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EVALUATION AND DESIGN OF A HAND FEED SYSTEM FOR A BENCH DRILLING MACHINE

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Abstract - Work related musculoskeletal disorders (WMSD's) have been reported by workers performing various kinds of manual tasks. Heavy workload, large force requirement, awkward postures, repetitive nature of tasks and working conditions were responsible for WMSD's in workers. Manual drilling was one such task in which the workers have reported various kinds of disorders. Manual drilling is either performed by a hand held drilling machine or by a bench drilling machine. In the present work, the drilling operation carried out on a bench drilling machine was studied. The task was to perform drilling operation on a mild steel block of dimensions 60 mm x 60 mm x 30 mm. The Existing Hand Feed System was evaluated with a view to design a new Hand Feed System so that the same may reduce the occurrence of work related disorders and human fatigue thereby improving the productivity. For evaluating the Existing Hand Feed System (EHFS) two independent parameters i.e., drilling speed and task duration were selected while the dependent variables taken were material removal rate (MRR), discomfort score, median frequency slope, root mean square value and EMG work done. The analysis of the data collected for the EHFS showed that the task duration and drill speed were significant in the context of MRR and discomfort score while task duration was found to be significant for EMG work done. Two new Hand Feed Systems were designed and evaluated on the above said parameters. Hand Feed System-1 (HFS-1) was fabricated using the handle with arms bent at 90^0. As far as Hand Feed System-2 (HFS-2) was concerned, it was fabricated by assembling various components e.g. bearing, driver and driven wheel, link chain etc. The evaluation of the two proposed systems showed that there was an increase of 6.67% in MRR for HFS-1when the task was carried out at 700 rpm for a duration of 5 min. while there was an increase of 18.02% for HFS-2 for a duration of 10 min. at 700 rpm. Also the discomfort score was found to be decreased by 29.39% for HFS-2 when the task was carried out for 10 min at 300 rpm. There was a decrease of 10.73% for HFS-1 when the task was carried out for 5 min. at 300 rpm for the discomfort score. On the basis of EMG readings it was further observed that the level of human fatigue was lower in both the Hand Feed Systems. From the present study it can be concluded that by using HFS-2, the human fatigue could be reduced and an appreciable increase in the MRR could be achieved.

Key Words: WMSD's, EHFS, material removal rate, Hand Feed System, etc.

1. INTRODUCTION

Manual mode of working is very common in developing and under developed countries / large workforce is carrying out drilling, welding and other tasks manually. Mizoue (1999) observed that the small and medium scale industries have about 80% of the workforce and have more than 90% contribution of all industries in developing countries. Dempsey (1998) found that daily working for prolonged period of task duration in a stationary standing posture could lead to the muscle fatigue, lower back pain, stiffness in the neck/shoulders, and other related health problems. These discomforts were commonly reported by assembly line workers, machine operators and others involved in such jobs characterized by prolonged standing. There was also a growing recognition that Musculoskeletal disorders (MSD) were a leading cause of productivity losses and work disability (Baldwin, 2004; Escorpizo, 2008; Glover et al., 2005; Kogi and Kawakami, 1997). Fatigued workers or workers who were recovering from injury might be at a greater risk for emerging a Work related musculoskeletal disorders (WMSD) than well rested healthy labours (Putz–Anderson, 1992).

Work-related injuries present a major public health problem resulting in serious social and economic consequences that could be prevented if appropriate measures were taken (Bhattachersee, 2003). According to WHO (2003), annually throughout the world, an estimated number of 271 million people suffer with work-related injuries, and 2 million die as a result of these injuries and the expected economic loss caused by work related injuries and disease was equivalent to 4 % of the world's gross national product. The impact was 10 to 20 times higher in developing countries, where the greatest attention of the world's workforce was located (Faris, 1998). WMSDs are the principal cause of both lost workday injuries and workers compensation costs (OSHA, 1999). Each year WMSDs account for more than $20 billion in workers compensation costs, 1/3 of the total money expended on workers compensation (OSHA, 1999).

As per the NIOSH publication (no.97-117, 1997), Jobs or working conditions generating different kinds of risk factors were found to have a high probability of causing a musculoskeletal problem. The level of risk depends on the intensity, frequency and duration of the exposure to these environments and the person's capability to meet the force or other job demands that might be involved.

With the Existing Hand Feed System (Figure 3.3), drilling task was performed by applying force on the handle. This force gets transmitted from the handle to the shaft and then from the shaft to the rack and pinion gear mechanism which controls the upward and downward feed. Subject was asked to perform drilling task for three task durations i.e., 5, 10 and 15 min which was quite stressful and fatiguing to perform. Hence, there is a need to design and evaluate a Hand Feed System so that a better working unit may be created for the drilling task.

1.1. Objectives of the present work

The objectives of the present study were as follows:

1. To investigate the effect of drilling speed on the worker while performing the drilling task using Existing Hand Feed System
2. To investigate the effect of work duration while performing the task using Existing Hand Feed System
3. To design a new Hand Feed System with a view to improve the performance of the worker
4. To evaluate the new Hand Feed System for the kind of the task undertaken in the study

2. Methodology

2.1. Problem statement

Bench drilling is one of the most demanding tasks in today's industry which is usually performed in nearly all type of manufacturing environments. The literature reviewed on the topic revealed that almost no work has been conducted in the past with a view to improve the working of a Bench drilling machine.

2.2. Experimental Design

A two factor repeated measure type of experimental design was used in the analysis of the data collected in the present work. The ANOVA model used as presented below:

$$Y_{ijt} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijt}$$

Where, μ - overall mean response,

α_i - Effect due to the i_{th} level of factor A,

β_j - Effect due to the j_{th} level of factor B,

$(\alpha\beta)_{ij}$ - Effect due to any interaction between the i_{th} level of A and j_{th} level of B

ε_{ijt} - Independent random variable

The factors selected were drill speed (at two levels i.e., 300 and 700 rpm) and task duration (at three levels i.e., 5, 10 and 15 min). The dependent variables were EMG parameters (median frequencies slope, EMG work done and RMS value), material removal rate (MRR) and discomfort score.

2.3. Participants

Seven subjects, all male students of the Zakir Hussain college of Engineering and Technology were selected for the study. They were not having any experience of performing drilling related task. An informal written consent was obtained from the subjects participated in the experiments.

Characteristic	Mean	Standard deviation (SD)
Age (years)	24.43	1.05
Weight (Kg)	67.43	2.55
Height (cm)	168.71	2.37
Hand Anthropometry	56.40	1.32

Table 3.1 Characteristic of subjects who participated in the study

The characteristics of the subject who performed the drilling operation on a bench drilling operation have been presented in the Table 3.1. The participants were of the (mean ± Deviation at 95% confidence interval)

2.4. Task

Before carrying out the actual experimentation, a training session was organized for the subjects. A mild steel plate of 60 mm x 60 mm x 30 mm was selected for performing drilling operation. Before performing drilling task the plate was fixed in the bench vice. Holes of 10 mm diameter using a high speed steel drill bit of 10 mm diameter were drilled in the plate. The drilling operation was carried out for three different durations i.e., 5, 10 and 15 min at two drill speeds i.e., 300 rpm and 700 rpm. Subject applied the force on the handles attached to the shaft (Figure 3.2). This force drives the rack and pinion mechanism, which was responsible for the up and down motion of the drill bit.

2.5. Drill speed

The bench drilling machine used in the present study could be run at three drill speeds i.e., at 300, 700 and 1200 rpm. The experiments were performed at two drill speeds i.e., at 300 and 700 rpm. The speed of the drill machine was changed using the lever of belt pulley mechanism. A belt run over the two pulleys (Figure 3.1) i.e., one pulley was connected to the motor and the other was connected to the chuck spindle of the machine. Drill speed could be adjusted with the help of lever.

Figure 2.1 Arrangement for changing the drill speed

Figure 2.2 EMG Base unit

Figure 2.3 EMG Subject unit

2.6 Task duration

The subjects were asked to perform the drilling task on a bench drilling machine for three different durations i.e., 5, 10 and 15 minutes. These durations were selected on the basis of the study conducted by Muzammil et al. (2003) in a study related to the hand drilling machine.

2.7 Hand Feed System

There were three Hand Feed Systems which were used in the experiments

1) Existing Hand Feed System
2) Hand Feed System-1
3) Hand Feed System-2

2.8 Experimental set up, Equipment and tools used

2.8.1 Experimental set up

The experiments were conducted using the Datalink software and hardware of M/s Biometric Ltd. (UK). The EMG readings were recorded at a sampling rate of 1024Hz using Surface EMG sensor (Model: SX230 EMG sensor; Make: Biometrics Ltd. UK). The pre-amplified signals of EMG were recorded employing 8 channel subject unit of DataLink (DLK900: No. M11138 2009-09; Make) with R7000 Lead (Make Biometrics Ltd. UK) which was then transferred to the Laptop from the Base unit using connecting lead (USB1800 Make: Biometrics Ltd. UK). The Earthing strap R206 was used for reducing noise and other unwanted signals. The signals were recorded using the specialized software (Data Link) of Biometrics Ltd. (UK). The shows the EMG base unit, subject units, muscle electrode and earthing strap of the EMG instruments which were used in the present study, respectively. Schematic diagram of the Experimental set up has been presented in the Figure 2.4.

Figure 2.4 EMG Muscle Electrode

Figure 2.5 EMG Earthing Strap

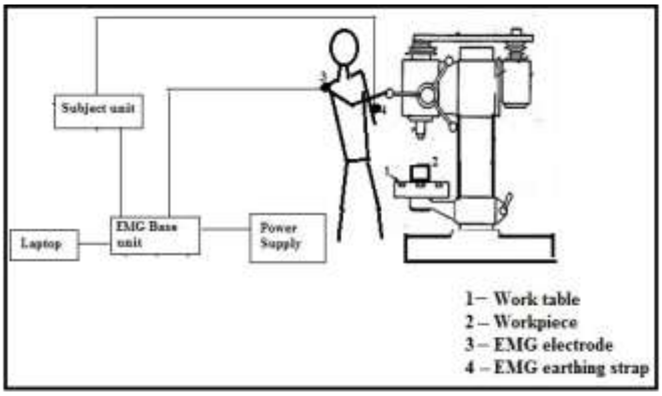

Figure 2.6 Schematic diagram of Experimental set up

2.8.2 Equipment and tools used

The following equipments were used in the present research

1. EMG Electrode
2. EMG Subject unit
3. EMG base unit
4. Laptop (Make : DELL)
5. Drill bit
6. Bench vice
7. Chuck key
8. Bench drilling machine

3. DATA COLLECTION AND RESULTS

3.1. Existing Hand Feed System (EHFS)

a) Material removal rate (MRR)

In this experiment, subject performed the task at various drilling speeds for three different task durations i.e., 5, 10 and 15 min. From the Table 3.1 it can be shown that at both the drill speeds the material removal rate decreased with the increase in task duration.

Table 3.1 MRR at different drill speed when the task was carried out for various durations

Material removal rate (mm^3 / min)	Subject	Task duration		
		5 min	10 min	15 min
Drill speed-1 (300 rpm)	1	1067.60	902.75	785.00
	2	1177.50	1099.00	910.60
	3	989.10	863.50	722.20
	4	894.90	690.80	653.90
	5	1130.40	1161.80	920.80
	6	1256.00	1193.20	1020.50
	7	1193.20	1138.25	879.20
	Mean	**1101.36**	**1007.16**	**841.52**
Drill speed-2 (700 rpm)	1	1491.50	1318.80	1277.20
	2	1617.10	1444.40	1387.10
	3	1413.00	1350.20	1350.2
	4	1758.40	1475.80	1413.00
	5	1727.00	1397.30	1297.61
	6	1915.40	1687.75	1664.20
	7	1852.60	1601.40	1570.00
	Mean	**1682.26**	**1467.95**	**1422.42**

Table 3.1 also showed that material removal rate obtained was maximum when the drilling task was performed for 5 minute at a drilling speed of 700 rpm.

A 2 way ANOVA was used to analyse the data presented in the Table 3.1. The result of the analysis (Table 3.2) showed that task duration and drilling speed both have a significant effect on the task performance of the operator. However, the two way interaction between drilling speed and task duration was found to be statistically non significant.

Table 3.2 ANOVA results when the task was carried out at different speeds for various durations (MRR measure)

Source	dF	Mean Square	F value	P value
Task duration	2	38.679	10.169	.000
Drill speed	1	498.526	131.06	.000
Task duration	2	2.726	.717	.495
Error	36	3.804		
Total	42			
Corrected	41			

b) Perceived discomfort level

After the task was completed by the subjects, perceived discomfort level was recorded on a visual analog scale proposed by Corlett and Bishop in 1976. The mean values of which have been presented in Table 3.3. It can be observed from the Table 3.3 that the perceived discomfort was minimum at a drill speed of 700 rpm when the drilling task was performed for a duration of 5 minutes while the average maximum discomfort level was found at a drill speed of 300 rpm when the drilling task was performed for 15 minute duration.

Table 3.3 Discomfort score at different drill speed when the task was carried out for various durations

Discomfort level	Subject	Task duration		
		5 min	10 min	15 min
Drill speed-1 (300 rpm)	1	5.4	6.6	7.8
	2	5.0	5.8	7.8
	3	6.2	7.2	8.0
	4	4.4	5.6	7.8
	5	6.0	6.4	7.4
	6	4.2	5.0	6.8
	7	6.0	7.8	8.4
	Mean	**5.3**	**6.3**	**7.7**
Drill speed-2 (700 rpm)	1	3.2	4.4	6.2
	2	4.4	5.0	7.2
	3	4.4	5.6	7.8
	4	3.2	4.8	5.6
	5	4.2	4.8	6.0
	6	4.4	5.6	5.8
	7	4.8	6.8	7.2
	Mean	**4.1**	**5.3**	**6.5**

A 2 way ANOVA was used to analyse the data presented in the Table 3.3. The result of the analysis (Table 3.4) showed that task duration and drilling speed had a significant

Table 3.4 ANOVA results when the task was carried out at different speeds for various durations (discomfort score measure)

Source	dF	Mean Square	F value	P value
Drill speed	1	13.944	23.338	.000
Task	2	20.690	34.629	.000
Task duration * Drill speed	2	.027	.045	.956
Error	36	.597		
Total	42			

Effect on the task performance of the operator. However, the two way interaction between drilling speed and task duration was found to be statistically non-significant.

c) EMG measurement

Different EMG values i.e., mean values of RMS of the muscle potential, EMG work done and median frequency of the muscle potential were recorded after performing the drilling task for three durations 5, 10 and 15 minutes. EMG work done was found to be increasing with the increase in task duration. It was also observed that the EMG work done was less at a drill speed of 700 rpm. As far as the slope of median frequency was concerned, an increase in values was obtained with the increase in task duration at a drill speed of 700 rpm. From the Table it was found that the mean RMS values of muscle potential were almost same when the task was performed at a drill speed of 700 rpm for 5 and 10 min. duration indicating low muscle fatigue at these durations.

4. CONCLUSIONS

On the basis of present research, following conclusions can be drawn

- Metal removal rate was found to be improved when the task was performed with Hand Feed System-1 and further improved when the task was performed with Hand Feed System-2 but the increment in the MRR was found to be decreased with the increase in the task duration while performing the task with all the three Hand Feed Systems at both the drill speeds when compared with the Existing Hand Feed System. A maximum increase of 18.02% in the MRR was found at drill speed of 700 rpm for 10 min while performing the task with the Hand Feed System-2. However, a maximum increase of 6.67% in the MRR was found at drill speed of 700 rpm when the same task was performed for 5 min with the Hand Feed System-2. Hence, Hand Feed System-

2 was found to be better when MRR was used as a measure of task performance.

- Appreciable reductions in discomfort level were found when the task was carried out using the Hand Feed System-1 and Hand Feed System-2. It was found that a higher percentage reduction of 29.3% in discomfort level was achieved when the task was carried out for 10 minutes at a drill speed of 300 rpm using the Hand Feed System-2. However, when the same task was carried out for 5 min at a drill speed of 300 rpm using the Hand Feed System-1, a reduction of 10.7% in discomfort score was obtained. Hence, Hand Feed System-2 was found to be better when discomfort level was used as a measure of task performance. It was also observed that the discomfort level increased with the increase in task duration at both the drill speeds while performing the task with all the three Hand Feed Systems.
- A reduction of 70.0% in the RMS value of muscle potential was found at drill speed of 700 rpm when the task was performed for 5 minutes using Hand Feed System-1. However, when the Hand Feed System-2 was used, a reduction of 58.88% in the RMS value of muscle potential was obtained at a drill speed of 300 rpm when the task was performed for the task duration of 15 minutes. Hence, it can be said that the muscle activity was appreciably reduced in both the types of Hand Feed Systems under study.
- Hand Feed System-2 was found to be largely capable in reducing the EMG work done (74.45%) when the task was carried at drill speed of 300 rpm for a work exposure of 5 minutes. However, it was found that the Hand Feed System-1 was highly capable in reducing the EMG work done (34.35%) at drill speed of 300 rpm for the task duration of 15 minutes. Hence, Hand Feed System-2 was found to be better when EMG work done was used as a measure of task performance.

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