

Two-Hand Actuator Placement for Power Press Operation: A Reexamination of After-Reach Speeds

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Abstract. This study reexamined data from an earlier study by the U.S. National Institute for Occupational Safety and Health addressing the after-reach speed of press operators—a speed that is a key part of standards for locating two-hand actuator buttons from the point of operation. The 60 participating press operators performed four reaches in each of two button placements. The investigators reported on the fastest of the four for each operator. They concluded that the 1.6 m/s value is inadequate to protect many of the faster press operators. For this paper, all reach speeds were analyzed and used to identify the percentiles of all after-reaches that were slower than several common percentile.

Keywords: After-reach speed · Safe distance · Machine safeguarding · Power press

1 Introduction

Among the many sources of industrial injuries, one is amputations involving operation of mechanical power presses. Two investigations illustrate the magnitude of this problem. First, a paper based on U.S. workers' compensation records estimated over ten thousand amputation per year involving presses [1]. Second, reports of occupational amputations submitted to the U.S. Occupational Safety and Health Administration contained 2184 cases; 29% were from presses using two-hand actuators [2].

The use of two-hand actuators on presses is widespread. Suokas reported results of a survey about mechanical power presses in Finland that found that over 60% used a two-hand actuation method for actuating the stroke [3]. To set up these kinds of press operations, the two-hand actuator buttons need to be far enough from the point-of-operation to protect an operator who may initiate the downstroke by pressing both buttons, then suddenly reaching with one hand to adjust a mis-positioned part [4].

A formula for achieving this protection is widely used throughout the world. The formula is used to compute a “safe distance” between the buttons and the point-of-operation. The formula computes this “safe distance” by multiplying the time it takes to remove the hazard of a descending ram by a “hand speed constant” [4]. According to a review of studies looking for a value to use for the hand speed constant [5], the commonly used value of 1.6 m/s originated during the 1930 based on a small study of reach speeds achieved by students participating in the study.

The U.S. National Institute for Occupational Safety and Health (NIOSH) revisited this “hand speed constant” by constructing a press simulator to use for further studies [6]. The largest and most representative of their studies was conducted by NIOSH investigator Timothy Pizatella [7]. He obtained cooperation of 60 machine operators working in two large machine shop. Most of them worked on mechanical presses as a major or minor part of their work. The results demonstrated that many of the participants could achieve hand speeds faster than 1.6 m/s [7]. From this finding, the logical conclusion is that the hand speed constant in the “safe distance” formula should be increased to some value greater than 1.6 m/s. The authors of the NIOSH paper concluded that to protect all operators, the value would need to be 3.0 m/s. If this were to be adopted, the “safe distance” would become so large it would require press operators to lean their upper body forward to reach the die on every cycle, and some with shorter arms would not be able to reach at all. Dellman studied press operations from an ergonomics perspective, resulting in recommendations to avoid setups that require the operator to lean forward on every cycle [8]. Because this apparent conflict among practical set up distances, ergonomics, and operator protection seems unresolvable, this study was undertaken to explore the NIOSH data in a different manner.

As described in earlier papers [4, 7], the NIOSH study examined two palm-button placements, an upper one about shoulder level, and a lower one about waist level. Measured from the floor, these were at 106 cm and 84 cm, respectively. Figure 1 illustrates these two placements and the direction of pushing the buttons. In each placement, the participating operator followed a protocol resulting in four after reaches. For each placement, the NIOSH investigators took the fastest of the four reaches by each operator. This resulted in a data set containing 60 out of the 240 after-reach times for each placement.

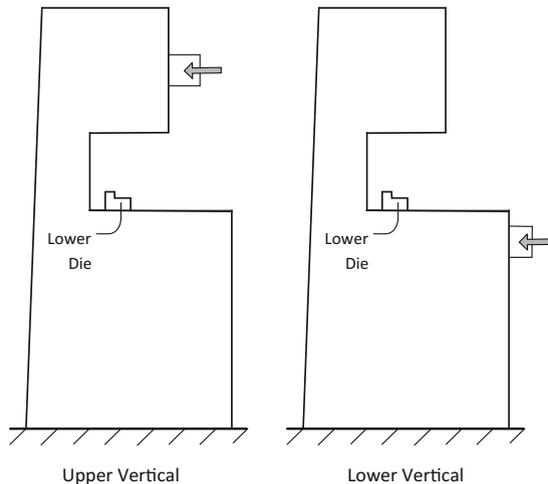


Fig. 1. Illustration of the two palm-button positions used in the NIOSH study [7].

For the present study, a different approach was taken. Instead of taking each operator's fastest of four after-reach motions, this analysis explored the inclusion of all four. By approaching the data this way, after-reach speed distributions may be developed—allowing identification of speeds for which particular percentiles of all 240 after-reach movements were slower. The end-point of this investigation is to provide information that will be available for consideration by standard-setting organizations concerned about the safe operation of mechanical power presses and other machines operated by two-hand actuation.

2 Methods

2.1 Data Source

After-reach data used for this analysis came from the NIOSH study of 60 machine operators. Each operator performed four after reach motions in a lower-level placement, and four in an upper placement. Using the NIOSH data, the approach reported for this paper was to include all of the 240 after-reach speed measurements in each placement.

2.2 Data Analysis

The initial analysis used two data sets—one for the upper placement, and one for the lower placement. Values were mean speeds for each of the 60 subjects. Plots clearly showed each distribution was other than normal; both being skewed to the right. In order to identify points in the distribution corresponding to percentiles, each subject-specific mean speed was transformed by its \log_{10} . Histograms and normal probability plots for the transformed datasets were generated for examination visually and statistically.

For each placement, all 240 after-reach speeds were combined in a data set and transformed to their \log_{10} values. Using the mean and standard deviation of each data set, speed values were identified corresponding to common percentiles levels (2, 5, 10, 25, 50, 75, 90, 95, 98, and 100). For each percentile point of the transformed data, the original after-reach speed values were identified.

3 Results

The initial aim of this statistical analyses was to establish data sets that fit a normal distribution. The steps described in the following subsections involved: (1) checking the raw speed data for normality, (2) finding a transformation that provides a normal distribution, and (3) identifying after-reach speeds corresponding to percentiles of the after-reaches.

3.1 Checking Raw Data for Normality

The subject-specific mean speeds (S) were organized into two data sets. These were initially examined for normality using Minitab 17 software. For each set of mean speed

data, the null hypothesis of normality was rejected ($p < .01$). Figure 2 contains graphs for the upper placement mean after-reach speeds. Figure 3 has the same types of graphs for the lower placements.

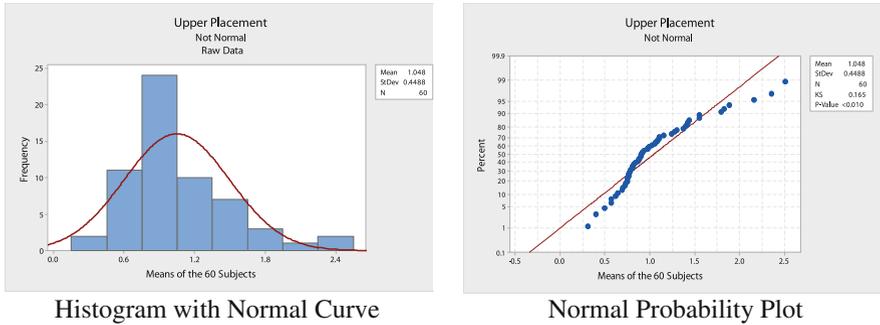


Fig. 2. Upper placement mean speeds in m/s for 60 subjects; not normally distributed.

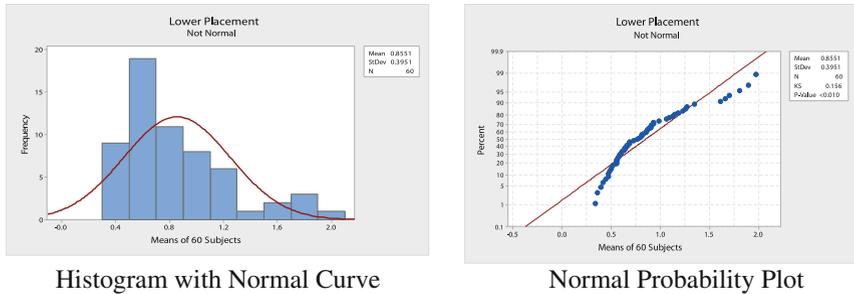
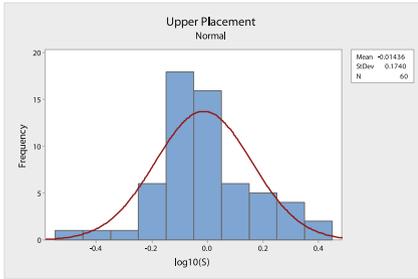


Fig. 3. Lower placement mean speeds in m/s for 60 subjects; not normally distributed.

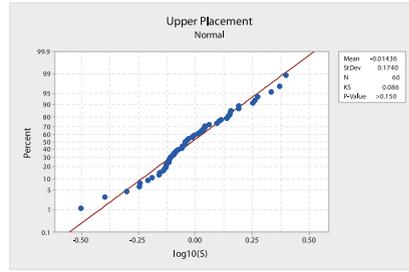
3.2 Transformation to Create a Normally Distributed Data Set

These subject-specific mean speeds were transformed using the function $\log_{10} S$. The two transformed datasets for upper and lower placements were tested for normality by visually examining histograms and running a Kolmogorov-Smirnov (KS) test. The null hypothesis was that the dataset is normally distributed.

Graphs of the upper-placement and lower-placement transformed data are displayed in Figs. 4 and 5, respectively. Also shown to the right of the plot are results of the statistical comparison. Both KS values were greater than the traditional 0.05 rejection level (each $p > 0.15$); therefore, the null hypothesis of normality was not rejected. Thus, subsequent analyses were based on the belief that each set of transformed data consisted of normally distributed values of $\log_{10} S$.

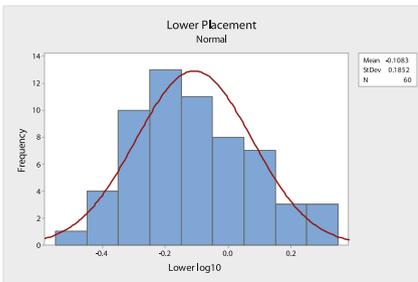


Histogram with Normal Curve

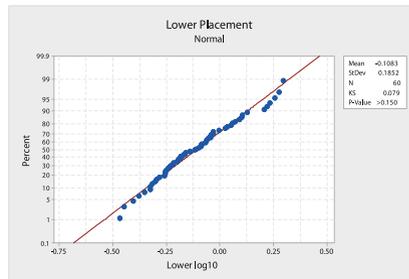


Normal Probability Plot

Fig. 4. Upper placement, transformed data distribution; normally distributed.



Histogram with Normal Curve



Normal Probability Plot

Fig. 5. Lower placement transformed data distribution; normally distributed.

3.3 After-Reach Speeds by Percentiles

Using the mean and standard deviation of the transformed data sets (each with 240 speed values), points were identified for various percentiles of values below the points. For each percentile point of the transformed data, the corresponding after-reach speed values (m/s) were identified. Table 1 contains the percentile values and the corresponding after-reach speed for the two placements.

An example of how the Table 1 data should be interpreted is illustrated using the 95 percentile value. Out of all after-reach motions made by press operators, 95% will be safe if the hand speed constant were to be 2.142 m/s for the upper placement, and 1.877 m/s for the lower placement.

Table 1. Percentile values and corresponding after-reach speeds

Percentile	After-reach speed (m/s)	
	Upper	Lower
2	0.297	0.200
5	0.387	0.272
10	0.460	0.340
25	0.632	0.480
50	0.914	0.719
75	1.302	1.066
90	1.677	1.523
95	2.142	1.877
98	2.643	2.401
100	3.160	3.626

4 Discussion and Conclusions

If standard-setting bodies decide to reconsider the after-reach speed value, they should appreciate two different approaches for choosing a speed constant in relation to percentage protected. The first is to seek a speed to protect the operators with the fastest speeds. That is the traditional approach used for occupational exposures to health hazards. The second is to seek a speed to protect a specified percentage of after-reaches that may occur among press operators. That is what this study explored.

One rationale for considering this alternative approach is our lack of knowledge of how frequently after-reach motions are made. Machine operators using a press with two-hand actuation may do so with frequencies ranging from infrequent to full time. Second, we do not know how frequently operators make an after-reach motion. For example, out of 100,000 cycles, how many after-reach movements can we expect, and of these, how many result in an operator reaching all the way to the point-of operation?

Another part of this rationale stems from the way occupational safety standards are developed. An example from the United States may serve to illustrate this point. In the process of making a fall protection standard, the consensus is that employers should only be required to provide fall protection when one of their employees is exposed to a fall greater than X feet. Various standards organizations have adopted different distances, e.g., 15, 10, 6, and 4 feet. Regardless of which height is adopted, some people who fall less than that distance will sustain a seriously injured, and some will die. Knowing this, the standard setting organizations have attempted to incorporate a fall distance that involves a compromise between protection and practicability. A relatively conservative standard like 4 foot will protect a large percentage of those who fall, but not 100%, and probably not even 90%. The point is that when occupational safety standards are developed, practicability plays a more significant role than when occupational health standards are developed.

In conclusion, this paper describes objective information on the distribution of after-reach speeds based on tests of 60 machine operators working in two American machine

shops. It identifies the after-reach speeds that were less than particular percentiles, and offers that information for consideration by standards making organizations.

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