ECF Technology

1. What is ECF

1-1) EHD (Electrohydrodynamic) Effect:

When a dielectric fluid with very low conductivity is subjected to a high electric field, electric body forces are induced by the nonuniformity of electric conductivity and dielectric constant. In DC fields, the Coulomb force acting on a space charge, which gives rise to small currents, dominates the dielectrophoretic force. Under certain conditions, the Coulomb force causes a hydrodynamic instability, yielding convective transport of the charge carriers or a convective current. The secondary motion of a fluid in electric fields, such as convection, chaos, and turbulence, is known as the electrohydrodynamic (EHD) effect.

1-2) EHD and ECF

In EHD convection, electric energy is directly converted to kinetic energy of the fluids. Therefore, EHD convection is very attractive in applications to a new fluid devices, but EHD convection has not been studied extensively.

In other hands, there is a fact that fluid moving phenomena in an electric field is generally called as EHD effect, although the mechanism is not fully solved yet. We investigated the publications and reports on EHD, and found 3 classifications, as follows.

Classification of EHD

Classification	Working Condition	Mobility
A) Electrophoresis / Ion Drug	5-10KVDC/mA	Small
B) EHD Convection	5-10KVDC/μA	Small
C) EHD Fluid Jet	25KVDC	80cm/sec
D) ECF	5-10KVDC/μA	100cm/sec

Most of fluid moving phenomena which were reported in the past were classified into Electrophoresis / Ion Drug. Mobility of ion was already calculated as 5mm/sec, and was observed as it is. In addition, most ion moves from minus (-) to plus (+).

EHD Convection was observed in space under microgravity condition. According to the report, moving of silicone oil in electric field under microgravity condition was observed during experiment of Marangoni Convection. EHD Fluid Jet was reported in 1992. Moving of Furon with a small amount of Ethanol was observed under 25 KVDC.

ECF, our technology, indicates 100cm/sec mobility in 5KVDC/μA. In addition, more than 50 kinds of ECF fluids were found which show fully

different chemical composition from silicone oil and furon reported in above. ECF is broadly categorised in EHD effect, but there are many differences from conventional EHD classifications.

For reasons, we put the name for our technology, ECF (Electro Conjugate Fluid), in 1996. We use the name of ECF through our congress publications and reports, and it is getting popular recently.

1-3) ECF Jet Flow

Most ECF show jet flow (ECF moving) from plus (+) to minus (-), as follows.

Fig.1 Measurement Equipment

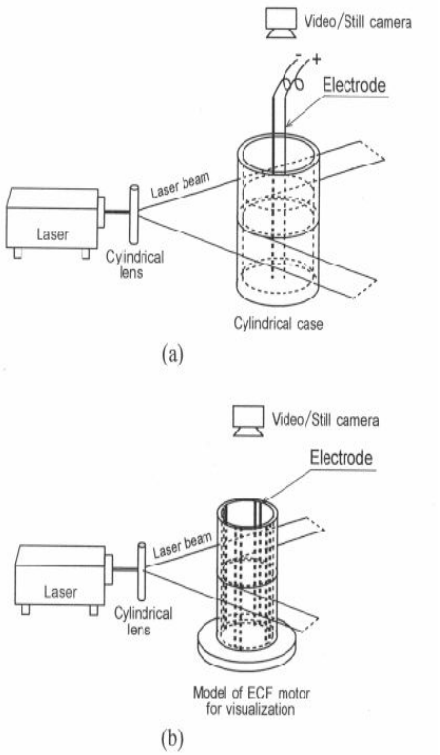
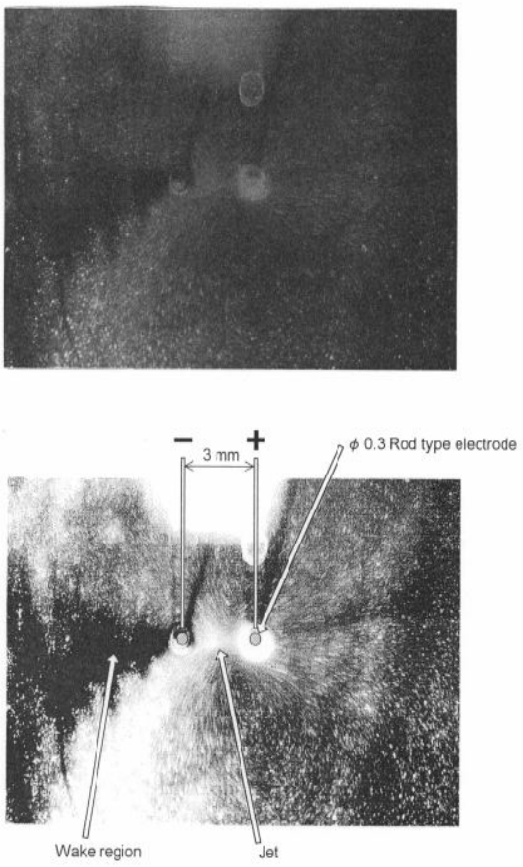


Fig2. ECF Jet Flow



Plastic fine particles were put in ECF as tracer, and jet flow was observed in 1 KVDC with red laser beam (Fig.1), as in above Fig.2. Jet flow is generated from plus (+) electrode, and flowed into minus (-) electrode.

In following Fig.3, jet flow among 3 electrodes were indicated. This showed the jet flow (generated from plus electrode) flowed between 2 minus (-) electrodes, not directly toward minus electrodes.

Fig.3 3 electrodes

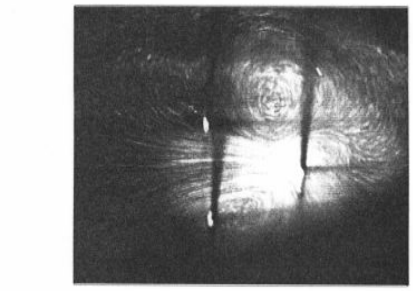
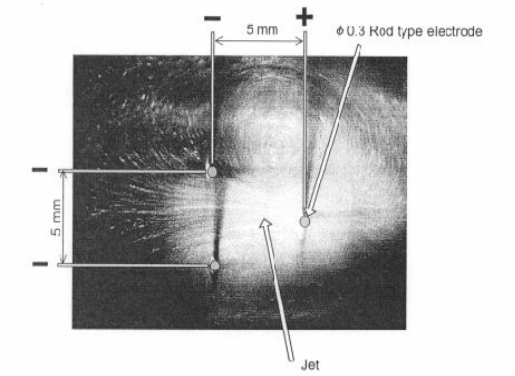


Fig.4 4 pairs electrodes

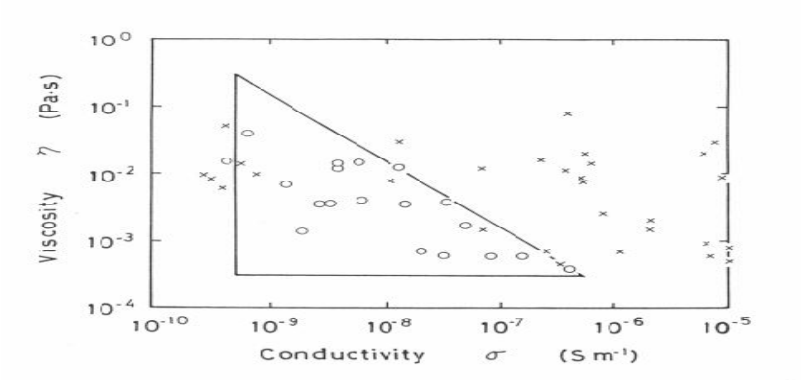


In Fig.4, the jet flow among 4 pairs of electrodes showed square flow. The jet flow generated in plus electrode seems not to need to go and touch minus electrode. This means, ECF jet flow would not depend on ion related phenomena, and would indicate some relationship with electric field force.

1-4) ECF Preparation

Detailed ECF mechanism is under investigation among our research group in Tokyo Institute of Technology and Chiba Univ., and we know properties of Conductivity and Viscosity of the fluids placed within a triangle in Fig.5 only provide a ECF jet flow.

Fig.5 Property of ECF



Above means, formulation is available to prepare ECF. When Fluid-X and Fluid-Y are located outside of above triangle, X and Y don't show ECF jet flow under electric field, resp. If a mixture of X and Y shows a property inside the triangle, the mixture shows ECF jet flow.

1-5) Our ECF Technology

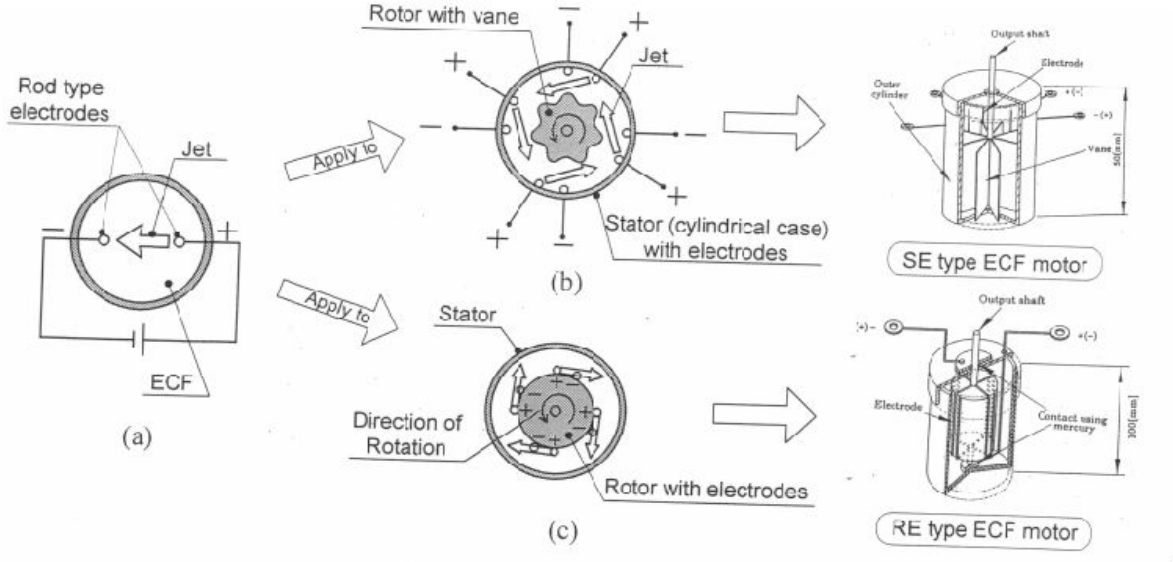
We already found more than 50 kinds of fluids which show ECF jet flow alone, and we can prepare a formulation, based on these 50 kinds of ECF, along various requirements for various applications.
Especially, noninflammable property is required in industries, and it is available in our formulation.

2. ECF Motor

2-1) Principle (Working Mechanism)

Two kinds of principles were developed, as follows in Fig.6.

Fig.6 ECF Motor Principle



Electrodes are installed in motor body, called as SE type ECF motor (indicated in above (b)). ECF jet flow, generated among 4 pairs electrodes, hits the bladed rotor. Rotational speed depends on voltage, and rotational direction depends on plus and minus.

Electrodes are installed on the rotor, called as RE type ECF motor (indicated in above (c)). ECF jet flow, generated from electrodes on the rotor, proceed the rotor itself. Of course, rotational speed depends on voltage, and rotational direction depends on plus and minus.

for visualization

(b)

2-2) ECF Motor

4mmΦSE type ECF motor was indicated (left with propeller in Fig.7-1) and 3mmΦSE type ECF was indicated in rights. Parts of SE type ECF motor were indicated in Fig.7-2.

Fig.7-1 SE ECF Motor

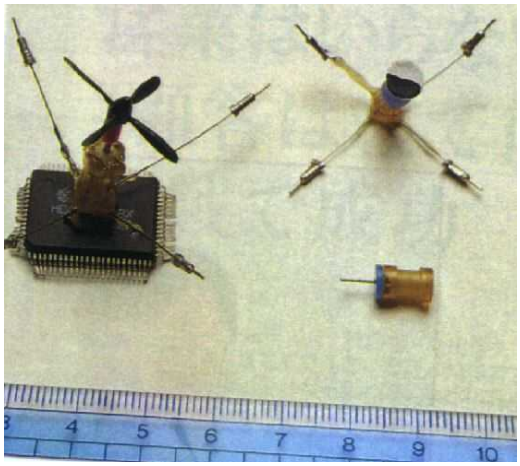
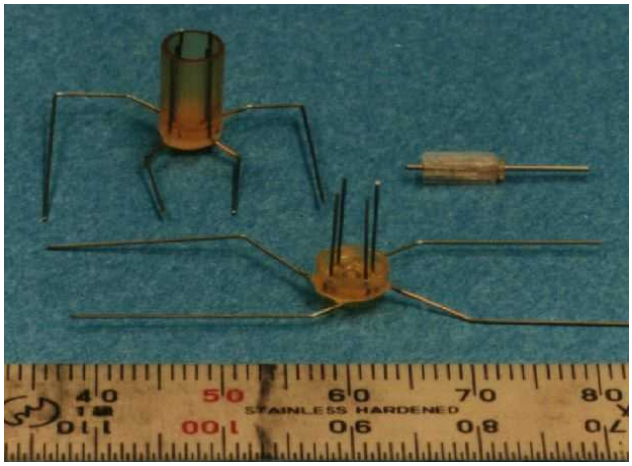


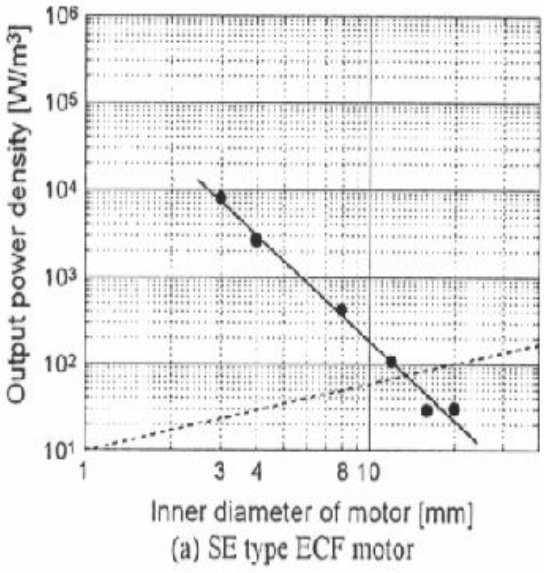
Fig.7-2 Parts of SE ECF Motor



2-3) ECF motor comparison

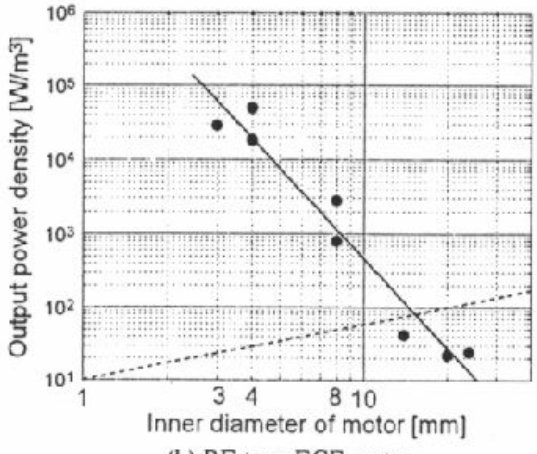
Since ECF motor drives on ECF jet flow, smaller size (smaller diameter of the rotor) shows higher rotational speed (rpm). In addition, power density of ECF motor increases along decrease of motor size, as follows. This property is fully different and opposite from conventional actuator system, such as magnetic motor. Black points in Fig.8 shows actual power density of each size ECF motor, and dotted line indicates typical magnetic motor property.

Fig.8-1 SE Motor Power Density



(a) SE type ECF motor

Fig.8-2 RE Motor Power Density



(b) RE type ECF motor

Fig.20 Miniaturization characteristics of ECF motor (Relation between inner diameter and output power density of ECF motor)

2-4) ECF Motor Property

ECF motor property depends on ECF property. For model development and evaluation, DBD is usually used as typical model ECF because of the cost and no smell. Maximum property with following test condition is follows.

Electric Field: 6.0 KVDC

ECF: DBD (Dibutyl decandioate)

We have more powerful ECF rather than DBD, which shows 2-3 times power density and effectivity in our house. According to our house data, 60-70% of effectivity was observed when ECF was LA-1, for your information.

Fig.9-1 Max.Property under 6KVDC

(Maximum rotational speed, Torque, Output power and Efficiency)

	SE type			RE type		
Inner diameter [mm]	8	4	3	8	4	3
Maximum rotational speed [rps]	28	54	60	25	93	98
Maximum torque[μNm]	8.8	4.2	4	30	16.5	15
Maximum output power [mW]	0.3	0.2	0.24	1.9	1.4	0.8

Fig.9-2 SE type ECF Motor

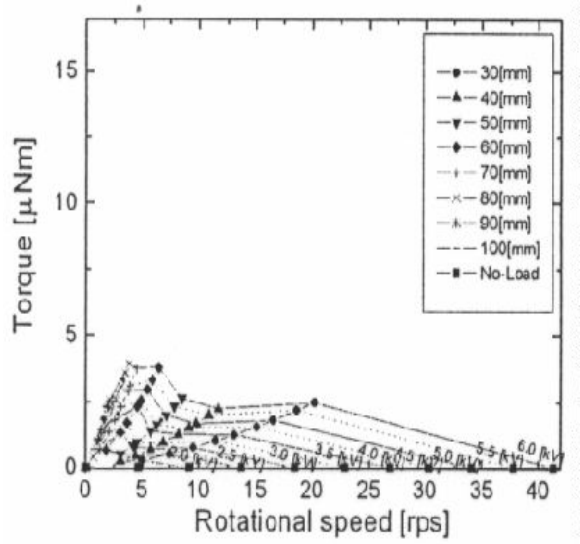
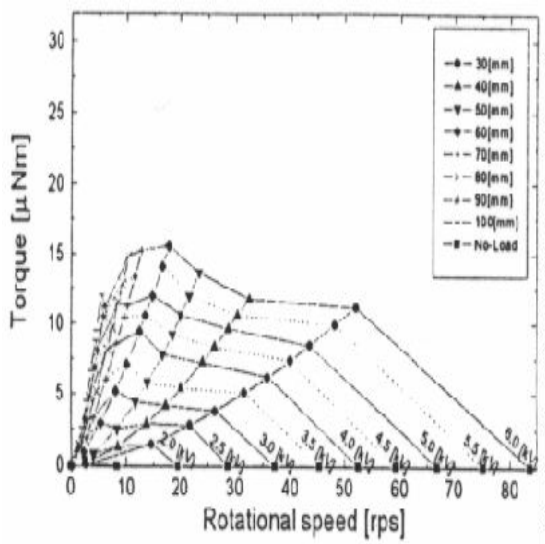


Fig.9-3 RE type ECF Motor



2-5) Our Recommendation, SE or RE ?

Each model has an advantage. If simple construction is important, we recommend SE type ECF motor. Light reflection purpose (rotor vane is mirror) is one of the applications. If power/torque is required, we recommend RE type ECF motor.

Thus, our recommendation depends on a requirement and an application.

2-6) Further Development

Disk-Plate type ECF Motor is under development. We already succeeded to prepare following prototype DP-RE ECF Motor (4.5mm thin), like as jacket button in Fig.10-1.

Our goal is very flat and powerful motor. Our target size for thickness is less than 2mm thin, like as one cent coin, and the target for power is bigger than magnetic motor. In this October, we could prepare 2mm thin motor with 0.2mm thin rotor (like as film) in it. In order to obtain more power and torque, we are developing multifilm rotor system which has several number of film rotors in one shaft. In 2mm thin motor body, 2-3 film rotors can be installed.

Fig.10-1 DP-RE Motor

Fig.10-2 Rotor of DP-RE type ECF Motor

3. Hydraulic Control System Using No Valve

3-1) Principle (Working Mechanism)

As explained above, ECF technology shows strong jet flow among electrodes. When a hydraulic fluid has a property of ECF, it can be moved among electrodes under electric field. We developed new electrode system which can generate strong jet flow between 2 flat electrodes. The new electrode system consists of one regular surface electrode and the other flocked fabrics surface electrode, as follows Fig.11-1,2.

When hydraulic fluid flows (due to pump power) from left to right in ECF valve system in Fig.11-1, we can control the flow with counter flow generated between electrodes by ECF technology. This ECF counter flow is so strong, and we can stop the pump flow in the system.

Fig.11-1:Jet Flow between electrodes

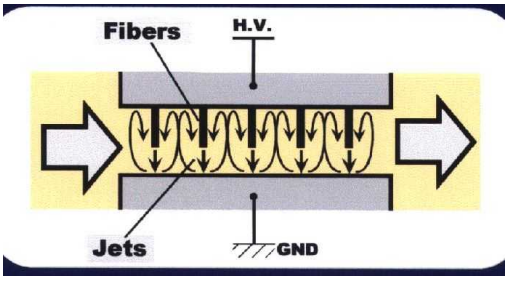
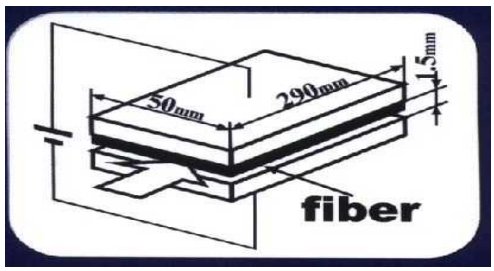


Fig.11-2:ECF Valve system



3-2) Hydraulic fluid control system (in our lab)

We prepared following system including above ECF valve system, Fig.12-1,2. Hydraulic fluid in our experiment was [Idemitsu Daphne Super Hydraulic Fluid 32] which is regular commercial hydraulic fluid, available in Japanese market supplied by Idemitsu company. We found the fluid (as supplied) shows ECF property under electric fields.

Fig.12-1: Total System

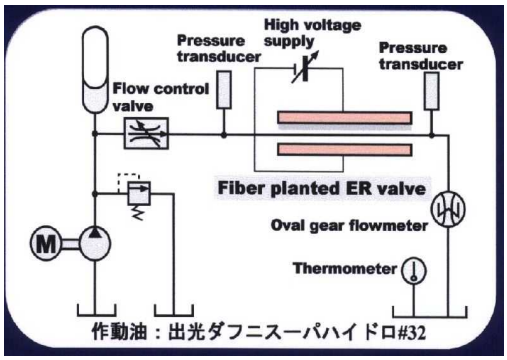
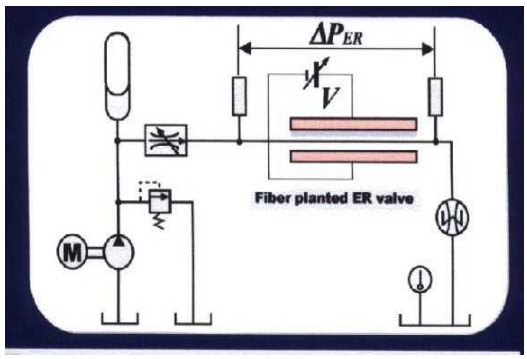


Fig.12-2:Valve Property Measurement



3-3) Valve Property

Using above experimental system, we measured following valve properties.

1)Differential Pressure -1)

Pressure along input voltage under constant flowrate: Fig.13

Differential pressure shows almost linear correlation with applied voltage.

2)Differential Pressure –2)

Pressure along flowrate under input voltage: Fig.14

Presuure doesn't depent on flowrate, and shows constant along constant voltage.

3)Differential Pressure –3)

Pressure along fluid temperature under flowrate and voltage: Fig.15

Pressure shows decrease along fluid temperature.

4)Differential Pressure –4)

Pressure stability under constant control condition: Fig.16

Pressure shows good stability under constant condition.

Fig.13:Voltage control

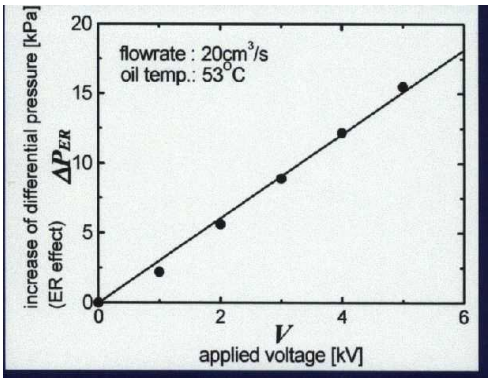


Fig.14:Flowrate control

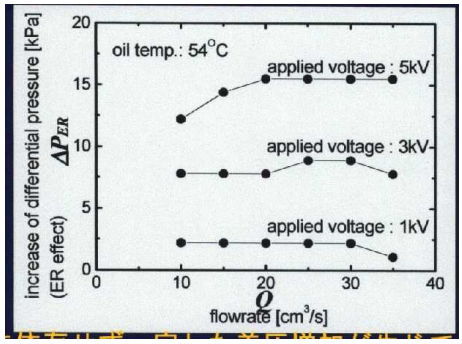


Fig.15:Temperature control

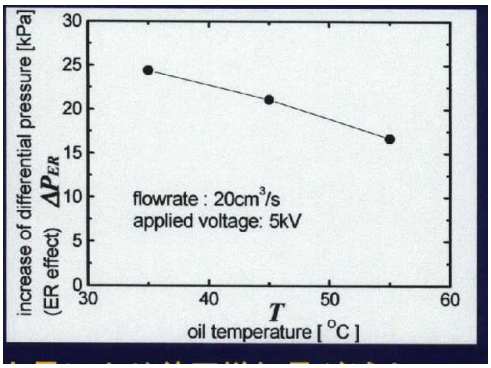
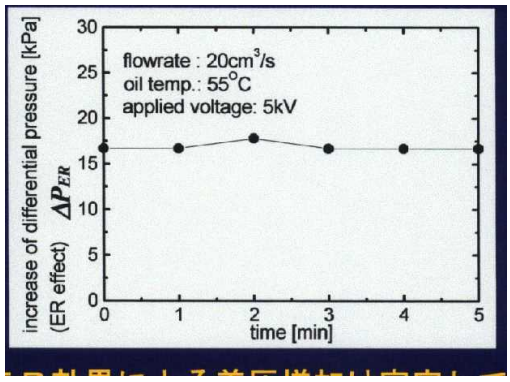


Fig.16:Stability



3-4)Further Development

Fundamental reaserch work will be finished soon. We are designing and preparing 4 port valve actuator with Wheatstone bridge, and our goal is to make a micromachine with the actuator.

In addition, several US patents of ECF technology were obtained in late 1999. This ECF hydraulic fluid control system was included in them, and we will start to find a joint development and business partners in US and EC.

4. Possibility of ECF Technology

ECF phenomena was just found only 10 years ago under joint research work among our company (New Technology Management Co.,Ltd., Edamura), TIT (Tokyo Institute of Technology, Prof.Yokota) and Chiba Univ. (Prof.Otsubo). However ECF technology is just a baby at this moment, we can expect many applications and possibilities, thanks to the unique principle.

Not using magnetic field, not using air pressure, not using mechanical and physical method, the liquid (so called ECF) generates a strong jet flow in electric field. Electric energy is directly converted into mechanical energy in ECF Technology. We also are looking for licensees to be a business partner to proceed ECF Technology development.