STUDY ON IMPROVEMENT OF SWING OPERABILITY OF POWER ASSIST SYSTEM

Hironao Yamada
Gifu University,
1-1 Yanagido,
Gifu City, Gifu 501-1193, Japan
yamada@gifu-u.ac.jp

Naoyuki Bando
Gifu Prefectural Research Institute of Information Technology,
1-21 Techno-Plaza, kakamigahara, Gifu, 509-0108 Japan
bando-naoyuki@rd.pref.gifu.jp

Katsutoshi Ootsubo
Kinjo Gakuin University,
2-1723, Omori, Moriyama-ku,
Nagoya, Aichi, 463-8521, Japan

Yoshiaki Yamamoto
Sumitomo NACCO Forklift Co., Ltd.
2-75, Daito-cho, Obu, Aichi,
474-8555, Japan

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ABSTRACT
In this research, we deal with a robot arm type electric power assist system used in factories and others. In the conventional electric power assist system, automatic control is performed for assisting the vertical movement, but automatic control is not performed for the turning operation. Therefore, in this research, we have constructed a system that senses the operator’s force input to the force sensor of the operation lever and performs power assist to the operator. In this paper, we evaluate how much the physical and mental burden of workers has been alleviated by using a power assist system equipped with automatic controlled turning assist / brake function. We compare the results and discuss the effectiveness of the power assist system with the swing assist / brake function.

INTRODUCTION
In order to reduce the physical burden of workers at the factory, it is effective to use the power assist system [1]-[5]. In this research, we study the robot arm type power assist system which is most used in the factory. In this conventional electric power assist system, automatic control is provided for assisting the vertical movement. However, with regard to the turning motion, the operator operated a simple actuator and brake with a manual operation button. Although this system is advantageous in terms of manufacturing cost, it is inferior in terms of usability.

In this research, we have developed a method to automatically perform this turning motion according to the movement of workers. In the developed system, the operating force of a worker is acquired by a force sensor, and the rotation angle of the arm is acquired by a rotary encoder attached to each shaft and taken into a computer. Thereafter, based on the sensor information, a command value is given from the computer to the turning assist device installed on each rotation axis of the arm, and the turning direction is controlled.

In the experiment, each subject is asked to carry out the transportation work of the transfer target object by using the electric power assist system with the swing assist / brake function. Then, the operating force applied to the operation lever was measured, and the mental burden evaluation by NASA-TLX was carried out. Evaluation was also made for the case of not using the turning assist and the brake function for comparison.

As a result of the experiment, by using the turn assist / brake function, the amplitude of the operating force waveform becomes smaller than when this function is not used. Therefore, it was found that by using the developed turn assist / brake function, it is possible to reduce the necessary operating force in the carrying operation. In addition, from the result of burden evaluation by NASA-TLX and consideration, by using swing assist / brake function, the mental burden was alleviated as compared with the case where this function is not used.

From the above results, it was confirmed that the turn assist / brake function proposed in this research is effective for reducing the physical and mental burden.
SYSTEM CONFIGURATION

In this research, industrial power assist system (ES50) manufactured by AIKOKU ALPHA Co., Ltd. shown in Figure 1 is used. This power assist system is a compact electric type with a rated load of 50 [kg]. In order to measure the operating force applied by the operator to the operation grip, a 6-axis force sensor (IFS-90 M31 A 25-I 50, resolution: 14 Bit, manufactured by Nitta Corporation) was installed at the base of the operation grip. In order to measure the rotation amount of the arm, a rotary encoder (RP-8524L, resolution: 2500 P/R, manufactured by Ono Sokki Co., Ltd.) was installed on the rotation shaft of the arm. In this research, we added a new automatic turning assist and brake function to this system. In this system, power assist control in the turning direction is executed as follows. An operating force of a worker is acquired by a force sensor, and the rotation angle of the arm is acquired by a rotary encoder attached to each shaft and taken into a computer. Thereafter, based on these signals, a command value is given from the computer to the turn assist device installed on each rotation axis of the arm.

MAGNITUDE OF OPERATING FORCE

Here, a method of calculating the operation force required for the operation using the information measured by the six axis force sensor will be described below. Using force $F_x$ (force in the front and rear direction), $F_y$ (force in the left and right direction), force $F_{xy}$ acting in the horizontal direction is obtained by Expression (1).

$$\sqrt{F_x^2 + F_y^2} = F_{xy} \quad (1)$$

EVALUATION INDEX NASA-TLX

In this study, we used “NASA-TLX” [6] for the assessment of the mental task load. The index is given subjectively, and the task load is divided into six indices: Mental Demand (MD), Physical Demand (PD), Temporal Demand (TD), Performance (OP), Effort (EF) and Frustration (FR). The larger values correspond to larger mental task loads.

First, prior to carrying out work to be subjected to burden evaluation, the importance of NASA-TLX to the six measures is evaluated by pairwise comparison. The number of times (maximum 5, minimum 0) selected as "more important" in the pairwise comparison is the weight of each scale given to the load rating evaluation described later. Next, work that is the object of burden evaluation is performed. Finally, after finishing the work to be evaluated for burden degree, the subjects give rating values in the range of 0 to 100 for the six scales. The rating value for each scale is closer to 0, which means that the burden is lighter. Weighted average of the evaluation values for the six scales and the weights obtained by the aforementioned pairwise comparison gives the WWL score (Mean weighted workload score) which is the evaluation result by NASA-TLX.

EXPERIMENT FOR EVALUATION

Each subject was asked to carry the transfer object 30 kg by using an electric power assist system with swing assist / brake function installed. The operating force applied to the operating
part was measured, and the mental burden was evaluated by NASA-TLX. Also in the case where the turn assist and brake function is not used, the same transport work was carried out in case of transfer object 30 [kg] and 0 [kg]. In the transportation work, as shown in Figure 2, the stop target position was clearly indicated on the floor surface, and the point indicating the position of the transfer object was projected onto the floor surface by the laser pointer. In the work, the turning motion was started from the stop target position ① (0 [sec]). Next, stopped at stop target position ② (3 [sec]). Then, a turning motion was started in the opposite direction from the stop target position ② (9 [sec]). Finally, stopped at stop target position ① (12 [sec]). Subjects were instructed to perform this round trip three times. The height of the operation part from the floor was adjusted so that the elbow of the subject was bent to about 90 degrees and the posture was reasonable for operation. Subjects who undertake this experiment are ten men who have no experience of operating this device. In addition, each subject rehearsed beforehand until it got used enough to the transportation work time interval.

RESULTS AND DISCUSSION
The operating force waveform of the operator measured in this experiment is shown in Figure 3. In the figure, the horizontal axis shows time and the vertical axis shows the operation force. The legend of each figure is shown in the figure.

![Figure 3: Operating physical force](image)

As shown in Fig. 3, by using the swing assist / brake function, the amplitude of the manipulation force waveform is small as a whole compared with the case where this function is not used. This indicates that the necessary operating force in the transportation work is reduced by using the turn assist / brake function. Next, Figure 4 shows the average value of all subjects of maximum operating force in each operation of the worker measured in this experiment. In the figure, the horizontal axis shows the operation in the transportation operation, and the vertical axis shows the operation force. The legend of each figure is shown in the figure.

![Figure 4: Operating physical force](image)

As shown in Fig. 4, when the turn assist / brake function is used, the maximum operating force is reduced as compared with the case where this function is not used. The reduction rate is about 18% at the time of right turn, about 29% at the time of right turning braking, about 13% at the time of left turning and about 21% at the time of left turning braking. This means that by using the turning assist / brake function, the operating force required for each operation in the carrying operation is reduced. From the above results, it was confirmed that the turn assist / brake function is effective to reduce the physical burden.

The mental burden of the work carried out in this experiment was evaluated by NASA-TLX and the results of averaging the WWL scores of all subjects are shown in Fig. 5. The legend of each figure is shown in the figure. The smaller the WWL score means, the lower the mental burden on the subject is.

![Figure 5: WWL Score](image)

As shown in Figure 5, by using the turn assist / brake function, the mental burden is reduced by about 21% compared with the case where this function is not used. This indicates that the mental burden of workers in transportation work is reduced by using the turn assist / brake function.
In order to examine the burden when using the turn assist / brake function in detail, the evaluation points of subjects used as a burden assessment index in NASA-TLX (MD, PD, TD, OP, EF, FR) are shown in the figure on the radar chart. The legend of each figure is shown in the figure. The smaller the evaluation score, the less burden is placed on the subject.

![Radar Chart](image)

**Figure 6: Radar chart**

Figure 6 shows the result of comparison with the case of using the turn assist / brake function (transfer object 30 kg [kg]) and when not using it (transfer object 0 [kg]). As a result, the perceptual requirement was about 66%, the work result was about 39%, the effort was about 2%, the evaluation point was high, the time requirement was about 35% and the frustration was about 10% lower. From the above results, it can be seen that in the case of using the turn assist / brake function, it is possible to carry out a calming transport operation more than when this function is not used (transfer object 0 [kg]). However, it turns out that it was necessary to operate while considering the turning method in order to use the assist function. This is because it was not familiar with the turn assist / brake function and it was not able to make good use of it in the work.

From the above results, it was confirmed that the turn assist / brake function is effective in order to reduce the mental burden.

**CONCLUSIONS**

In this research, we have constructed a system that automatically controls the turn assist / braking function for the robot arm type electric power assist system which is most used in the factory. Then, we performed an experiment to evaluate how much the physical and mental burden of workers will be reduced by turning motion. From the experimental results, it was confirmed that it is effective to use the power assist system with the swing assist / brake function installed in order to reduce the physical and mental burden.

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**REFERENCES**