A Study on Approach Speeds of the Hands under Metal Press Machine Operation

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The study described herein entailed measuring approach speed of the hands under simulated press machining conditions using two types of safety devices. A total of eight subjects were used in the experiment: four males in their twenties and four males in their fifties. Hand speed was faster for the photoelectric safety device (PSDI) than for safety devices activated using both hands (TWO) for both subject groups, in excess of 1.6 m/sec. The study showed that safety devices capable of automatic detection such as PSDI safety device more effectively ensure safety and work efficiency than the TWO type.

Introduction

In Japan, an average of about 2,000 accidents involving metal press operation are reported yearly. Not properly observing precautions regarding safe distance and safety devices established as a physical environment condition for press operation to facilitate "multi-item, large-lot production" has been cited as the primary cause of such accidents. Safety devices are roughly divided into those for presses equipped with an emergency stop function and those not equipped with emergency stop. The formula for calculating safe distance also differs according to whether or not the press is equipped with emergency stop. A hand speed of 1.6 m/sec is commonly used as a constant term for the safe distance calculation formula (JMSIA,1998). That is to say that "hand speed" is an important parameter for calculating safe distance.

Safety measures for operating metal presses call for mounting safety devices and maintaining safe distance in compliance with industrial safety and health regulations. On the other hand, it has been pointed out that excessively restrictive safety distance and use of safety devices can inhibit production efficiency, and, therefore, require further consideration (JMSIA,2001; Fukaya 1977) .

This study involved taking measurements to determine variation in hand speed, the basis for calculating safe distance in this study, when metal press with two different types of safety devices is used, and determining the fundamental values for reconsideration of safe distance.

Shortening of safe distance is expected to enhance press operation efficiency while positively affecting adoption and use of safety devices.

Method

C-frame single press machines made by Amada Co.Ltd. (Model TP-110EX) were used to simulate press operation(see Fig.1). Press capacity was 110 tons. The press machine was mounted with two different types of safety devices. One was a safety device activated using both hands (TWO: two-hands-trip safety device) for press machines without emergency stop and the other was a photoelectric safety device for press machines with emergency stop. The TWO safety device is activated by pressing pushbutton switches with both hands simultaneously while operating the press. The device is designed to avoid physical injury by the press (see Fig. 2). The photoelectric safety device employs presence sensing device initiation (PSDI), and is mounted on a press machine with emergency stop. The photoelectric type safety device detects when someone enters a certain area of the operation platform of the press machine and shuts down operation while presence is detected.

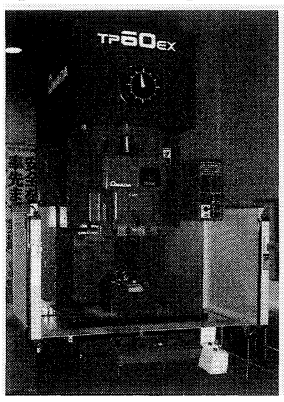

Fig.1 A view of C-Frame press machine with safety devices

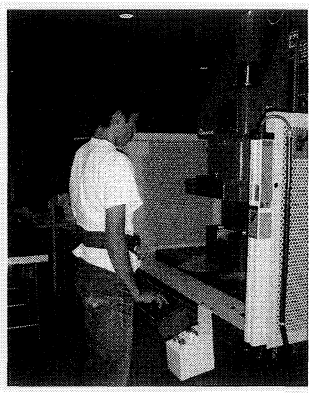

Fig.2 Operation under TWO safety device.

A total of eight healthy male subjects were used in the experiment, including of an elderly group of four (aged 50-55 years, average age 53 years) and a young group of four (college students aged 21-23 years, average age 22 years). Only two of the males in their fifties were experienced at using a press machine. All subjects were right-handed.

The simulated task consisted of simultaneously moving a disc-shaped piece of work (f20 cm, 100 g) placed on the die and another placed in the work storage in advance; when the experiment started, the subjects had to move the work on the die to the work storage area, and work in the work storage area to the die with both hands simultaneously. When the interchange was completed, the subjects had to activate the press machine by simultaneously pushing the pushbutton switches. With the PSDI safety device, when the interchange was completed, the subjects were required to activate the press by moving both hands out of the sensor detection range. The test was finished when this was repeated ten times. The simulated task was conducted as the operator's own pace (self-paced) and at a faster pace (fast-paced). The test was conducted with subject standing upright.

An NAC high-speed video system (HSV-500) was used to measure hand speed. The video system was set immediately to the left of the subjects. The video camera was located to capture a small lamp synchronized to light when the safety device is activated and deactivated on the screen. After recording 250 frames/sec, the frames were analyzed taking brightness of the screen into account.

Distance prescribed by safety regulations was adopted as the safe distance. 548.3 mm was used for the TWO safety device activated by both hands and 189.0 mm was used for the photoelectric safety device (PSDI).

Results and Discussion

Video data is recorded at 250 frames/sec, which amounts to an enormous volume of data. Therefore, three attempts were selected at random from among the last five of 10 attempts for analysis.

1) Speed of advance/retreat of left/right hand

There was no restriction as to which hand would be advanced toward the disc-shaped work first when moving the work on the die to the work storage area. The speed at which the left or right hand was advanced toward the work on the die and work storage area and speed at which the hand retreated from the work after placing it in its position were determined by frame analysis.

Analysis of variance showed no significant difference in speed of advance and retreat between the elderly and young groups of subjects when the subject were allowed to operate the TWO device activated by both hands at their own pace. It did however show a significant interaction between the speed at which left and right hands were advanced and retreated for the elderly group ($F_{(3, 18)} = 4.257$, $p < 0.05$). This means that the speed at which the right hand is retreated was faster than the speed at which it was advanced for the elderly group, but the left hand was advanced faster than it was retreated. With the young group, on the other hand, the right hand was advanced faster than it was retreated, but the left hand was retreated faster than it was advanced (see Fig. 3a).

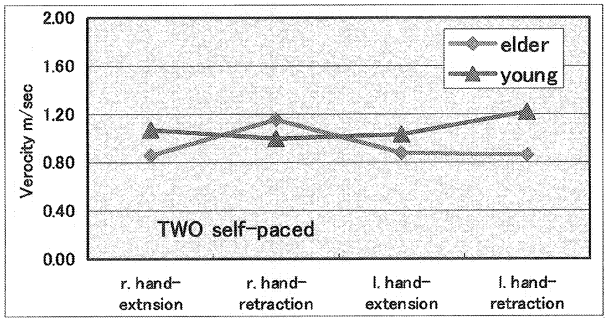

Fig.3a:Speed of advance / retreat of both hands (TWO)

The reverse phenomenon was observed between advance/retreat speed of the left/right hands between the elderly and young groups, but the reason for this is unknown. ANOVA showed no significant difference between the two age groups when the subjects were required to operate at the fast-pace using TWO, ($F_{(1, 6)} = 10.531$, $p < 0.05$). The young group advanced and retreated the left/right hand faster than the elderly group. The subjects of the young group advanced and retreated their hands at approximately the same speed. The subjects of the elderly group, on the other hand, retreat of the right hand was fastest, and retreat of the left hand was slowest (see Fig. 3b).

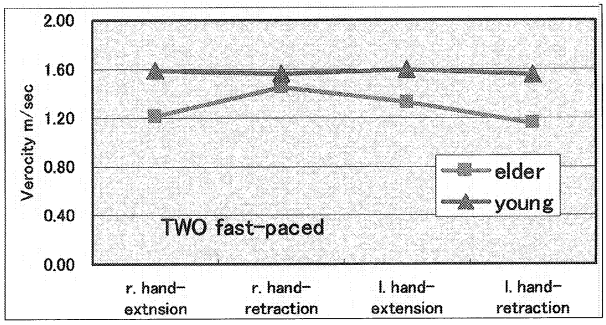

Fig.3b:Speed of advance / retreat of both hands (TWO)

ANOVA showed no significant difference between the two age groups concerning how fast the left and right hands were advanced or retreated when the subjects were allowed to operate at their own pace with the photoelectric safety device (PSDI). The mean speed of advance and retreat was 2.0 m/sec (see Fig. 4a). When subjects were required to operate at faster pace with the PSDI safety device, ANOVA showed significance between the two age groups ($F_{(1, 6)} = 10.166$, $p < 0.05$). Hand speed was significantly faster for the young group than for the elderly group (see Fig. 4b). Analysis also showed the advancement speed of the right hand (2.88 m/sec) to be significantly faster than the left hand (2.15 m/sec) for the young group ($F_{(3, 18)} = 3.511$, $p < 0.05$).

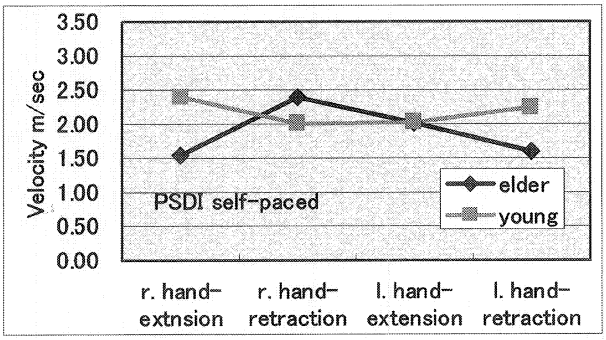

Fig.4a:Speed of advance / retreat of both hands (PSDI)

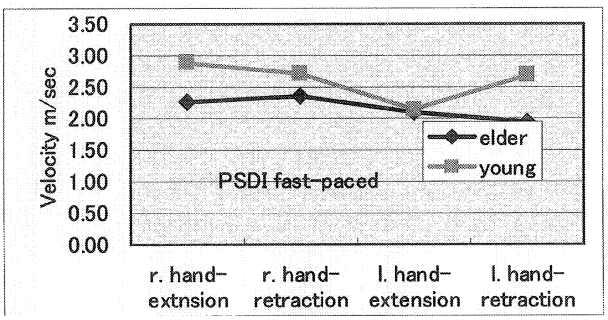

Fig.4b:Speed of advance / retreat of both hands (PSDI)

2) Hand speed for two types of safety devices

The TWO device requires dual pushbutton switches be pushed simultaneously with both hands to deactivate the device. The photoelectric sensor of the PSDI type automatically detects when someone enters or leaves. The basic difference between the PSDI and TWO type is that the PSDI type does not require a switch to be operated.

Fig. 5a gives a comparison of hand speed using the TWO and PSDI type safety devices when the subject were allowed to operate at their own pace. Hand speed was significantly higher for the PSDI than the TWO type for both age groups ($F_{(1, 5)} = 41.69$, $p < 0.01$), approximately double the difference in speed. Hand speed was significantly higher for the young group than the elderly group ($F_{(1, 5)} = 9.93$, $p < 0.05$). The difference in hand speed between the groups was larger for the PSDI type, reaching about 1.0 m/sec.

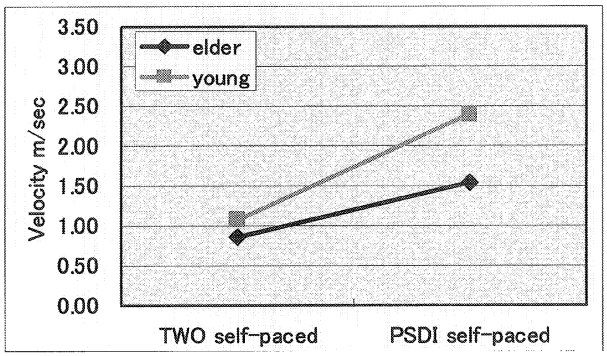

Fig.5a: Speed deifference of self-paced by safety device.

Fig. 5b shows hand speed for the TWO and PSDI safety devices when the subjects were required to operate at a faster pace. The figure shows hand speed for the PSDI to be approximately twice that of the TWO, indicating a significant difference in hand speed between the two devices ($F_{(1, 6)} = 80.53$, $p < 0.01$).
A significant difference was also obtained between the elderly and young groups ($F_{(1, 6)} = 19.29$, $p < 0.01$).

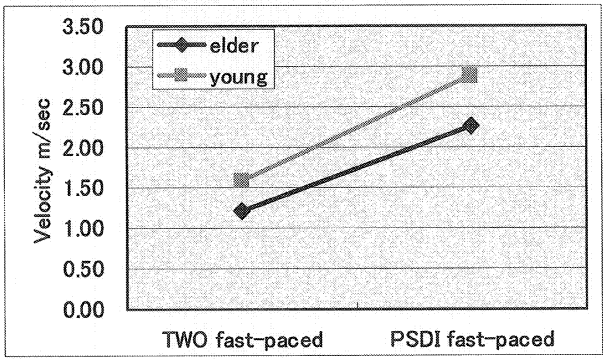

Fig.5b: Speed deifference of fast-paced by safety device.

With the TWO safety device, there was less difference in hand speed between the two age groups, and it is therefore logical that there is not much difference in hand speed when subjects were allowed to operate at their own pace and when they were required to operate at the fast-pace. The reason for this

is probably because enhancement of work pace is inhibited due to the fact that the subjects are forced to use both hands to push the pushbutton switches.

The heteronomous restrictions of such a work pace could reduce the operator's willingness to use the safety device. The PSDI safety device, on the other hand, achieves about twice the speed of the TWO type safety device. This is particularly true of the young group that was inexperienced at using the press. The mean value when allowed to operate at their own pace was 2.40 m/sec and 2.88 m/sec when required to work at the fast-pace and greatly exceed the Japanese safety standard of 1.60 m/sec.

Fig. 6 shows mean value of hand speed by age group for the two types of safety devices respectively. Hand speed used as the standard value for safe distance calculation in Japan is 1.6 m/sec. The elderly group achieved 1.6 m/sec under usage conditions for the PSDI device. The young group did not achieve 1.6 m/sec under usage conditions for the PSDI device when not required to operate at the fast-pace.

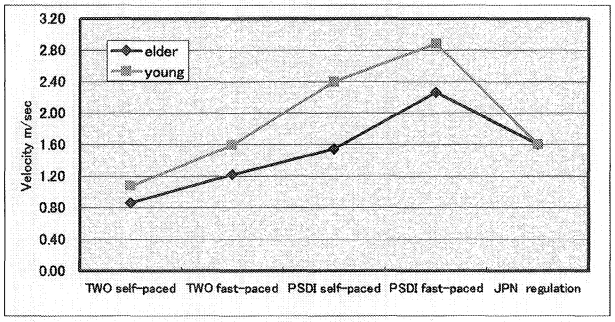

Fig.6: Average hand speed by age group

In conclusion, the study has shown that automatic safety devices such as the photoelectric type (PSDI) more effectively ensure safety while maintaining work efficiency of metal presses than those activated using both hands (TWO).

Acknowledgement

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