Ergonomics Risk Factors at Manufacturing Industry: A Prelude Study

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Abstract- **Manufacturing industry has been recognized as a vital contributor to nation economy as it offers enormous job opportunities to local and foreign workers. In recognition the importance of manufacturing industry, workplaces should be designed ergonomically so that workers could perform jobs in a healthy working environment. The objectives of the current study are to identify ergonomics risk factors present in the workplaces and propose a solution to minimize the risk of occupational injuries. The objectives were achieved through an ergonomics survey conducted in a metal stamping company that utilized questionnaire and video recording to reveal the real situation. Based on the survey, there were evident that workers have been exposed to ergonomics risk factors associated with awkward working posture. Working posture assessment has been performed and redesign of workstation was proposed as a control measure to minimize occupational injuries associated with awkward working posture. The study concluded that the redesign of the workstation has shown a potential solution for a safe working posture.**

*Keywords- **Manufacturing industry, ergonomics risk factors, awkward posture, workstation design***

I. INTRODUCTION

The manufacturing industry contributes important roles to boost Malaysia's economy. In May 2009, the sales value of the manufacturing industry and the total employees engaged in this industry recorded RM 36.6 billion and 935,761 respectively [1]. The performance of manufacturing industry was propelled by growth in domestic and export-oriented of 11 sub-industries: electrical & electronics products, chemicals, transport equipment, wood products, iron & steel, processed food & beverages, rubber products, non-metallic mineral products, fabricated metal product, textiles & apparel, and machinery & equipment. The huge numbers of job employments and workplaces offered by the manufacturing industry indicate that the occupational health, safety and ergonomics are primary concern at the workplaces so that such industry remains competitive in global industrialization world.

Ergonomics risk factors (ERFs) are regarded as main sources to occupational injuries amongst industrial workers and they can be found in any industries. The ERFs refer to jobs and working environment that pose to the risk of injury to the workers. The most common ERFs have been discussed in the literatures include handling of heavy loads, performing jobs in awkward working postures, working in extreme temperatures (too cold or too hot), repetitive movements, exposed to vibration, static posture, and contact stress [2-4]. As the effects of the ERFs, workers may experienced various symptoms such as discomfort of neck, pains in the shoulder, upper/ lower back, elbow, hand, hip and knee, swelling and burns.

In addition, reference [5] estimated that manufacturing industry was one of the highest numbers of occupational injuries in Malaysia. Realizing the importance to minimize the ERFs to safe level, a prelude study was carried-out in a manufacturing company to identify ERFs present in the workplaces and perform ergonomic assessment to improve the working condition. In the workplaces, awkward working posture has been identified as the most critical ERFs and the workstation was redesigned to enable workers perform jobs in a safe working posture.

II. METHOD

The study was conducted in a metal stamping company situated in Shah Alam, Selangor. The main activities of the company are performing metal stamping operation, die maintenance, and making restoration of products when necessary. In general, the company consists of several workstations such stamping machines having capacities ranging from 300 tons to 1200 tons, workstations for die maintenance, a handwork section for product restoration, and few administration offices. The end products of the company are metal stamped parts for vehicle assembly which have various designs and geometries.

The study has applied two ergonomics assessment techniques namely questionnaire and video recording to identify the most critical ERFs present at the workplaces. Once the critical ERFs have been identified, it is being assessed and a control measure is proposed to minimize the risk of occupational injuries. In this study, the awkward working posture has been identified as the most critical ERFs and it needs immediate investigation and improvement. Fig. 1 demonstrates the processes involved in the study to identify, assess and minimize the ERFs at workstation. Each approach is elucidated in the following sections.

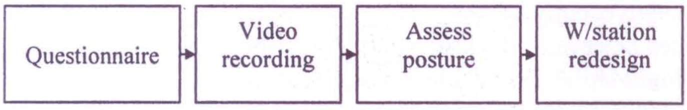

Fig. 1. The process flow involved in the study

A. Questionnaire

A set of questionnaire has been distributed among the production workers to obtain their personal details and usual activities that they perform in their workstations. A one-page questionnaire was developed and delivered among the workers to capture the required information. In the questionnaire, the following questions were addressed and the workers are required to answer all of them: employee number, age, gender, working experience, marital status, body mass, height, shoe size, physical disability, name of workstation, job description, working experience of doing the current job, working mode either shift or normal working hours, and various working conditions and activities that they have performed during works such as prolonged standing, standing with side bending, standing and walking frequently, prolonged sitting, prolonged bending, standing on the vibrated area, straight standing, static standing, standing and walking rarely, reaching goods, prolonged kneeling, sitting on the vibrated area, standing with forward bending, standing with body twisted, standing and sitting intermittently, lifting heavy goods, squatting, and handling imbalance goods. These details are provided with check boxes so that the workers could select the appropriate box(es).

The questionnaire form was filled by the workers during their morning and evening breaks. Furthermore, the researchers monitored the answering session so that the workers could ask any unclear questions. To appreciate their participation, all respondents were given a token of appreciation.

B. Workplace survey and video recording

The main purpose of workplace survey and video recording is to identify the present of various ERFs in the workstations. In addition, this approach allowed researchers to classify the safe and improper workstation designs. The safe workstation will be maintained meanwhile, ergonomic intervention will be proposed to improper workstation to establish a harmonious and conducive working environment.

A video camcorder was used to record the work activities and working conditions such as working posture of workers at their existing workstation. The advantage of using video recording technique is that the recorded actions could be paused or replayed so that any work activities and working conditions such as body posture or workstation layout can be examined. Moreover, any missing information can be retrieved at any time when necessary.

C. Working posture assessment

The Rapid Upper Limb Assessment (RULA) [6] available in CATIA software was applied to assess working posture of workers while they performing jobs in their workstation. The outputs of RULA will be in the form of scores and action levels for the assessed postures. "Action Level 1" indicates that the current posture is acceptable if it is not maintained or repeated for long periods. "Action Level 2" indicates that further investigation is needed and changes may be required. "Action Level 3" indicates that investigation and changes are required soon. "Action Level 4" indicates that investigation and changes are required immediately. TABLE 1 describes the scores and action levels in RULA method.

TABLE 1
DESCRIPTION OF RULA SCORE AND ACTION LEVEL

Score	Action Level	Description
1 or 2	1	The posture is acceptable if it is not maintained or repeated for long periods
3 or 4	2	The posture needs further investigation and changes may be required
5 or 6	3	The posture needs investigation and changes are required soon
7	4	The posture needs investigation and changes immediately

To perform RULA analysis, any inputs related to physical of workers and working conditions need to be considered. It includes the body dimensions (anthropometry) of workers and information on working postures such as angles of upper arm, wrist, lower arm, neck and trunk, legs condition; modes of posture either static, intermittent, or repeated; the shoulders and arms either supported or unsupported; the arms working across body midline; and the body position whether balanced or unbalanced. All information were observed, measured, recorded and keyed in to determine the postural loads of assessed worker.

Since the working posture of a worker is directly determined by the relationship of the body parts orientation and the workstation [7], the study focused on analyzing and redesigning the workstation to improve working posture. The study comprises two stages of working posture assessment. The first stage of assessment was carried-out at existing workstation. On the other hand, the second stage assessment was performed when ergonomic intervention has been proposed to the workstation. To reduce cost and time saving, the proposed ergonomic intervention was evaluated through computer simulation. Finally, the effectiveness of the proposed ergonomic intervention was determined by comparing the results from both stages of assessment.

D. *Working posture assessment at existing workstation*

A workstation at the end of stamping production line was selected as a case study. Through video recording, this workstation required workers perform jobs in awkward working posture, thus further investigation should be made immediately. In the workstation, a worker was assigned to collect the stamped parts from an incoming conveyor and arrange them in a cage. To perform this job, four working postures have been adopted: 1) 20° to 40° torso flexion while reaching the products from the incoming conveyor, 2) ~180° body rotation to transfer the products to a cage, 3) 20° to 30° torso flexion while attempting to load the products into the cage, 4) more than 90° torso flexion to arrange the products in the cage. All the postures adopted are demonstrated through Fig. 2 to Fig. 3. The worker has to perform the job manually with job cycle is more than four times per minute.

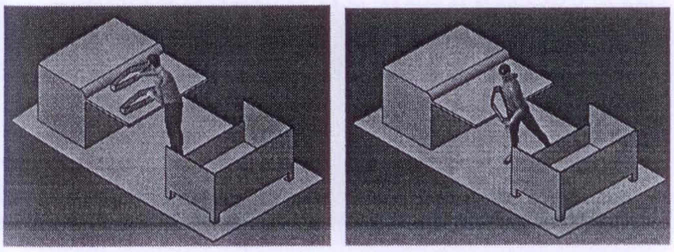

Fig. 2. Working posture of worker while he reaching the products from the incoming conveyor (left) and transferring them to a cage (right)

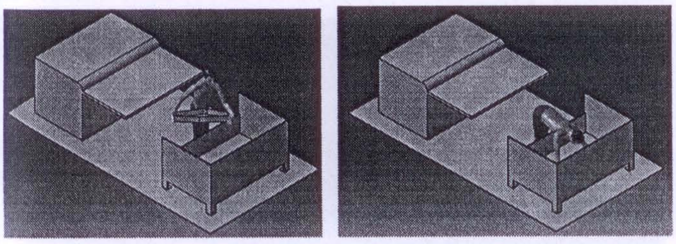

Fig. 3. Working posture of worker while he manage to put the products into the cage (left) and arrange them properly (right)

E. *Working posture assessment at redesigned workstation*

The existing workstation was redesigned after RULA analysis has been performed. The outcomes of the RULA analysis gave information on which body orientations need immediate improvement. This information enables the researchers to propose appropriate control measures to improve working posture. Once the existing workstation has been redesigned, the RULA analysis was performed again to determine the effects of new design of workstation to worker's posture. To validate the effectiveness of redesigned workstation, a comparison of RULA score between the existing and redesigned workstations is carried-out.

III. Results and Discussion

A. *Outcomes from questionnaire survey*

Thirty three male production workers were participated in the questionnaire survey. Information on the workers' details such as age, working experience, body mass, height, and working experience for the current job are tabulated in TABLE 2. Other captured information includes shoe size (mean = 7, SD = 1). Almost half of workers perform their jobs at the stamping process production lines, while the remaining workers perform their jobs at maintenance workstation. The company runs its production using three modes of working shift namely normal, morning, and evening. Out of 33 workers, 19 workers work in shift basis while the rests work from 8.00 am to 5.00 pm. In terms of working conditions and activities, 90% of workers perform their work in prolonged standing, 78% involved in heavy lifting, performing jobs in forward bending counted 19 workers, and sitting on the vibrated area was very minimum (3%).

TABLE 2
Workers Age (years), Working Experience (years), Body Mass (kg), Height (m), Working Experience of Current Job (years)

Age		Work exp.		Body mass		Height		Current exp.	
mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
28	7.9	9	6.6	62.5	13	1.68	0.06	4	5.8

SD = Standard Deviation

B. *Outcomes from workplace survey and video recording*

Numerous ERFs have been identified through workplace survey and video recordings, among them are discussed as follow:

i. Awkward working posture

In ergonomics, some postures are considered to be a serious factor for discomfort, reduced efficiency and occupational injuries [8-9]. It has been discussed in the recent literature, there is an association between awkward working posture and occupational injuries [9]. Awkward posture means performing jobs with various parts of the body in bent, extended or flexed positions rather than in a straight or neutral position. In other words, the posture of the workers' body deviates significantly from the neutral position. When a worker performs jobs in an awkward working posture, he needs to apply more effort compared to neutral position, thus increase concentration in his muscles. This condition leads to discomfort such as muscle fatigue and lower back pain. Fig. 4 depicts workers arrange products from the conveyor into cages. The jobs require workers to perform them in forward bending posture. As an effect, this unsafe posture may lead to lower back pain if it is practiced in long periods.

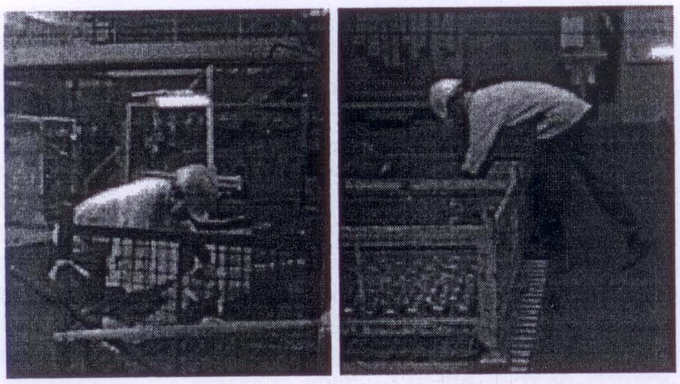

Fig. 4. Workers perform the jobs in awkward working posture

ii. Vibration

In occupational ergonomics, vibration exposure has been hypothesized as a risk factor for muscle fatigue among industrial workers. As a consequence of the vibration, workers may feel fatigue or light stress when they are exposed continuously in their working hours. Many studies have proved vibration is a risk factor for occupational injuries such as muscular fatigue and increased the risk of lower back pain [10-13]. This study revealed that majority of the workers have exposed to Hand-Arm Vibration (HAV) associated with vibrating hand tools when they used a hand held grinder to remove excessive materials on the product surface. Furthermore, workers who performed metal stamping operation had exposed to mechanical vibration due to high impact between plunger of stamping machine and die. The cyclic loading transfers its vibration to workers' body through the machine foundation and causing Whole-Body Vibration (WBV) exposure. Both HAV and WBV exposures may result to blood circulatory problem in long term. Fig. 5 illustrates workers exposed to HAV and WBV due to hand grinding and metal stamping processes.

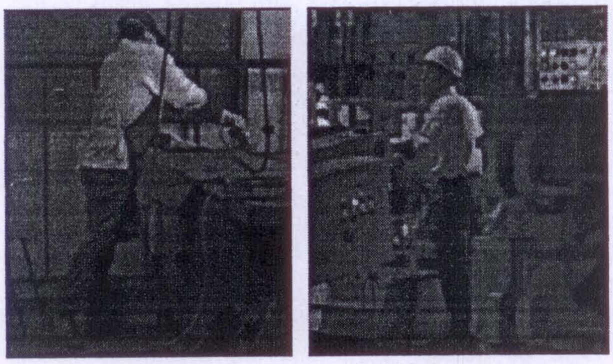

Fig. 5. The workers are exposed to HAV (left) and WBV (right)

iii. Contact stress

Contact stress can be found from a repeated contact between soft tissue in the stomach area and hard surface of workstation. This is clearly shown in Fig. 6 when a worker needs to reach stamped parts on the workstation platform. Once he grasped the parts, his body touches a hard platform of the workstation. The contact between worker and platform has created localized pressure over a small area of the stomach that could inhibit blood flow.

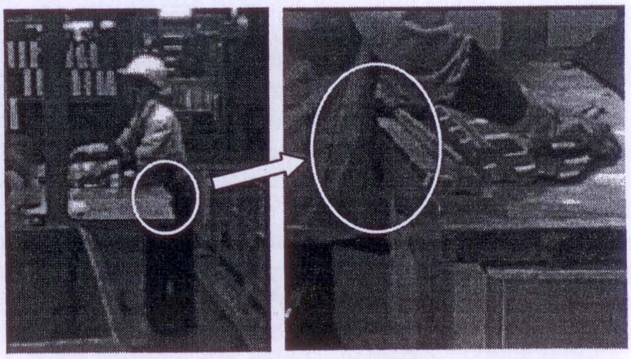

Fig. 6. Contact stress between worker's stomach and workstation platform

Based on workplace survey using video recording, it can be observed that the workstation at the end of stamping production line required workers to perform job in awkward posture. The researches performed further investigation to this kind of ERFs as it is expected to be unsafe to the workers.

C. Outcomes of working posture assessment at existing workstation

TABLE 3 shows results of working posture assessment while a worker perform jobs at the existing workstation design. The analysis highlighted four working postures: 1) torso flexion while reaching the products, 2) ~180° rotates the body to transfer the products, 3) torso flexion while attempting to load the products into the cage, 4) torso flexion during arranging the products. The RULA analysis is performed based on 5th, 50th and 95th percentiles of population. Based on the RULA analysis, all the assessed postures obtained unsafe condition and required immediate improvements. Details of the RULA analysis found that several body parts such as upper arms, wrists, lower arms, neck, trunk and legs were affected due to the posture. In other words, these body parts experienced postural stress and required immediate improvement.

TABLE 3

RESULT OF WORKING POSTURE ASSESSMENT AT EXISTING WORKSTATION

Working postures	Percentiles	RULA Score	Affected body parts
Torso flexion (reaching)	5^{th}	7	Upper arm, wrist, lower arm, neck, trunk, leg.
	50^{th}	7	
	95^{th}	7	
~180° body rotation	5^{th}	7	Wrist, lower arm, neck, trunk, leg
	50^{th}	7	
	95^{th}	7	
Torso flexion (loading)	5^{th}	7	Wrist, lower arm, neck, trunk, leg.
	50^{th}	7	
	95^{th}	7	
Torso flexion (arranging)	5^{th}	7	Wrist, lower arm, neck, trunk, leg.
	50^{th}	7	
	95^{th}	7	

D. *Outcomes of working posture assessment at redesigned workstation*

Following control measures have been proposed in the new design of workstation to improve working posture. 1) The platform of workstation was redesigned to be adjustable in term of its width and height. The platform is fitted with two sets of lead screw. A lever was provided to activate the lead screws so that the width of the platform could be adjusted corresponding to the products sizes. Besides, the height of platform also can be adjusted to accommodate the height of workers. The benefit of this intervention is that the posture while reaching the products from the incoming conveyor can be adopted neutrally. 2) Furthermore, the cage is suggested to be equipped with a lifting mechanism and its location has been relocated closely to worker's side. The proposed lifting mechanism allows the workers to adjust the height of cage with regards to an appropriate working level. This modification eliminated body rotation and extreme flexion while the worker transferring and arranging products in the cage. Fig. 7 through Fig. 8 present the redesigned workstation.

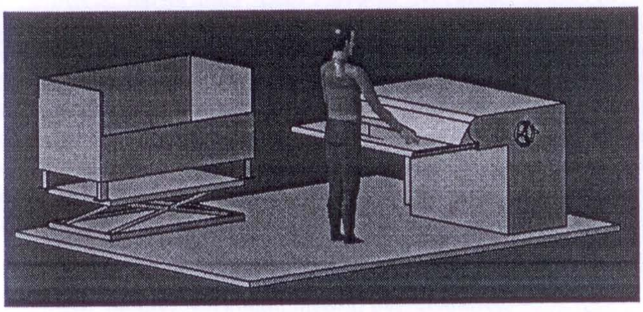

Fig. 7. The platform is fitted with a lever to adjust its height and width

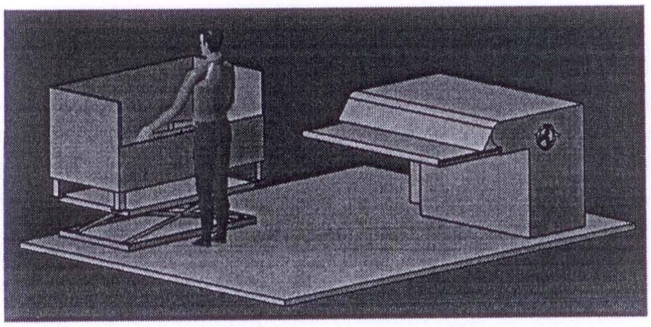

Fig. 8. The cage is equipped with a lifting mechanism to accommodate worker's height. This facility allows the worker to load and arrange the parts in neutral working posture

Results of RULA score in TABLE 4 summarized the impacts of redesigned workstation on working posture. The working postures were improved as the workstation has been redesigned. Based on the RULA analysis, it is clearly shows that the torso flexion while reaching the products has been improved to RULA score of 5 for all population percentiles. Besides, the posture during loading the product into the cage (torso flexion) also obtained an improvement as indicated by RULA score of 5. Based on the RULA definition, these postures still required improvement soon [6]. The study found that the repeat frequency of the posture has influenced the RULA score. It is expected that the posture will be more safe if the repeat frequency is controlled to be less than four times per minute.

TABLE 4
RESULT OF WORKING POSTURE ASSESSMENT AT REDESIGNED WORKSTATION

Working postures	Percentiles	RULA Score	Improvement remarks
Torso flexion (reaching)	5^{th}	5	Repeat frequency > 4 times/ minute.
	50^{th}	5	
	95^{th}	5	
Torso flexion (arranging)	5^{th}	5	Repeat frequency > 4 times/ minute.
	50^{th}	5	
	95^{th}	5	

Comparison results of RULA score in TABLE 5 proved the effectiveness of the redesigned workstation in improving working posture. The existing workstation required workers to perform jobs in an awkward working posture as indicated by RULA score of 7 for all cycle working postures and population percentiles. In contrast, the redesigned workstation has promoted safe working postures as shown by RULA score of 5 while reaching the products from the incoming conveyors and torso flexion during loading and arranging the products in the cage. Interestingly, both unsafe working posture body rotation and extreme flexion have been eliminated and thus reduce the cycle time to perform the jobs.

TABLE 5
COMPARISON OF RULA SCORE BETWEEN EXISTING AND REDESIGNED WORKSTATIONS

Working postures	Percentile	Existing workstation	Redesigned workstation
Torso flexion (reaching)	5^{th}	7	5
	50^{th}	7	5
	95^{th}	7	5
~180° body rotation	5^{th}	7	The posture has been eliminated
	50^{th}	7	
	95^{th}	7	
Torso flexion (loading)	5^{th}	7	5
	50^{th}	7	5
	95^{th}	7	5
Torso flexion (arranging)	5^{th}	7	The posture has been eliminated
	50^{th}	7	
	95^{th}	7	

IV. CONCLUSION

Identification of ERFs in the workplaces has been carried out and the ergonomic intervention has been proposed. Major findings of the current study can be summarized as follows:

i. Through workplace survey and video recordings, ERFs associated with awkward working posture, vibration exposure and contact stress have been identified as potential threats for occupational injuries in the company;
ii. The authors have conducted two stages of working posture assessment - at existing workstation and redesigned workstation. The existing workstation was found to be unsafe as it required workers to perform jobs in an awkward working posture. Modifications on the platform and cage designs have been proposed to the existing

workstation. Comparison results of RULA analysis revealed that the redesigned workstation has offered an effective solution to improve working posture. Furthermore, the redesigned workstation also able to improve work efficiency.

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