Utilization of Participatory Ergonomics for Workstation Evaluation Towards Productive Manufacturing

Anna Liza C. Nacion, Alma L. Tangcuangco

Abstract*: Principles of workstation configuration decrease work environment ergonomic hazards and improve worker's productivity. The participatory ergonomics approach is one of the best methods for eliminating or upgrading manual tasks with the aim of reducing the occurrence of related occupational musculoskeletal issue. This study assesses the workstation of a foundry shop in terms of musculoskeletal occurrences and ergonomic hazards employing Ergonomic Symptom Survey, Illumination Measurement, Noise Measurement, and Postural Analysis using REBA and RULA. The molding area average lux reading of 97.12 was far below the recommended light levels set by the DOE. The production area produces unbearable noises. REBA and RULA results reveal that activities in the foundry shop are very risky and need immediate investigation and changes. In general, the workstation is not properly layout. Improvement of material handling equipment such as the use of trolleys, rolling shelves or belt conveyors lessen the transfer time from one process to another leading to reduction of the current production time. In most cases, maintaining health and safety practices provides a much better way for the production performance of the foundry shop as well as its workers.

***Keywords*: Musculoskeletal Disorder, Workstation Evaluation, Participatory Ergonomics, REBA, RULA**

I. INTRODUCTION

Ergonomic issues at the workplace and horrendous affiliation are a bit of the contributing risk factors to word related security and restorative issues. Different conditions inside the workplace are speculated to add to the extending enormity of musculoskeletal disorders (MSDs) suffered by the workers, including postural stress from postponed sitting, standing, or ungraceful position; stereotyped and bleak endeavors inciting unending harm; peak over-load wounds to the vital or periphery skeleton; biological parts; and mental factors including mental nerves, work dissatisfaction, and complex social issues [1].

Ergonomics is frequently seen in a disentangled manner as it focuses mainly on the physical aspects of work; force, repetition rate and posture [2]. According to Dohrmann Consulting [3], ergonomics is the process of planning or arranging work environments, products and frameworks for the wellness of the individuals utilizing it. Workers profoundly presented to physical hazard factors at the work environment are bound to report manifestations of MSDs [1]. According to Burgess-Limerick [4], participatory ergonomics improves efficiency and decreases hazard to safety and wellbeing of an individual.

As stated by Middlesworth [5] there are five proven benefits of a strong workplace ergonomics process, these are: ergonomics reduces costs; improves productivity; improves quality; improves employee engagement; and creates a better safety culture. By planning a workstation to take into consideration great stance, less exertion, less movements and better statures and scopes, the workstation turns out to be more effective. Moreover, if workers do not experience weariness and distress during working hours, it can diminish absenteeism, improve confidence and increase worker involvement.

The rationale of this study is to evaluate the ergonomics risk factors present in the foundry shop associated with MSDs using Participatory Ergonomics approach.

II. METHODOLOGY

The following methods were employed in evaluating the workstation of the foundry shop.

A. *Ergonomic Symptom Survey*

In identifying parts of the workers' bodies that are experiencing increased level of discomfort resulting from poor job design, the Musculoskeletal Discomfort (MSD) form based on the Nordic Questionnaire [6] was employed. Moreover, this symptoms survey helps to find out when workers are experiencing not only discomfort but also pain, or developed disability that may be related to workplace activities.

B. *Illumination Measurement*

One of the fundamental ergonomic principles is to provide adequate lighting. Poor lighting is a common problem in the workplace that can affect worker's comfort level and performance. To assess the lighting, a light meter, infrared distance meter and lighting survey form were used. The illuminance reading was evaluated using the guideline of Department of Energy (DOE) [7].

Formula: Lighting Index = $\frac{Total\ Wattage}{area}$

C. *Noise Measurement*

Nowadays, occupational noise exposure is one of the most prevalent health concerns found in the workplace. Noise

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induced hearing loss is a common injury occurring in foundry work [8]. A sound level meter was used in finding the specific source of noise in a workplace. OSHA has a regulatory standard which has a criterion and threshold of 80 dBA – 90 dBA.

D. *Postural analysis*

Postural analyses tools used to evaluate work posture are Rapid Upper Limb Assessment (RULA) [9] and Rapid Entire Body Assessment (REBA). Ansari and Sheikh [10] conducted evaluation of work posture using RULA and REBA. Awkward postures used in the workplace may lead to work pain and injury [11]. The evaluation of the body posture was carried out using the REBA tool. The REBA is a postural analysis tool sensitive to musculoskeletal risks in a variety of tasks and assessment of working postures [12]. RULA, on the other hand, is a survey method developed for use in ergonomics investigations of workplaces where work-related upper limb disorders are reported [13]. Below represents the level of MSD Risk based from the generated score.

For REBA Results

Score	***Level of MSD Risk***	***Recommended Action***
1	Negligible risk	No action required
2 – 3	Low risk	Change may be needed
4 – 7	Medium risk	Further investigation, change soon
8 – 10	High risk	Investigate and implement change
Above 10	Very high risk	Implement change

For RULA Results

Score	***Level of MSD Risk***	***Recommended Action***
1 – 2	Negligible risk	No action required
3 – 4	Low risk	Change may be needed
5 – 6	Medium risk	Further investigation (change soon)
Above 6	Very high risk	Implement change now

E. *Workstation analysis*

Mali and Vyavahare [14] found out that ergonomic problem are major issues faced by the foundry industry, and that the workstation layout and work design were found to be affecting workers' efficiency most.

III. RESULTS AND DISCUSSION

A preliminary survey was carried on visits to and observation of a foundry shop workplaces during which problems relating to the working conditions of the workers were noticed.

Table 1. Profile of the Workers

Gender	All are male
Ave. Height (cm)	166.10
Ave. Weight (lb)	133.76

Twenty-one (21) out of the total 40 production workers were the respondents of the study. Table 1 and table 2 present the results of the survey. All the workers in the production area are male with an average height and weight of 166.10 cm and 133.76 lbs, respectively. The most claimed injury among the workers is the both wrist (80.96%), followed by both shoulders (71.43%). It should be noted also that all the molders experienced low back pain while all the kiln operators experienced upper back pain. Furthermore, four (4) of the workers claimed injuries in the knee.

Table 2. Distribution of Reported MSD

Job	N	S	E	W/H	UB	LB	T	k
Kiln Op	1	4	2	4	3	1	0	1
Molders	0	5	1	4	0	5	3	3
Lathe Man	4	3	2	4	2	3	2	3
Finishers	1	3	0	5	4	2	1	1
%	28.6	71.1	23.8	81.0	42.9	52.4	28.6	38.1

N-Neck; S-Shoulder; E-Elbow; W/H-Wrist/Hand; UB-Upper Back; LB-Lower Back; T-Torso; K-Knee

Based on the discomfort survey results, almost all the production workers claimed injuries in their body parts during their stay in the company. These results are indications that the workers have a great risk of having MSD.

ILLUMINATION

The shearing and molding areas are too dim (Figure 4). The lighting indexes in the shearing and molding area are 3.22W/m^2 and 2.38W/m^2, respectively. These data are below the maximum lighting power density. The minimum lux reading of 35 lux (corner) and the maximum lux reading was 348 lux (open area), on the average the measured lux was 97.12 lux which is far below the recommended light levels set by the DOE. As to the recommended design, illuminance level of lighting for working interiors in general offices is 300 – 750 lux (lumen/m^2).

Dimly lit workplace causes eye fatigue and put workers at a greater risk of getting injuries. The other source of light in this area that comes from the polycarbonate sheets mounted in the roof is from the overhead holes in the wall of the production area that serves as windows. However, these holes produce glare that causes headaches and also affects the eyesight of the workers.

Noise and Vibration

Table 3 shows the testing result of the sound level in the foundry shop. The results show that the shearing area (Ave. 112.73 dBA) is the main source of noise in the area followed by the kiln area (105.75 dBA).

Table 3. Sound Level Testing

Employee	Job	Average Sound Pressure level (dBA)
Employee 1	Kiln Operator	107.3
Employee 2	Kiln Operator	104.2
Employee 5	Molder	74.3
Employee 7	Molder	72.5
Employee 9	Molder	75.7
Employee 10	Lathe Man	113.2
Employee 12	Lathe Man	110.4
Employee 13	Lathe Man	114.6
Employee 16	Finisher	98.4
Employee 21	Finisher	86.7

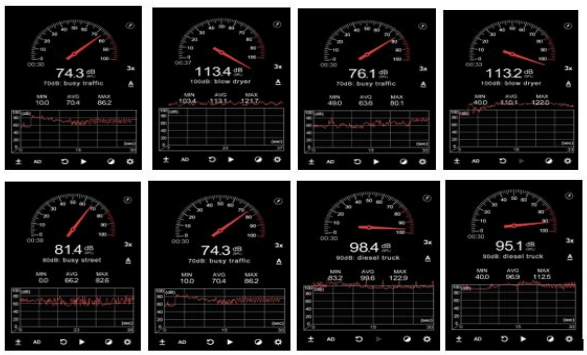

Figure 1 Sample Noise Testing

The noise inside the production area is unavoidable and also unbearable; this is due to the improper feeding of metals that are being transferred to the kiln and when the workers shear the molded pots. Moreover, the shearing process produces a very loud clatter that the office workers hear it even they are inside their working area.

Figure 2 Shearing Area affected by Noise and Vibration

Foundry workers are exposed to forceful exertions and vibration [15]. The shearing operator is exposed to hand-arm vibration. The lathe machine is used in the shearing process which rotates the metal pots and covers during which the operator trims the inside bottom and edges with the shearing blade. The hearing acuity of the worker might be threatened [16] because during this process the shearing operator is not wearing earplugs or any hearing protection.

Posture

During the preliminary information-gathering, awkward postures of workers were observed, as seen in Fig. 3. The activities performed by the manual molding workers require physical exertion especially when handling molds when they are being fashioned. In performing this repetitive activity, workers stand/sit in an awkward posture, which is a causal factor for fatigue [11] and higher rate of lower back pain. This corroborates the result of the MSD survey that all the workers assigned in the molding area had trouble in their lower back during the last 12 months.

Figure 3 Worker's Posture in the Molding Area

The shearing worker also exhibits an awkward posture of holding fixed grip during the process. Moreover, the worker exerts more force in performing this job (Fig. 4).

Figure 4 Worker's posture in the Shearing Area

The drilling worker also exhibits an awkward posture and at the same time the pot that is being drilled is being pressed to his knee during the process resulting to pressure points or local contact stress (Fig. 5).

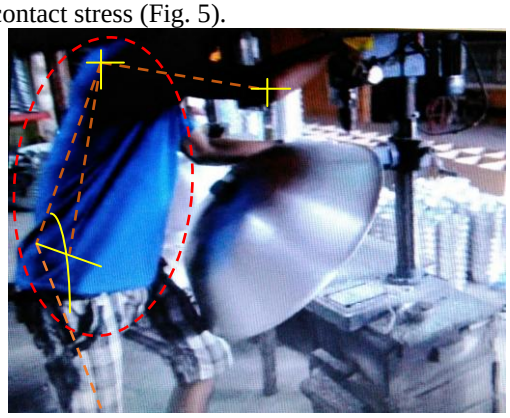

Figure 5 Worker's Posture in the Drilling Area

Based from the results of the REBA assessment of the workers in Fig. 3 and Fig. 5 the REBA Scores were 14 and 13, respectively, an indication that these were very high-risk positions. The RULA assessment of the worker in Fig. 4 is 7 with also a very high level of MSD risk.

Thus, the REBA and RULA employee assessment results reveal that the activities of the foundry workers are very risky and need immediate investigation and changes.

Workstation

The working environment of foundry is generally hazardous which leads to injuries of foundry workers [16] [17]. In the current layout of the Foundry Shop, backtracking is very visible. The aisle used in moving the scrap aluminum to the kiln is very narrow. When the kiln operator transfers the raw materials to the kiln using a wheel borrow, the aisle cannot be used by the other workers considering that this is the only way that connects the

molding area with the shearing area.

The molding area is divided into two areas; one for the pots and the other is for the pot covers. The molders have a hard time carrying the melted aluminum because they need to pass through the corners of the kiln that separates it to the molding area (Fig. 6). The storage area of the molded products is very far (approx. 45 meters) from the next process, this requires more time for the workers to transfer them in the shearing area. It is also worth considering the weight of the products (each approximately ranges from 0.3 kg to 7 kg).

Figure 6 Foundry Shop Material Handling

There is also an observed poor material handling in transferring the aluminum scrap to the kiln using only a wheel borrow. Another is the transfer of melted aluminum to the molding area using a dipper that is done manually.

Figure 7 Foundry Shop Material Handling

Safety measure is one of the most important aspects to be considered in a production system. The workers of the foundry shop do not have proper uniform and safety gears such as gloves (Fig. 7), face mask and ear piece to protect them from possible risks inside the workstation. Their skin was also exposed to health hazard such as skin lesions [18] because of scrap aluminum. Moreover, signages for safety instructions or warnings are not posted which could increase the occurrence of accidents inside the working area.

Figure 8 Foundry Shop Material Handling

Manual carrying of dangerous or hazardous materials is a major source of hazards and problems for industrial workers [19]. In the case of the Foundry Shop, this may affect not only the efficiency and effectiveness of the workers due to job strain [20] but also their health because of the risk in handling hot liquid such as melted aluminum (Fig. 8). This manual handling of materials will indeed cause the workers CTD's (Cumulative Trauma Disorders).

Furthermore, the production area of the Foundry Shop is not properly ventilated. It has no exhaust fan as well as windows that can allow fresh air to enter the production area. The temperature in the molding area is too hot (37ºC - 41ºC) due to heat radiated from the kiln where aluminum scraps are melted. To reduce the high temperature inside the production area, electric fans were provided for the workers.

Hedge [21] presented a clear association between office work performance and indoor environment conditions. Applying a temperature comfort zone (20ºC - 25ºC) to workplace will reduce energy consumption, cost, error by 44%, and saves in lost productivity.

IV. CONCLUSION AND RECOMMENDATION

Adverse ergonomic working conditions can cause visual, hearing and muscular strains for example eye strain, cerebral pains, exhaustion, MSDs such as chronic back, neck and shoulder torment, Cumulative Trauma Disorders (CTDs), Repetitive Strain Injuries (RSIs), and Repetitive Motion Injuries (RMIs). Furthermore, awkward working posture affects the productivity of workers and it is evident through the results of the REBA and RULA assessment that the activities of the foundry workers are very risky and need immediate investigation and changes.

Considering the weight of the products produced which are being transferred manually from one process to another, the transfer causes Cumulative Trauma Disorders. Improvement of material handling equipment is recommended such as trolleys, rolling shelves or belt conveyors. Having these materials will also lessen the transfer time from one process to another leading to reduction of the current production time.

To reduce the noise hazard in the foundry shop, it is recommended to have all workers be fitted with proper hearing protection to lower their exposure limits. Give more attention to the shearing operators and kiln operators. Another recommendation is to have an annual audiogram testing to verify that workers are not showing signs of hearing loss.

An exhaust ventilation system is recommended around

the furnace area of the foundry, specifically when aluminum is melted. This will also lessen the temperature inside the production area and will help circulate fresh air. Workers will feel more comfortable and can perform their jobs effectively and efficiently.

Illumination may increase by painting the wall of the production area with lighter color such as glossy white or light cream. This will also improve the temperature in the production area.

In general, maintaining health and safety practices will provide a much better way for the production performance of the foundry shop as well as the its workers. Furthermore, it will prevent and ultimately impede any progression of future hazards in the workplace if proper uniforms and protective gears will be provided.

For further study, variables such as worker's performance must be considered to show the effects of an ergonomically designed work station in the worker's productivity and efficiency.

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