DESIGN WORK STATION OF PIPE WELDING WITH ERGONOMIC APPROACH

Silvi Ariyanti¹, Lamto Widodo², Muhammad Zulkarnain³, Kevin Timotius²

¹Department of Industrial Engineering, University of Mercu Buana
Raya Meruya Selatan, Kembangan, Jakarta 11650, Indonesia
²Department of Industrial Engineering, University of Tarumanagara
Letjen. S. Parman, Grogol, Jakarta 11440, Indonesia
³Departement of Marine Engineering Technology, University Kuala Lumpur
Malaysian Institute of Marine Engineering Technology
Bandar Teknologi Maritim, Lumut, Perak, Malaysia
Email: silvi.ariyanti@mercubuana.ac.id, lamto-mesin@tarumanagara.ac.id,
m.zulkarnainn@unikl.edu.my

Abstract -- The activity of welding specimens on a big pipe that causes various problems for the body, in this activity the worker is at a risky position such as lifting a pipe weight 90 kg, lifting the specimen and welding the pipe with the specimen and the final process is to lower the pipe that has been connected. The purpose of this study is to design workstation by the principles of ergonomics to help reduce physical worker complaints. The research method in this study was the Nordic Body Map (NBM) questionnaire to determine complaints of musculoskeletal disorders (MSDs); the work posture was analyzed by the Rapid Entire Body Assessment (REBA) method. From the results of this study, it can be concluded that the welding work requires a tool in the form of a bench, pipe support, a pulley used at a new welding workstation. With a new workstation, poor work posture can be repaired. With a new work station, there is an efficiency of 8.33 minutes of work time from previous working conditions.

Keywords: Pipe Welding; MSDs; NBM; REBA

INTRODUCTION

The basic premise of ergonomics is that job demands should not exceed workers' capabilities and limitations to ensure that they would not be exposed to work stresses that can adversely affect safety and health as well as the company's productivity (Mansor et al., 2014; Jaffar et al., 2011). Working conditions assessment showed that the main ergonomic problems in the workshops studied originated from awkward working posture, improper workstation design, poorly designed hand tools and incorrect material handling (Nodooshan et al., 2016). The productivity of worker much depends upon the ergonomic design of workstations. Efficient ergonomics in workstation design shows better interaction between man-machine systems. A lot of research has been done on analyzing and improving ergonomics of workstation, facility layout, and tool design (Mali & Vyavahare, 2015).

The welding process is one of the mechanical processes to produce a product, and it requires the welder to stay in a static posture for a long period of time (Md Yusop et al., 2018). In welding operation, physical dimensions of the workstation are of significant influence from the viewpoint of production efficiency and operator's physical and mental well-being. The physical dimensions in the design of an industrial workstation are of significant importance for perspective of production efficiency and occupational health and safety (Brito et al., 2017). Rae & Esson (1995) stated some of the factors that require consideration when analyzing and designing the welding environment to include physical ability of the worker, weight of the gun, design tools, body mechanics during welding, type of protective equipment in use, workspace, and physical requirement of the job and position of the work. The types of work that is physical if done in ways that are not right, then slowly can cause complaints of muscular skeletons (musculoskeletal disorder). If this is not handled seriously, it can cause more severe consequences. Since a strong relationship exists between other occupational risk factors and work posture, there is a need to assess how they interact intending to raise productivity (Torik, 2017).
The activity of welding specimens on a big pipe that causes various problems for the body, including muscle pain in the neck, arms, waist, and legs. In this activity the worker is at a risky position such as lifting a pipe weighing 90 kg, lifting the specimen and welding the pipe with the specimen and the final process is to lower the pipe that has been connected. The following is an illustration of the pipe welding process carried out can be seen in Fig. 1.

![Figure 1. Illustration of Pipe Welding Process](image1)

Based on Fig. 1, it can be seen that the postures have risks that are quite dangerous for health, so this activity needs attention. Workers need a range of 75-90 minutes to complete welding one pipe, while the result of a bad position causes workers to need an additional resting interval of around 10-15 minutes. This condition takes a lot of time for additional breaks required by workers in addition to cracks that have been determined by the company. For the bad condition of the posture, workers do not apply their full efforts to their work, which results in lower productivity (Rahman et al., 2015). To optimize the workforce, what needs to be considered is the human aspect so that alternatives are needed, which include designing the layout of work equipment and work facilities that support workers so that they do their work regularly without causing significant fatigue (Husein, 2009). This work requires change work postures to be more secure and ergonomic. Therefore, the purpose of this study is to design workstation following the principles of ergonomics to help reduce physical worker complaints.

**METHOD**

The research was conducted at pipe welding workshop begins the body map questionnaire, a questionnaire Nordic Body Map (NBM) to determine the complaints of musculoskeletal disorders (MSDs) (Fajariani, Ardyanto & Basuki, 2013).

Then the work posture is analyzed by the Rapid Entire Body Assessment (REBA) method. The REBA method is recommended to verify the effectiveness of the changes (Lasota, 2014). After discovering the cause of the problem along with physical complaints, and then redesigned the welding workplace.

**RESULTS AND DISCUSSION**

The welding process starts with taking a pipe which is then lifted and placed into a tool, and then the worker receives the specimen to be lifted and also puts it on both sides of the pipe. The next step is to measure the pipe again to check whether it is per the specifications and small welding is done to connect the specimen with the pipe. After that, the pipe will be welded thoroughly and will be lowered and put into storage. The time needed for workers to complete one cycle of work ranges from 5220 seconds (87 minutes).

**Rapid Entire Body Assessment (REBA)**

REBA is a common tool used to facilitate the measurement and evaluation of the risks associated with working postures as a part of the ergonomic workload (Schwartz et al., 2019). Based on the photo of work posture, REBA analysis was carried out for each pipe welding work posture. For example, measurements using REBA on the work posture of taking a pipe can be seen in Fig. 2 and Fig. 3.
Physical Complaint Analysis of Welding Workers

Physical complaints analysis that can be considered work posture performed by workers. Musculoskeletal complaints are one of the most prevalent occupational problems (Andersen et al., 2007; Janwantanakul et al., 2008) and also contribute to an economic burden in terms of direct medical costs, loss of work productivity, work disability, absenteeism and presenteeism (loss of productivity while at work) (Bevan 2015; Buchbinder et al., 2013; CDC, 2013; Lambeek et al., 2011). The whole body parts analyzed, 11 were the highest physical complaints supported by officers from the NBM. The following are the parts of workers that can be seen in Table 1.

Complaints obtained from the NBM questionnaire were then investigated to produce workplace welding design characteristics as listed in Table 3.

Based on Analysis of Complaints, Expectations, Needs, and the Nordic body map questionnaire resulted in the design of the pipe welding work station, as shown in Fig. 4. For the bench design on the welding work station, it is adjusted to the worker anthropometric data, as shown in Fig. 5.
Table 1. REBA Results for All Work Posture on Pipe Welding Activities

| Activities                  | REBA Score | Risk level   | Analysis                                                                 |
|-----------------------------|------------|--------------|---------------------------------------------------------------------------|
| Taking a pipe               | 9          | High Risk    | There needs to be an investigation and implementation of change            |
| Lifting Pipe                | 5          | Medium Risk  | There needs to be further investigation and change as soon as possible     |
| Putting Pipe                | 6          | Medium Risk  | There needs to be further investigation and change as soon as possible     |
| Taking specimens            | 9          | High Risk    | There needs to be an investigation and implementation of changes           |
| Lifting Specimens           | 5          | Medium Risk  | There needs to be further investigation and change as soon as possible     |
| Putting specimens           | 8          | High Risk    | There needs to be an investigation and implementation of change            |
| Welding                     | 8          | High Risk    | There needs to be an investigation and implementation of change            |
| Rotating                    | 9          | High Risk    | There needs to be an investigation and implementation of change            |
| Taking finished goods       | 9          | High Risk    | There needs to be an investigation and implementation of change            |
| Lifting Finished Goods      | 7          | Medium Risk  | There needs to be further investigation and change as soon as possible     |
| Putting Objects             | 4          | Medium Risk  | Put Finished Goods Need further investigation and change as soon as possible|

Table 2. Analysis of Physical Complaints and their Causes

| Physical complaints                  | Analysis of the Causes of Complaints                                                                 |
|--------------------------------------|-----------------------------------------------------------------------------------------------------|
| Pain in the upper neck               | Complaints on the neck due to workers doing their work with a state of bowing down in a long enough |
| Pain in the right and left shoulder   | time when welding takes place, as evidenced by a bad REBA posture.                                 |
| Pain in the upper and lower waist    | Workers are in a bent position while doing the welding process for a long time causing the shoulder|
|                                      | to be in a bent position so that the shoulders get tired faster, as evidenced by the bad REBA posture.|
| Pain in the left and right thigh,    | Welding tools that have a position that is too low and the absence of a chair causes the worker    |
| the left and right knee, the left and right calf | to bend over a considerable time and cause the waist to be attracted, as evidenced by the bad  |
|                                      | REBA posture.                                                                                       |

Table 3. Analysis of Complaints, Expectations, Needs, and Design

| Complaint                                      | Expectation                              | Needs                                                                 | Design                                                                 |
|------------------------------------------------|------------------------------------------|----------------------------------------------------------------------|------------------------------------------------------------------------|
| Muscle pain in body parts such as the neck,    | Higher placement of workpieces so that   | The design of this tool is adapted to the anthropometry of workers   | Design a machine using a roller to help ease the rotating process     |
| shoulders, and waist due to poor work posture  | it can improve work posture and reduce   | so that the work posture becomes more ergonomic and reduces bending   |
|                                                | complaints of muscle pain                | posture                                                             |
| Muscle pain in body parts such as the waist,   | use a bench to support your body weight, | The design of the tool is adapted to the worker anthropometry to make |
| thighs, knees, and calves due to a squat work  | so worker don't squat                    | it more comfortable and complaints less                              |
| posture                                       |                                          | A work tool that helps reduce pipe lifting that is too heavy         |
| lifting a heavy pipe cause muscle injury       |                                          | Design of pipe lifting tools                                         |
| The process of turning heavy workpieces during | Workers can rotate workpieces during the | Design a machine using a roller to help ease the rotating process     |
| welding                                        | welding process easily                   |                                                                      |                                                                        |

S. Ariyanti et al., Redesign Work Station of Pipe Welding with Ergonomic Approach
| Activity               | Current Work Posture | REBA Score | Tool Design                  | Activity               | REBA Score |
|------------------------|----------------------|------------|------------------------------|------------------------|------------|
| Taking a pipe          |                      | 9          |                              | Hang a rope to lift    | 4          |
| Lifting Pipe           |                      | 5          |                              | Pull the pulley to     | 1          |
|                        |                      |            |                              | lift the specimen      |            |
| Put Pipe               |                      | 6          |                              | Put the pipe into the  | 3          |
|                        |                      |            |                              | aid                    |            |
| Lifting Specimens      |                      | 5          |                              | Put the specimens to   | 2          |
|                        |                      |            |                              | be welding             |            |
| Weld                   |                      | 8          |                              | Do welding             | 3          |
| Rotate                 |                      | 9          |                              | Rotate the specimen    | 3          |
Posture analysis work with the REBA method

The design of the selected welding work station is simulated using CATIA software. The results of the design simulation are compared with existing working conditions, and work posture assessments are carried out using the REBA method, as shown in Table 4.

The following is a bench; pipe support and work station of pipe welding that has been developed, as shown in Fig. 6, Fig. 7, and Fig. 8.
The time needed for workers to complete one work cycle using a new workstation is 4720 seconds (78.67 minutes) with a break time of 360 seconds per work cycle, this time is shorter than the previous work time of 5220 seconds (87 minutes). There is an efficiency of 8.33 minutes of work time. This condition means that a good work posture can reduce work fatigue and increase productivity.

CONCLUSION
Based on results founded of this study, it can be concluded that welding work requires tools such as benches, pipe supports, and pulleys used in new welding stations by adjusting the body posture of the worker. With a new welding workstation, poor working posture can be improved and can reduce the power in lifting pipes and specimens. By comparing the old work station with the new work station, there is a decrease in work time of 8.33 minutes, so that it can increase the number of products produced in one day.

REFERENCES
CDC, C. for D. C. and P. (2013). Workers’ compensation claims for musculoskeletal disorders among wholesale and retail trade industry workers--Ohio, 2005-2009. MMWR. Morbidity and Mortality Weekly Report. 

Andersen, J. H., Fallentin, N., Thomsen, J. F., & Mikkelsen, S. (2011). Risk factors for neck and upper extremity disorders among computers users and the effect of interventions: An overview of systematic reviews. PLOS ONE. http://doi.org/10.1371/journal.pone.0019691

Bevan, S. (2015). Economic impact of musculoskeletal disorders (MSDs) on work in Europe. Best Practice and Research: Clinical Rheumatology, 29(3), 355-373. http://doi.org/10.1016/j.berh.2015.08.002

Brito, M. F., Ramos, A. L., Carneiro, P., & Gonçalves, M. A. (2017). Ergonomic design intervention in a coating production area. In Occupational Safety and Hygiene V: The International Symposium on Occupational Safety and Hygiene (SHO 2017), Guimarães, Portugal (pp. 293-298). http://doi.org/10.1201/9781315164809-59

Buchbinder, R., Blyth, F. M., March, L. M., Brooks, P., Wooff, A. D., & Hoy, D. G. (2013). Placing the global burden of low back pain in context. Best Practice and Research: Clinical Rheumatology, 27(5), 575-589. http://doi.org/10.1016/j.berh.2013.10.007

Fajariani, R., Ardyanto, Y. D. W, & Basuki, H. N. (2013). The Influence of Individual Characteristics and Work Posture toward Musculoskeletal Disorders (MSDs) to the Inpatient Nurse in X Hospital Area of Surabaya. International Journal of Science and Research (IJSR), 4(5), 3232-3235.

Husein, A. S. (2009). Designing an Ergonomic Work System to Reduce Fatigue Levels. Jurnal Ilmiah Teknik Industri.

Jaffar, N., Abdul-Tharim, A. H., Mohd-Kamar, I. F., & Lop, N. S. (2011). A literature review of ergonomics risk factors in construction industry. Procedia Engineering, 20, 89-97. https://doi.org/10.1016/j.proeng.2011.11.142

Janwantanakul, P., Pensri, P., Jiamjarasrangsi, V., & Sinsongsook, T. (2008). Prevalence of self-reported musculoskeletal symptoms among office workers. Occupational Medicine, 58(6), 436-438. http://doi.org/10.1093/occmed/kqn072

Lambeek, L. C., Van Tulder, M. W., Swinkels, I. C. S., Koppes, L. L. J., Anema, J. R., & Van Mechelen, W. (2011). The trend in total cost of back pain in the Netherlands in the period 2002 to 2007. Spine, 36(13), 1050-1058. http://doi.org/10.1097/BRS.0b013e3181e70488

Lasota, A. M. (2014). A Reba-Based Analysis Of Packers Workload: A Case Study. Scientific Journal of Logistics, 10(1), 87-95.

Mali, S. C., & Vyawahare, R. T. (2015). An ergonomic evaluation of an industrial workstation: A review. International Journal of Current Engineering and Technology, 5(3), 1820-1826.

Mansor, M. R., Sapuan, S. M., Zainudin, E. S., Nuraini, A. A., & Hambali, A. (2014). Conceptual design of kenaf fiber polymer composite automotive parking brake lever using integrated TRIZ–Morphological Chart–Analytic Hierarchy Process method. Materials & Design (1980-2015), 54, 473-482. https://doi.org/10.1016/j.matdes.2013.08.064
Md Yusop, M. S., Mat, S., Ramli, F. R., Dullah, A. R., Khalil, S. N., & Case, K. (2018). Design of welding armrest based on ergonomics analysis: Case study at educational institution in Johor Bahru, Malaysia. *ARPN Journal of Engineering and Applied Sciences, 13*(1), 309-313.

Rahman, C. M. L., Uddin, S. M., Karim, M. A., & Ahmed, M. (2015). Evaluation of work postures - The associated risk analysis and the impact on labor productivity. *ARPN Journal of Engineering and Applied Sciences, 10*(6), 2542-2550.

Rae, J. & Easson, M. (1995). *Work, Health and Safety, An Inquiry into Occupational Health and Safety*. Industry Commission Report, 1, Melbourne, Australia.

Nodooshan, S., H., Koohi Booshehri, S., Daneshmandi, H., & Choobineh, A. R. (2016). Ergonomic workplace assessment in orthotic and prosthetic workshops. *Work, 55*(2), 463-470. https://doi.org/10.3233/WOR-162401

Schwartz, A. H., Albin, T. J., & Gerberich, S. G. (2019). Intra-rater and inter-rater reliability of the rapid entire body assessment (REBA) tool. *International Journal of Industrial Ergonomics, 71*, 111-116. https://doi.org/10.1016/j.ergon.2019.02.010

Torik, T. (2016). Postural Analysis of Motor Vehicles for Evaluation of Dimensions Parts are Sitting. *SINERGI, 20*(3), 223-228. http://doi.org/10.22441/sinergi.2016.3.008