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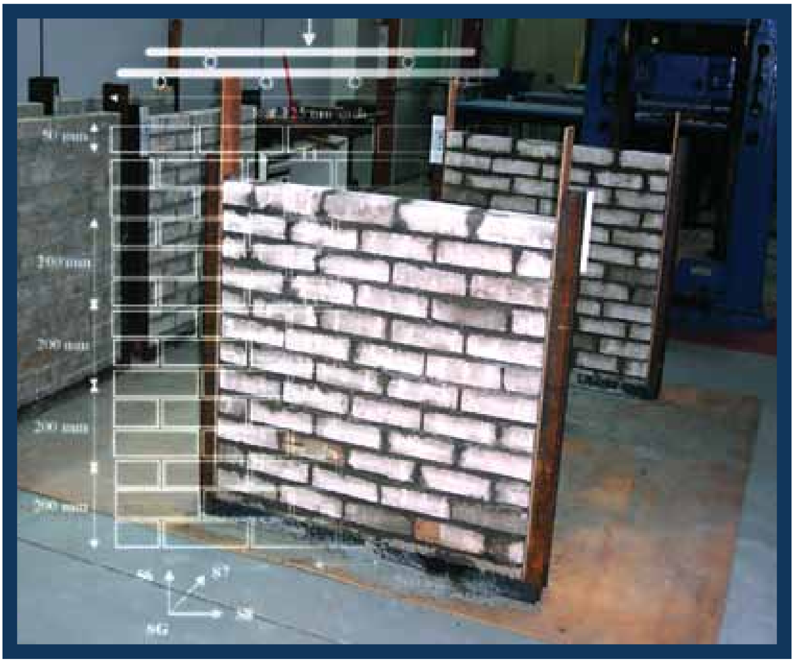

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Ergonomics Analysis of Muscle Activity of Workers in a Metal Stamping Industry

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ABSTRACT

Occupational health is considered as a crucial element in almost every Small and Medium Industries (SMIs) and it is believed to be one of vital challenges that can influence productivity and competitiveness. It has been known that the metal stamping industry involved a lot of materials handling tasks such as carrying stamped parts from machine to packaging section, transferring moulds from tools store to machines, sorting the finished products and others. Appropriate materials handling equipments are not often provided in SMIs because of the limitation of capital and lack of ergonomics awareness. The workers have to handle the materials and goods manually. These practices may lead to occupational injuries particularly back pain and musculoskeletal injuries. The objectives of the research are to assess and analyze the muscles activity of workers in metal stamping industry. Three male workers who performed metal stamping process using manual technique were participated in the research. Ergonomic assessment associated with Surface Electromyography (SEMG) was used to capture and interpret the data related to muscles activity at before and after the ergonomic intervention. For the purpose of muscle activity assessment, SEMG electrodes were attached to eight critical muscles: deltoid muscle-medial part (left), deltoid muscle-medial part (right), trapezius muscle (left), trapezius muscle (right), erector spinae muscle (left), erector spinae muscle (right), gastrocnemius muscle (left) and

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gastrocnemius muscle (right). An ergonomically designed workstation has improved working posture and reduced the total muscle work/loading by about 43 % if it is properly utilized. This design approach can be adopted to improve the working conditions of industrial workers and thus enhance the occupational health practices.

***Keywords**: Occupational Health, Ergonomics, Muscles Activity, Electromyography, Metal Stamping Industry*

Introduction

In today's fast changing of technology, occupational health plays an important role in maintaining competitiveness and productivity in metal stamping industry. One of the common practices that can be used to achieve a feasible occupational health is through ergonomics approach. Ergonomics is a scientific study of designing equipment or work systems that take into account worker capabilities and limitations. The aim of ergonomics is to ensure the worker and equipment or work systems function in complete harmony. It incorporates elements from many subjects including anatomy, physiology, psychology and design. Ergonomics has a wide application to everyday domestic situations, but there are more significant implications for efficiency, quality, productivity, safety and health in work settings. In addition, ergonomics is able to increase comfort, provide safe and healthy working condition in the workplace.

A study has shown that manual materials handling task was identified as one of the main contributors to occupational diseases [1]. Manual materials handling including lifting, carrying, pushing and pulling represent occupational risk factors that have to be confined within safe limits [2]. Despite increase of mechanized and automated materials handling systems, manual materials handling techniques are still common in many workplaces and become more essential functions of many jobs [3]. Workers' compensation losses associated with manual materials handling is one of the critical issues in many industrial sectors [4].

In metal stamping industry, manual materials handling tasks are very common. Tasks such as lifting, carrying and feeding can be found easily. Even though these tasks are considered risky to the workers' muscles, current occupational health and safety researches are not particularly focused towards these tasks. Therefore, this research was undertaken with the objectives of assessing muscles activity while the workers were performing manual materials handling task in metal stamping industry.

The data gathered from the research can be used to improve the design of work systems so that the problems related to muscles activity can be eliminated or reduced to safe limits.

Application of Surface Electromyography (SEMG) Technique in Occupational Health Research

In occupational health research, ergonomics plays an important role to improve the muscles activity. Ergonomics practitioners use various tools to assess and analyze the muscles activity of the subject. The most common tool that can be used for muscles activity assessment is Surface Electromyography (SEMG). SEMG offers a valuable tool for the indication of muscular fatigue in occupational field studies [5]. It can be used to analyze muscles activity from global perspective. A classic application of the tool for global muscle assessment is the evaluation of muscle fatigue to obtain the work/loading on muscles. The analysis of muscles activity using SEMG especially in fatigue assessment has shown advantages and has been applied for classifying healthy and non healthy subjects in relation to lower back pain; this was approved by previous study [6] on analysis of low back muscles for both healthy subjects and lower back pain patients. In research field, SEMG technique has been extensively applied to analyze the muscles activity of subjects who involved in manual materials handling activities [7]. High spinal loading during manual handling is contributed mostly to forces generated by the muscles of the back and abdomen; so it is good idea to use SEMG to analyze the effect of these forces to trunk muscles. The SEMG technique also has been widely used in manufacturing industry. For example, it was utilized to evaluate localized muscle fatigue in the shoulder muscles in overhead and shoulder-level welding [8].

However, this research applied SEMG to analyze the effectiveness of workplace ergonomic interventions for workers' muscles activity during metal stamping process.

Research Methodology

The assessment on muscles activity was conducted among the workers to determine the effect of manual materials handling task to the worker's muscles. Muscles activity was assessed and analyzed using electromyography (EMG) technique. There are two types of EMG technique, surface electromyography (SEMG) and needle electromyography (NEMG). SEMG technique involves the application of the electrodes placed on the surface of worker's skin, over the muscles under investigation. These electrodes read the electrical activity of the muscles and send the information to the computer, where this information is processed. Usually the computer monitor displays the information in a graphic form and the software performs various statistical manipulations and data interpretation. On the other hand, NEMG is used for assessing neurophysiologic characteristics in the study of neuromuscular diseases. The assessment involves placing small needle into the muscles, hence there is some discomfort occurs on the worker's skin. During the assessment, the worker may feel pain when the needles were injected into the worker's skin.

SEMG was used for the purpose of this research. A ME3000P4 (MEGA Electronics, Finland) instrument together with MegaWin Software were used to record, store and interpret all the data associated with muscles activity of the worker. The SEMG system is equipped with the electrodes to detect the myoelectric signal of worker while the task is performed. The electrodes were attached conscientiously to worker's skin to measure the muscles activity of worker. Eight locations where the muscles activities were suspected to be critical have been selected for the assessment. Before these muscles were selected, the movements of workers while performing the task were observed through recorded videotaping. Through videotaping, it can be observed that both left and right deltoid-medial part muscles (shoulder muscles) involved while the workers reaching the raw materials from the bucket and place the finished products into product's bucket. The left and right trapezius muscle (neck muscles) involved when the workers turn their neck to left and right while reaching the raw materials and place the finished products. The workers have to bend their bodies downwards to reach the raw materials that were located in a lower position. At this posture, both left and right erector spinae muscles (lower back muscles) that corresponded to the movement were affected. Since the stool is not provided, the workers have to perform the task in standing posture and thus affecting both left and right gastrocnemius muscles (leg muscles). Figure 1 shows the selected muscles of workers for the muscles activity assessment.

Figure 1: A Worker is Completely Attached with SEMG Electrodes

SEMG system is equipped with the electrodes to detect the myoelectric signal of workers while they performed the tasks. This myoelectric signal will be captured by bipolar disposable Ag-AgCl (Blu Sensor Medicotest, Olstykke, Denmark) electrodes, within 5 mm × 5 mm of the active area. The skin was properly prepared to obtain inter-electrode resistance which was below 2 kΩ. The distance of inter-electrode was 20 mm for every muscle and they were attached to different channel: deltoid-medial part (left) to channel 1, deltoid-medial part (right) to channel 2, trapezius muscle (left) to channel 3, trapezius muscle (right) to channel 4, erector spinae muscle (left) to channel 5, erector spinae muscle (right) to channel 6, gastrocnemius muscle (left) to channel 7 and gastrocnemius muscle (right) to channel 8.

The assessment of muscles activity was conducted based on real time monitoring. All electrodes were connected to data logger and the signals from data logger were monitored through the screen of PC monitor using wireless networking. The aim of this system is to ensure that the assessment is under controlled throughout the whole of assessments process. MegaWin Software was used to store and interpret the data related to muscles activity.

Case Study

This research was conducted in a SMIs company situated in Shah Alam. This company produces metal-based products such as stamped parts for automotive, electrical and electronics industries. In this company, the production shop consists of stamp machines with capacities ranging from 25 tons to 250 tons. For this study, a process to produce stamped parts has been selected. The process began with picking of raw materials (300g each) manually from the bucket to the stamp machine. At existing workstation, the workers' standing position was at upright posture (about 90 degrees with respect to the body midline) and his body was close to the stamp machine. As shown in Figure 2, the bucket was located on the

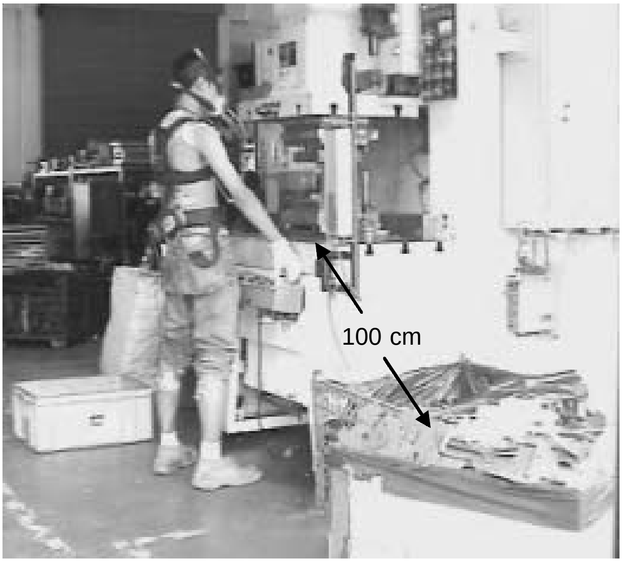

Figure 2: Worker Stands in Front of Stamping Machine

Figure 3: Worker Reaches the Raw Materials in Bending Posture

floor on the right side of the worker. The distance between worker's hand and raw materials was approximately 100 cm. Since the bucket was at a lower position, the worker had to bend his body downwards to reach the raw material. At this instant, the distance of his shoulder and the floor was approximately 100 cm as depicted in Figure 3. After the raw material has been picked, it was then placed to machine die for stamping process (Figure 4).

The machine, which had a capacity of 110 tonnes, punched the raw material according to the geometry of the die. The finished products were then thrown to another bucket on the left side of the worker. At this position, the worker was in partial upright working posture, but he had to bend his body slightly to the left as shown in Figure 5. The same process had to be repeated at the rate of five to eight cycles per minute throughout the whole shift.

Two male production workers (19 to 23 years old) took part in the muscles activity assessment. They had good physical health and free from any occupational injuries. They represented about 30 % of the machine operator population in the company.

The existing workstation has been improved to improve working posture and muscles activity. The improved workstation designed was

Figure 4: Worker Feeds the Material into Machine Die

Figure 5: Worker Throws the Finished Part into Empty Bucket

Figure 6: Improved Workstation Design – Intervention of Adjustable Table and Sit-stand Stool

equipped with an adjustable table and a sit-stand stool (Figure 6). The advantages of the improved workstation are working height could be adjusted to an appropriate height so that bending posture is eliminated. Moreover, sit-stand stool offers workers to perform job either in standing or sitting working positions.

Result and Summary

The results of muscles activity assessment before and after ergonomic intervention are presented in this section. The analysis of work/loading on muscles is beneficial for obtaining the work/loading exerted on the workers' muscles while they performed the task. The amount of work/ loading exerted on the workers' muscles is measured in microvolts (μVs). Table 1 summarizes the results of muscles activity measurement for every worker while performing stamping work in the existing and improved workstations. The first and the second workers experienced highest work/ loading on both left and right erector spinae muscles (lower back's muscles) with corresponding myoelectric signals of 90676 μVs and 184665 μVs, and 46649 μVs and 59518 μVs respectively. The work/loading exerted on these muscles are higher than the other muscles.

Based on the assessment of muscles activity in the existing workstation, it can be summarized that the effort and work/loading are concentrated on lower limb's muscles. This might be due to the bending and throwing postures while the workers reaching the raw materials in the lower position and throwing the finished products into finished products' bucket as depicted in Figure 3 and Figure 5 respectively. However, after the implementation of ergonomic workstation design, both workers had experienced drastic reduction of work/loading exerted on their lower limb's muscles. An adjustable table and rotated sit-stand stool had enabled the workers to pick and throw the materials/products without bending their bodies.

Table 1: Results of Amount Work/Loading Exerted on Workers' Muscles

Worker	Deltoid Medial part (L) μVs	Deltoid Medial part (R) μVs	Trapezius (L) μVs	Trapezius (R) μVs	Erector Spinae (L) μVs	Erector Spinae (R) μVs	Gastroc-nemius (L) μVs	Gastroc-nemius (L) μVs
1	49518	44941	85453	84715	90676	184665	47977	72320
	24908	81374	170447	113612	22231	19763	4350	7530
2	35341	29785	33452	23273	46649	59518	37546	31424
	46665	48817	12632	149759	12484	20137	4450	6983

Existing Workstation (light shading) — Improved Workstation (dark shading)

Figure 7 through Figure 9 show a comparison of results of muscles activity measurement associated with work/loading analysis for the two workers. Figure 7 shows that the work/loading on lower limb's muscles of the first worker was decreased drastically due to implementation of improved workstation design. However the work/loading exerted on upper limb's muscles was slightly increased. In general, the improved workstation design had able to reduce the work/loading by 31 %, from 660266 μVs to 452750 μVs (Figure 7).

As depicted in Figure 8, the second worker experienced similar reduction of work/loading exertion on lower limb's muscles due to implementation of improved workstation design. However, the work/loading on upper limb's muscles especially on both left and right trapezius muscles showed drastic increment. Overall, the total of work/loading of

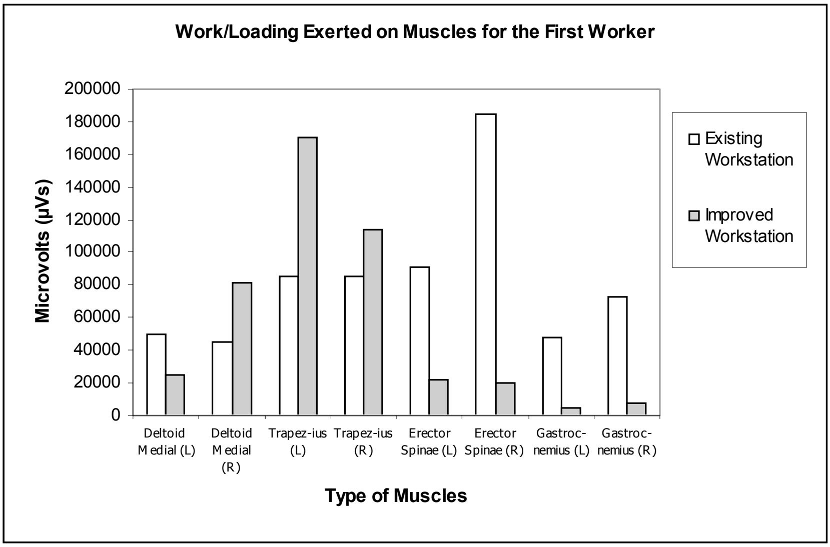

Figure 7: Comparison Result of Work/Loading Exerted on Muscles for the First Worker

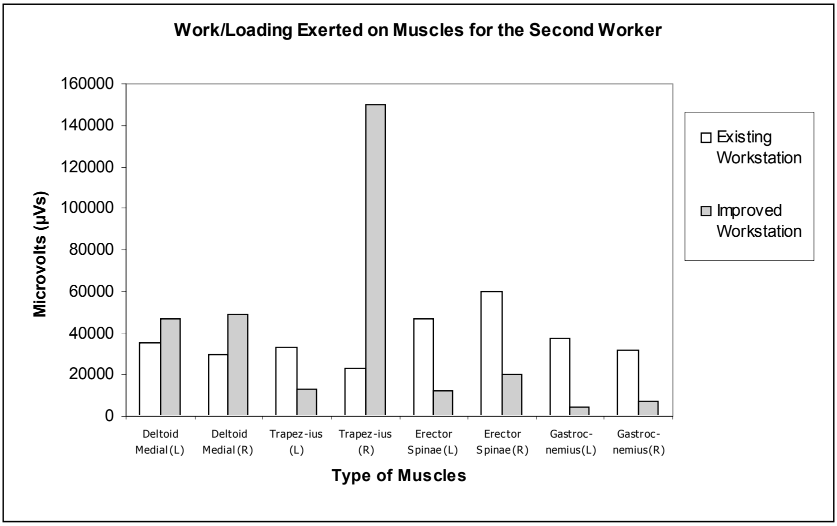

Figure 8: Comparison Result of Total Work/Loading Exerted on Muscles for the First Worker

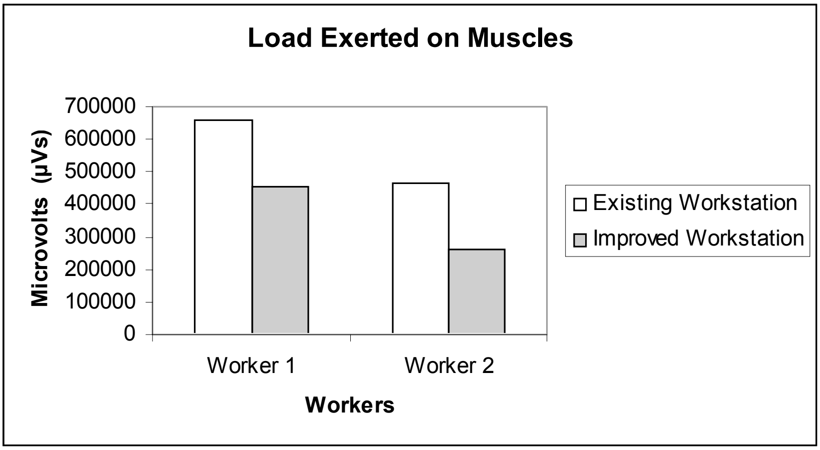

Figure 9: Comparison Result of Work/Loading Exerted on Muscles for Both Workers

second worker was reduced by 43 % from 463076 µVs to 263659 µVs (Figure 9). From the comparison results of muscle activity measurement, it can be seen that the improved workstation design offers a potential solution to improve muscles activity of stamping machine operators.

Conclusion

This paper presents the effect of ergonomic intervention to reduce discomfort experienced by machine operators while performing stamping operation in a SMI in Shah Alam. SEMG technique was used to analyze work/loading exerted by the workers' muscles for before and after the ergonomic intervention. This analysis is performed using A ME3000 P4 instrument together with MegaWin Software. The ergonomically designed workstation is capable of reducing the total muscle work/load by about 43 % if they are properly utilized. Figure 6 shows the ergonomically designed workstation. This design approach can be adopted to improve the working conditions of industrial workers and thus reduce the risk of occupational injuries such as back pain and musculoskeletal injuries.

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