

# Development of ER Clutch for the Walking Support Machine

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## ABSTRACT

Walk training is good rehabilitation for old people and handicapped people. Then it is considered the effective measurement for decreasing bedridden people and wheelchair users. In walk training, they frequently use walkers, walking sticks, etc. It is a problem that these kinds of support tools are not flexible and mobile because their handicap conditions are different. New support tools are demanded to be intelligent and personalized.

We are developing a new walking support machine for old people and handicapped people, because they expect to move easily by themselves. The machine is equipped with two ER devices which compose an electrorheological fluid clutch (ER clutch) and a motor, and able to work with smooth power assistance or safety braking.

In this paper, we refer a developing concept in the new walking support system, and explain a mechanism and design of the ER devices. In addition, we also report some experimental results, because we have examined on characteristics of the ER devices.

## KEY WORDS

ER Clutch, Walking Support Machine, Torque Transmission

## INTRODUCTION

In aging society with declining birth rate, the population of the elderly people with some kind of functional disorders will be increased. The labor population of helper

will be decreased. Then, we have been studying about the development of the welfare equipment to assist the independence of the elderly people. Especially, muscular depression that becomes a problem with aging causes a moving decrease in the chance, and causes further muscular depression. Therefore, the maintenance and

recovery of the muscular power at the early stage are important preventive plans and handicapped persons will be decreased.

As for the equipment concerning the walking assistance, it is commercialized over many kinds, and the number of users is also increasing now. However, the use of these commodities in the place where there are walking obstacles of bump etc. is the large burden. The range of the action is inevitably limited. Therefore, they are used only as assistive device for people who can walk independently.



Fig.1: walking assistance equipment

We have been developing an intelligent walking support machine that can correspond to the walking situation of the road and user's trouble level as a movement support tool intended for handicapped persons and the preliminary group. To do the power assistance and the brake control for driving part of this walking support machine, the torque transmission device composed of the DC servo motor and the clutch with the ER fluid is used. In this paper, we mention about the construction of experimental prototype and the evaluational result of power transmission part, where ER device is used.

## DESIGN CONCEPT OF WALKING SUPPORT MACHINE

### Basic concept

We had examined walking pattern with existing walking support machine previous year. Our assumption of subject users and a basic concept of the power assistance system are given as follows.

#### *Subject user*

- a) Subject user is able to walk by themselves.
- b) The range of the action area is limited in a present walking assistance machine.
- c) The recovery is expected if undergoing rehabilitation though the trouble begins to appear a little in the leg strength.

### *Walking support concept*

- i) User's leg strength is bring out to its maximum. User's will is perceived on that and the walking mode changes.
- ii) The turn able radius is assumed to be zero, in order to achieve effective small turn.
- iii) Gradual start, Safe braking.
- iv) The walking speed is maximum 4[km/h].
- v) The bump riding past is 50[mm] or less.
- vi) The gradability is about 10[deg].
- vii) Weight is about 15[kg].
- viii) Redundancy of safety device.

These settings will be introduced, however, the setting will be changed according to user's moving ability and life environments.

### Assist method by walking support machine

When the set concept was achieved, the examination subjects was decided as follows as a content of the control.

- 1) In order to detect the object's posture and orientation of the movement, strain gauge is installed.
- 2) Confirmation of practicality and safety of ER clutch.
- 3) Detecting obstacles.
- 4) The mechanical brake besides the control brake is installed.

These items are choose, by the experiment aiming at commercialization in consideration of domination and the cost side.

### Power transmission part(ER clutch)

The ER fluid has the characteristic that the viscosity is changed by the impressed voltage, and is excellent in conformity. Moreover, power more than the surrender stress is not transmitted. Therefore, the ER clutch that uses this characteristic can be expected a gradual start depending on the impressed voltage, compared with the the motor directly connected type. Even if there is abnormal control occurred, fear to reckless driving is alleviated while maximum transmission power is limited by the characteristic of ER of the clutch.

Then, main topic of this research is to develop the control method to realize smooth power support and a safe braking

at the practical use of the ER clutch. Moreover, we will evaluate about the ER device that can maximize the ER effect.

## OUTLINE OF WALKING SUPPORT MACHINE

### About the examination prototype

The prototype was developed in order to evaluate the performance and for further discussion(Fig.2). Both self-propelled and the joystick operation by driving program are developed.

The system configuration is as shown in Fig.3. The input signal of driving program or the joystick is sent to the control board by the personal computer. Distance of the movement is sent from the control board to the motor through the servo amplifier. The motor and the ER clutch are connected with the belt,



Fig.2: Prototype

and the speed is controlled by changing the impressed voltage of the ER clutch. Moreover, encoder information installed in the motor and the tire is sent back to the personal computer through the control board. By the way, sensors other than the encoder are not installed, but other sensors will be added if it's necessary while advancing the experiment in the future.

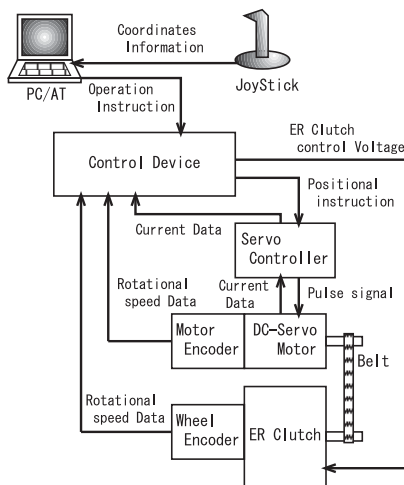


Fig.3: The system configuration

### Control board

Open motion controller 'SPX-8000' (Fig.4) made by the techno company Ltd.. is used. This control board can possess the control of nine axis, and can send and receive the data respectively.



Fig.4: SPX-8000

Two axis for the motor control and the ER clutch control for both right and left are used (Total 4 axis). And the current and rotation of the motor and the rotational speed of the tire are monitored.

### Motor

DC brushless motor (EC-40), the servo amp and the encoder, which are made by the maxon company are used. A basic characteristic concerning the motor is shown in Table.1. The diameter of the tire is 200[mm]. It follows that the output torque at the condition 4 [km/h] (106[r.p.m]) in actual use becomes 30[Nm]. The motor torque was calculated with 5[Nm] by the design value until the previous year. These conditions fulfill the requirement of planning.

Table.1: Motor characteristic

Motor (EC 40)	
Rotational speed / Torque	9.9 [r.p.m/mN·m]
Torque constant	19 [mN·m/A]
Rotational speed constant	500 [r.p.m/V]
Gear (GP 42 C)	
Reduction ratio	53 : 1

### ER clutch

The ER clutch is made by ER Tech Ltd.(Fig.5).

The disk type clutch (Fig.6) is used for the system. Two kinds of fluid (the dispersed ER fluid and the homogeneous ER fluid) are prepared and comparative study are made.



Fig.5: ER clutch

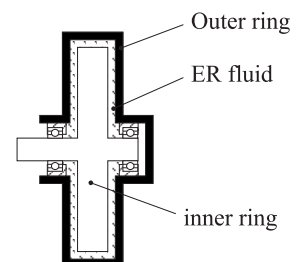


Fig.6: section of clutch

### Self-propelled examination

The figure shown below is an example of the data obtained by the prototype. The example is the reciprocation to make the tire by one rotation with motor rotational speed of 28[r.p.m].

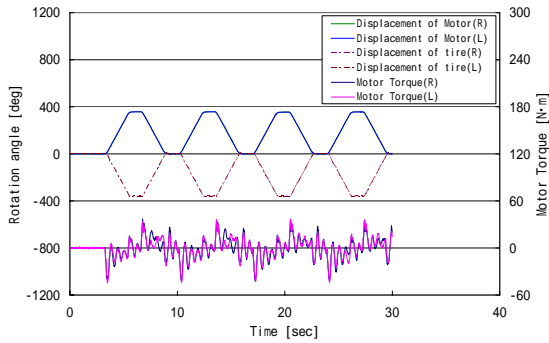


Fig.7: Example of the data

The content of the examination in the future is to change the voltage of the ER clutch, and to measure actual traction. Moreover, this prototype has the problem such as being not able to get over the bump immediately before the bump. The corrective strategy is examined about other problems including this thing.

### UNIT EXPERIMENT OF ER CLUTCH

In the ER fluid, it is divided roughly into two kinds, the dispersed ER fluid and the homogeneous ER fluid. Each of fluid has different behavior when the electric field is impressed. This time, a basic characteristics of both fluid were evaluated in order to install them to the ER clutch for the walking support machine. By the way, it experimented on the impressed voltage by the specification of the device by 1.5kV max.

#### Experimental apparatus

The construction of the experimental device is shown in Fig.8. In the actual experiment, the rotational speed and the torque of each impressed voltage were measured, when the rotation was added with the clutch output side (tire side) fixed.

#### Torque characteristic of ER clutch

The transmission torque was measured when a constant voltage was applied to the ER clutch and the motor was rotated at a constant speed.

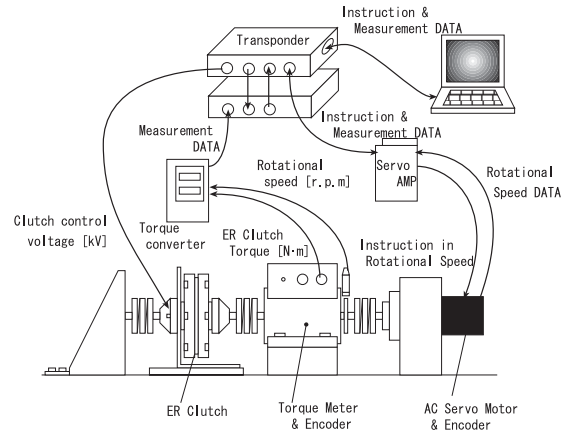
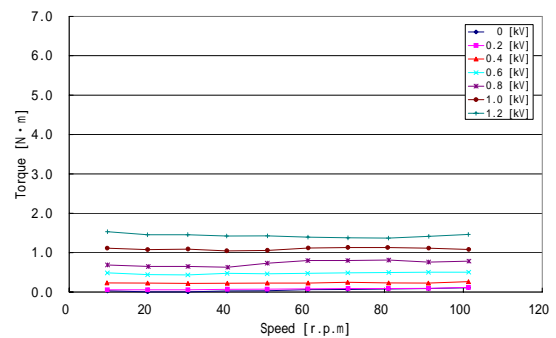
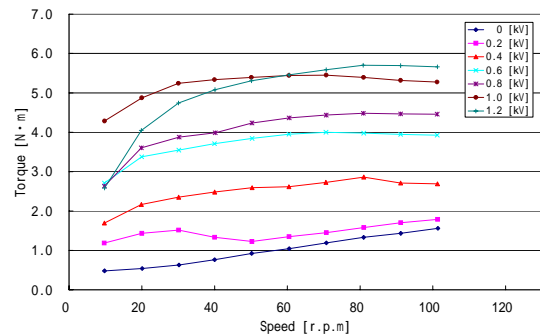


Fig.8: Experimental device



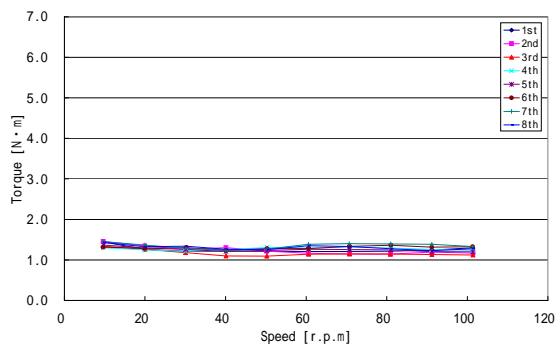
(a): Dispersed ER fluid



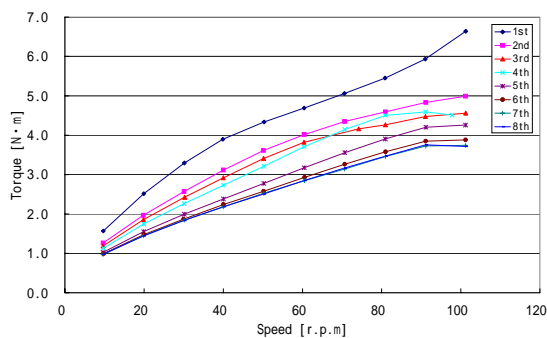
(b): Homogeneous ER fluid

Fig.9: Rotational speed - Torque

As it is well known, the fluid of homogeneous ER fluid obtained the result that the transmission of Torque is higher than the other. However, the decrease in the ER effect by the rise of temperature was observed in the fluid of homogeneous ER fluid. Then, change of each ER fluid's characteristics through time was confirmed. The impressed voltage to ER fluid is set to 1.0[kV], the rotational speed of the motor is given as a step input for 10[sec] at each iteration, and this sequence was done for three times. Input rotational speed is changed from 10 to 100[r.p.m], and this sequence was repeated. The experimental result is shown in Fig.10.



(a): Dispersed ER fluid



(b): Homogeneous ER fluid

Fig.10: Change of ER fluid's characteristics

As a result of the experiment, stable torque was observed in a dispersed ER fluid. However, a decrease of the ER effect was confirmed in the homogeneous ER fluid until the seventh times. About 30 minutes had passed, ER effect becomes stable.

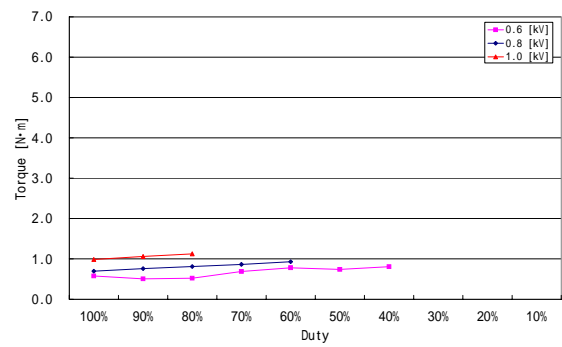
### PWM drive experiment

Generally, it is assumed that the ER fluid has a long life if it is driven in PWM method. We will evaluate the ER effect when ER fluid is driven in PWM method and Duty ratio is changed. A impressed voltage with Duty ratio was set to 0.6, 0.8, and 1.0kV.

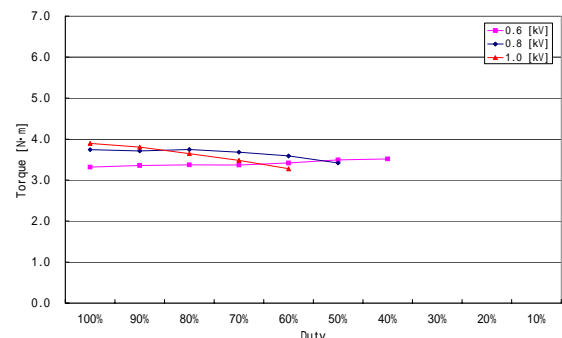
As a result, the increase of the transmission power in the dispersed ER fluid was observed when Duty ratio is decreased. But it is decreases in the homogeneous fluid. However, it is necessary to reconfirm in different operating condition, because if the homogeneous fluid is continuously driven, the ER effect is reduced.

### About the design of the ER clutch

Existing device is evaluated in this paper. And, problems such as the insulating and torque shortage were found. The ER equipment is divided roughly into the clutch and



(a): Dispersed ER fluid



(b): Homogeneous ER fluid

Fig.11: PWM drive Torque

the brake type. Moreover, the structure is divided into the disk type and the cylinder type. The redesign and the further examination are planned for the sub-optimal combination of the elements for practical use.

### SUMMARY

We had developed the experimental prototype. And the characteristic of Dispersed ER fluid and Homogeneous ER fluid, which is used for the transmission device, was evaluated. The control that can draw out the ER effect in the maximum method is examined. To that end, it is necessary to get experimental data in various conditions, and to confirm the characteristic. Moreover, a suitable device for this equipment is designed in the present stage, and we would like to have the chance of the report again.

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