanism is investigated in this study. Many advantages can be obtained in this kind of motors, for example, the structure of the motor is simple and it can be minimized easily.

In the experiments, electrodes are located both at the bottom and on the side wall of a cylinder, in which the LC and the rotor (sampled as a turbine) is placed. The rotating electric field of three-phase alternating current is generated to add it on the electrodes in a motor. Two kinds of LC with different properties, such as viscosity etc. are tested during the experiments. The rotation speed of the rotor is measured under given electric fields with constant frequency [2,3]. One main contribution of this investigation is the comparison in rotation speed when motor is placed under different LC in two cases. One case is that the electrodes are placed just at the bottom of the cylinder. In the other one, the three-phase alternating currant is added on all electrodes in the cylinder. Additionally, the influence of viscosity on rotation speed is also investigated. Moreover, the theoretical study on torque generation is studied too.

TEST BENCH

The test-bench is shown in Fig.1. The height and the diameter of the cylinder are both 4mm. Six electrodes are located at the bottom every 0.2mm (In Fig.1, the electrodes are equipped both at bottom and the side wall). The faced electrodes as 1 and 4 are the same in voltage level. The 3-phase power supply used in the experiments is same in frequency and the angle is $2/3\pi$ delay in the sequence 1→2→3. Theoretically, the liquid crystal should flow in the clockwise way. An impeller with diameter 2.6mm and height 1.5 mm is dipped in the LC (see Figs.1 and 2). The rotating speed is measured by images of the rotor taken using digital camera placed over the cylinder. The input for the equipment A (see Fig.3) is the AC with frequency 50Hz and effective voltage 200V. The output of the transformer A can be adjusted form 0V to 240V. The transformer B is with the transformation ratio 15, which is the final voltage for each electrode. During the experiments, the speed measurement is executed with different voltage level. Furthermore, in experiments, the tests with different dielectric constant of isolation are taken and discussion between two cases is illustrated.

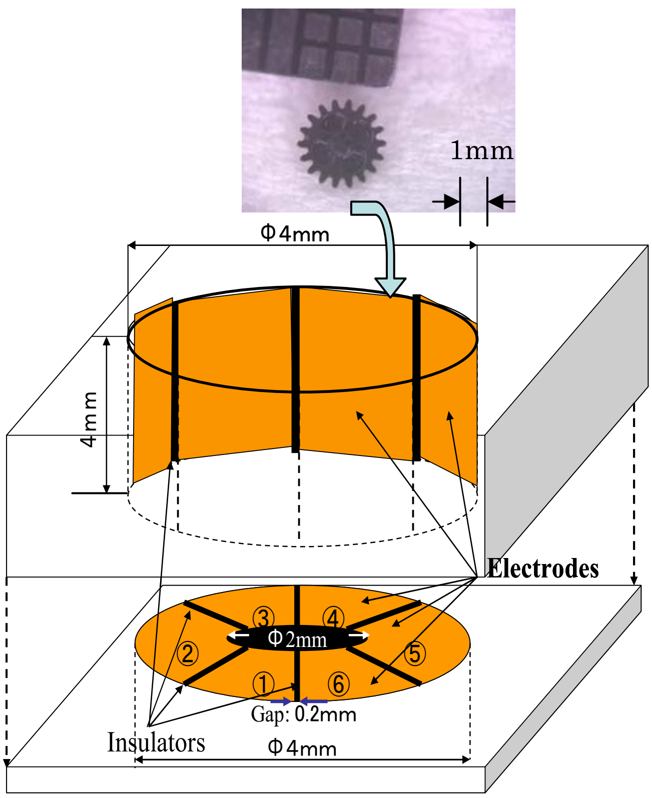

Fig.1 Present motor and rotor

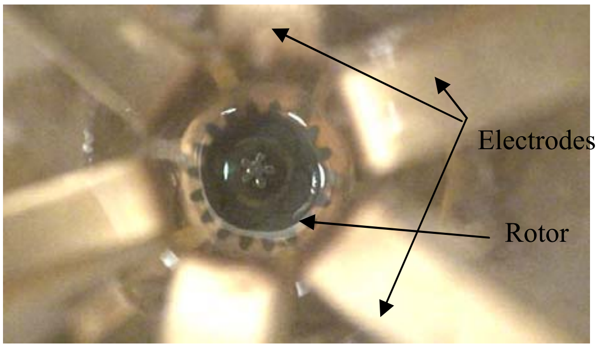

Fig.2 Photo of electrodes and rotor
(Inner diameter:4mm, Diameter of rotor:2.6mm)

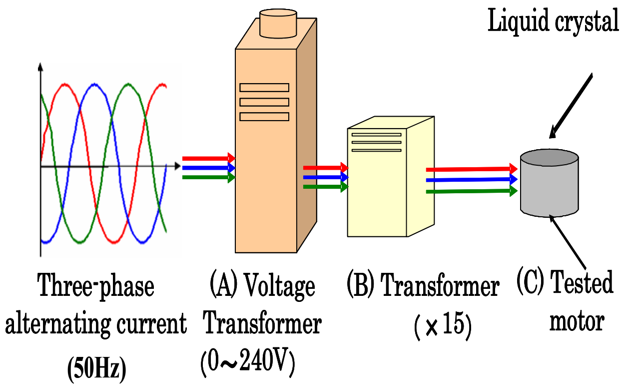

Fig.3 Experimental apparatus using three-phase alternating current

EXPERIMENTAL VALIDATION

The results for experiments A and B are demonstrated as follow.

For experiments A, three kinds of LC (Mixed LC MLC6650, Pure LC K-15 and Mixed LC MJ0669) are tests. Figs.4 and 5 show the curves of speed of rotor with different dielectric constant and voltage level. The average of five measurement of speed is taken for evaluation. The voltage changes from 353V to 1420V in experiments. *h* is the height of the LC surface.

In Figs.4 and 5, it is clear that in the same frequency, high voltage implies high speed.

Meanwhile, the speed changes with the variation of dielectric constant. In Fig.4 polyamide films is used with dielectric constant 3.5

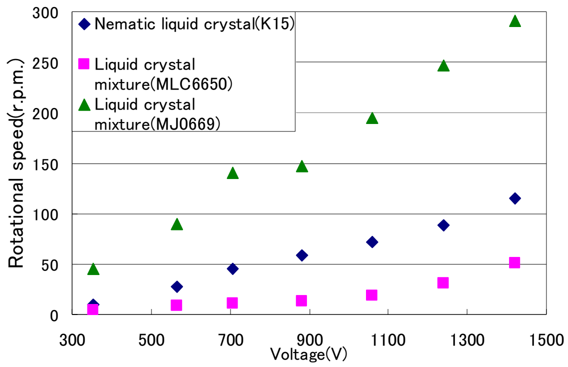

Fig.4 Relationship between rotational speed and voltage for experiment A
(Using polyamide film,
specific **permittivity**=3.5, *h*=2mm)

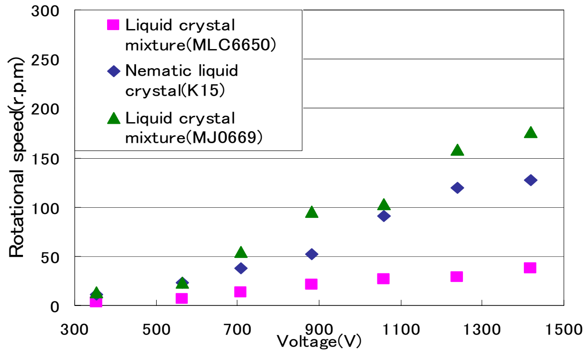

Fig.5 Relationship between rotational speed and voltage for experiment A
(Using glass epoxy board,
specific **permittivity**=4.6～4.8, *h*=2mm)

In the other way, as the experiment shown in Fig.5, glass epoxy is adopted and the dielectric constant range is from 4.6 to 4.8. According to MJ0669, experiment result shows that small dielectric constant lead to high speed. Furthermore, among these 3 kinds of LC small kinematic viscosity and dielectric constant makes high speed. The highest speed appears in LC MJ0669, then K-15 and finally MLC6650. The kinematic viscosity are 13mm^2/s, 20 mm^2/s, 76 mm^2/s, respectively. The parameters of dielectric constant are 11.2, 26.1, 62.8 along the molecule axis and 3.9, 6.0, 10.2 in the vertical direction.

Figs.6 and 7 illustrate the results for experiment B. The mentioned two cases are compared and the result shows that the speed is high when both the electrodes at bottom and on the side wall are activated. The reason for this phenomenon is that the interface is large in the second case, which provides us the future issue for influencing rotating speed in more effective way.

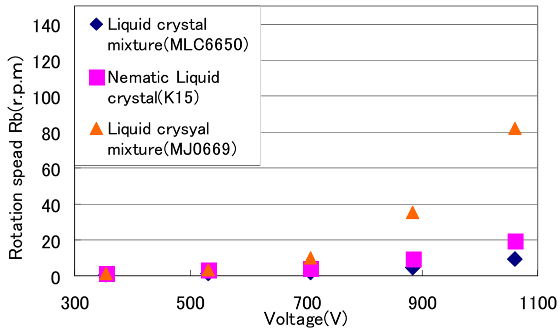

Fig.6 Relationship between rotational speed and voltage for experiment B
(Using polyamide film, on the bottom surface, h=1.8mm)

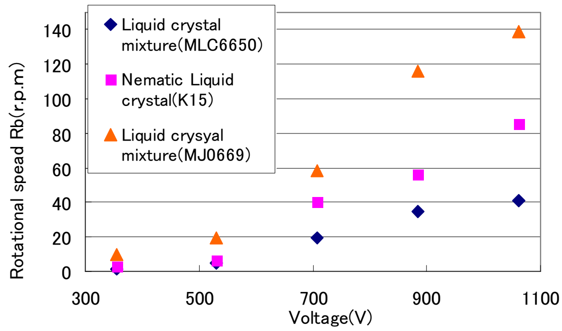

Fig.7 Relationship between rotational speed and voltage for experiment B
(Using polyamide film, on the bottom surface and side face, h=1.8mm)

TORQUE CALCULATION

From Newton secondary law, Eq(1) exists:

$$T = J\frac{d\omega}{dt} \qquad (1)$$

where T is the starting torque generated from LC flowing, ω is the angler velocity of the rotor and J (=1.36×10^{-7}kgm^2) is the rotary inertia.

The moment of inertia of the gear (J) is obtained from the geometrical calculation.

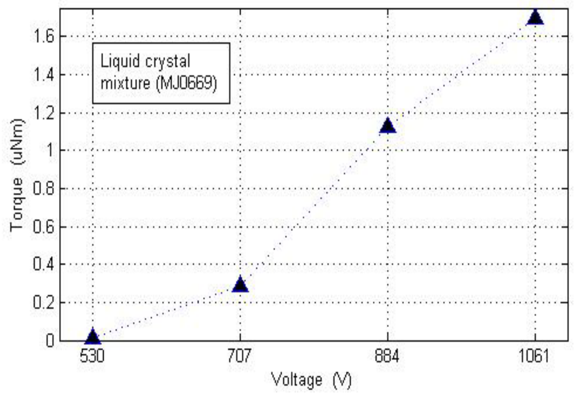

Fig.8 Relation between torque and voltage (on the bottom surface and side face， *h*=1.8mm）

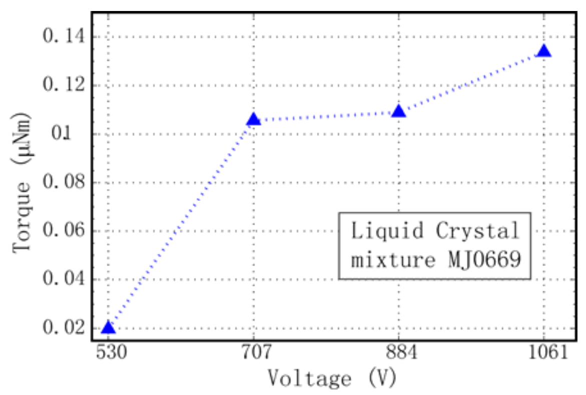

Fig.9 Relation between torque and voltage (Only bottom surface， *h*=1.8mm）

The starting torque *T* is obtained by calculating *dω/dt* from the images of the rotor, taken by video camera. Meanwhile, the rotating angler acceleration (*dω/dt*) is measured through a video recorder. The results of the torque are shown in Figs. 8 and 9. The order of the torque is about μNm for Fig.9 and 10^{-7}Nm for Fig.10. It is found that the torque for the motor with electrodes both on the bottom surface and side face is greater one order. In fact, since the friction exists, the real torque generation (*T*) from power supply is greater than the values shown in the figure, which is the product of *J* and *dω/dt* .

CONCLUSIONS

In this paper the experimental tests for driving motor with LC is taken. In details, the experiments emphasize the influence of voltage level and dielectric constant on speed. The main result is as follow.

(1) The rotating speed changes when the dielectric constant adjusts, especially with MJ0669, small dielectric constant makes high speed.

(2) The speed of the rotor increases with the electrodes both on the bottom surface and side face compared with only on the bottom surface electrodes and the further development of the electrode situation to produce a large electric field is the future work.

(3) The starting torque is estimated theoretically and its order is 10^{-6} Nm with the electrodes both on the bottom surface and side face

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