Effect of Drilling Speed and Task Duration on Discomfort Score and Metal Removal Rate on Workers Performing a Drilling Task

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ABSTRACT

Work related musculoskeletal disorders (WMSD's) have been reported by industrial workers performing various kinds of manual tasks. Heavy workload, 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 being 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 drilling speed at two levels (300 RPM and 700 RPM) and task duration at three levels (5, 10 and 15 minutes) were selected to determine material removal rate (MRR) and discomfort score. The two way ANOVA of the data collected showed that the task duration and drill speed both were significant in the context of MRR and discomfort score. It was found that at both the drill speeds (i.e., 300 and 700 RPM) the material removal rate decreased with the increase in task duration. Results also showed that the perceived discomfort score was found to be minimum at a drill speed of 700 rpm when the drilling task was performed for 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.

Key words : Drilling speed, discomfort score, metal removal rate

INTRODUCTION

Manual mode of working is very common in both developing and under developed countries. A large number of workforces is performing manual tasks. Balasubramanian et al. (2009) reported that continuous standing for long working hours such as assembly line jobs might lead to musculoskeletal disorders including increased fatigue, pain and stiffness in active muscles [2]. The occurrence of musculoskeletal disorders (MSD) and low-back pain (LBP) in workplaces has been recognized as a signi?cant loss to companies, society and the health care system [1, 12]. According to the reports of Liberty mutual workplace safety index (2006), the compensation cost involved due to occurrence of WMSDs in 2006 was estimated to be

$48.6 billion [7]. Bureau of Labor Statistics (2004) revealed that there were over 5,20,000 cases of WMSDs with days away from work and about 34% of total number of injuries and illnesses were reported. Genaidy et al. (1994) found that an uncomfortable posture might result in MSDs, causing a decrease in the working ability [4]. A high prevalence of shoulder MSDs in the general population, with elevated risk was reported particularly in those with jobs requiring overhead work [6, 8, 9].

Literature reviewed on the topic showed that injuries were very common in workers performing task manually for long task durations. Literature also showed that not much work has been carried out in the past to assess the performance of the worker in a drilling task. Keeping this in mind the present study was designed and a hypothesis was framed as has been presented below:

The drilling speed and working duration have a significant effect on the drilling task performance of the worker.

METHODOLOGY

Subjects

Seven subjects, all male students of the Zakir Husain college of Engineering and Technology were selected for the study. They were not having any experience of performing drilling related task. An informed written consent was obtained from the subjects participated in the experiments. The characteristics of the subjects who participated in the study has been presented in Table 1.

Table 1: Characteristic of subjects who participated in the study

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

Experimental Task and Procedure

Subjects for the present work were selected from a pool of individuals. They were asked to perform drilling task for different exposure durations under varying drilling speeds. The dependent variables used in the present work were discomfort score and material removal rate (MRR). A bench drilling machine (NRD-24 Make: Namiki Machine Mfg. Co. Ltd. Japan) was used for performing the drilling 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 used for performing drilling operation. Holes of 10 mm diameter using a high speed steel drill bit were drilled in the plate. The drilling operation was carried out for three different

durations i.e., 5, 10 and 15 min at two different drilling speeds i.e., 300 rpm and 700 rpm. Subject applied the force on the handle attached to the shaft (Figure 2.1) to perform the drilling task.

Hand Feed System

As shown in the Fig 1, the Hand Feed System consisted of a handle having three arms each at an angle of 1200. The handle shaft was connected to the rack and pinion mechanism for controlling the feed. Subject applied the force to the handle to give the feed to the work piece to perform drilling task. Due to downward motion, the tool removed the metal from the work piece.

Fig 1: Hand Feed System

Material Removal Rate (MRR)

Subjects performed the task as described earlier. After performing the experimental task for a stipulated duration, total depth of the material removed was measured using a screw gauge. Material removal rate was obtained using the following formula.

MRR = Volume of metal removed (mm3)/Task duration (minutes)

Discomfort score

Discomfort score was obtained to estimate the fatigue generated while working. The subject was asked to rate the fatigue experienced by him in different parts of body on a 10 point scale (Fig 2) during the task. Visual analogue scale proposed by Bishop and Corlett (1976) was used to assign discomfort values. A '0' value indicated no fatigue while a value of '5' represented appreciable fatigue. A value of 10 referred to a condition that the subject could not continue with the task further. The participants were asked to fill up the observation sheet after completing the task. Corlett-Bishop (1976) diagram was used to indicate most stressful part of the body.

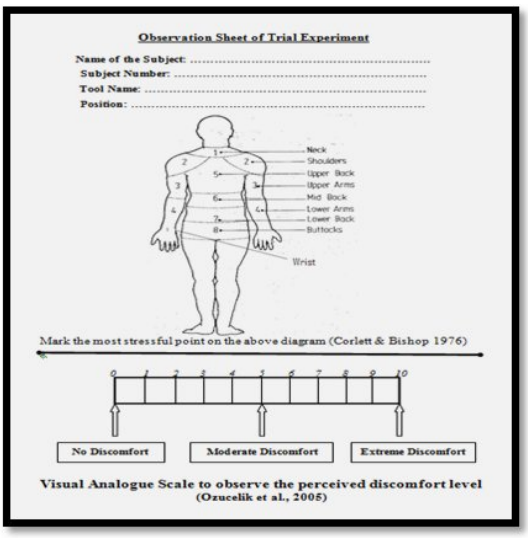

Fig 2: Discomfort Score Sheet

RESULTS

Discomfort Score

The bar chart for the discomfort score values has been shown in the Figure 3. The discomfort score was obtained when the drilling task was performed at drill speeds 300 and 700 rpm. The task was carried out for a period of 3 minute. From the Fig 3 it can be observed that discomfort score was higher for the shoulder while it was less for the upper arm at both the speeds of drilling.

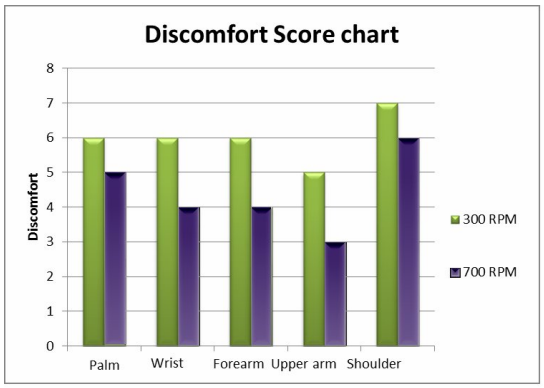

Fig 3: Discomfort Score values obtained for various parts of arm while performing drilling at different drilling speeds

Perceived discomfort level

After the task was completed by the subjects, perceived discomfort level was recorded on a visual analog scale (Corlett and Bishop ,1976). The mean values of which have been presented in Table 3. It can be observed from the Table 2 that the perceived discomfort was minimum at a drill speed of 700 rpm when the drilling task was performed for 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 2 : Discomfort score at different drill speed when the task was carried out for various durations

Task duration (minute)	Discomfort level at	
	Drill speed-1 (300 rpm)	Drill speed-2 (700 rpm)
5	5.3	4.1
10	6.3	5.3
15	7.7	6.5

A 2 way ANOVA was used to analyse the data presented in the Table 2. The result of the analysis (Table 3) showed that task duration and drilling speed both had 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: ANOVA results when the task was carried out at different speeds for various durations (discomfort score measure)

Source	dF	Mean	F value	P value
Drill speed	1	13.944	23.338	0.000
Task duration	2	20.690	34.629	0.000
Task duration * Drill speed	2	0.027	0.045	0.956
Error	36	0.597		

Material Removal Rate (MRR)

The material removal rate obtained at different drilling speeds for various durations has been presented in Table 4. From the Table it can be observed that at both the drill speeds the material removal rate decreased with the increase in task duration. It can also be seen that material removal rate obtained was maximum when the drilling task was performed for 5 minute at a drilling speed of 700 rpm.

Table 4: MRR at different drill speed when the task was carried out for various durations

Task duration (minutes)	Material removal rate (mm^3 / min)	
	Drill speed-1 (300 rpm)	Drill speed-2 (700 rpm)
5	1101.36	1682.26
10	1007.16	1467.95
15	841.52	1422.42

A 2 way ANOVA was used to analyse the data presented in the Table 3. The result of the analysis (Table 5) showed that task duration and drilling speed both had 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 5: 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 * Drill speed	2	2.726	.717	.495
Error	36	3.804		
Total	42			
Corrected Total	41			

DISCUSSION

Results of the study showed that task duration and drill speed were significant when the material removal rate and discomfort score were used as a measure of task performance in the HFS. The results of the present study showed that material removal rate was found to be highest (1682.26 mm3/ min) when the task was performed at drill speed of 700 rpm for 5 min of task duration while it was minimum (841.52 mm3/ min) when it was performed for 15 min at drill speed of 300 rpm. Results also revealed that the mean discomfort score was more at a drill speed of 300 rpm for task duration of 15 min while it was less at a drill speed of 700 rpm when the task was performed for 5 min. It was also found that the mean discomfort level increased with the increase in the task duration and decreased with the increase in the drill speed. The result obtained emphasised the need to design HFS ergonomically to improve the productivity and reduce the discomfort level. Previous studies conducted by Das et al. (2007) and Rempel, 2010 [10] have shown that ergonomic intervention resulted in the improvement

of the worker's performance. Though not much work has been conducted in the past, the results of the study with regard to task duration are in line with other studies conducted in the related area [5, 11]. As far as drilling speed is concerned the studies are almost non-existent. Since both drilling speed and task duration have been observed to be significant, more elaborative studies are required to be performed to reach to a conclusion. The discomfort score levels obtained at various hand positions indicate towards the need to redesign the HFS as the existing HFS has not seen much design changes in the recent past.

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