UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **DESIGN OF SHIELDED METAL ARC WELDING (SMAW) WORKSTATION FOR SAFE POSTURE AND WELD QUALITY.**

SESI PENGAJIAN: **2014/15 Semester 2**

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Management) (Hons.). The member of the supervisory is as follow:

……

(Dr. Isa bin Halim)

DECLARATION

I hereby, declared this report entitled "Design of Shielded Metal Arc Welding (SMAW) for Safe Posture and Weld Quality" is the results of my own research except as cited in references.

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ABSTRAK

Di dalam industri pembuatan, proses kimpalan arka logam berperisai (SMAW) adalah aktiviti yang memerlukan ketelitian. Pengimpal perlu mengekalkan postur badan mereka di dalam tempoh yang lama untuk memastikan produk kimpalan di dalam kualiti yang baik. Walau bagaimanapun, para pengimpal terdedah kepada faktor-faktor risiko ergonomik seperti tempoh berdiri yang lama, tekanan haba, dan pergerakan berulang semasa melakukan proses SMAW. Tujuan kajian ini ialah untuk menerapkan kriteria ergonomik pada stesen kerja SMAW. Faktor-faktor ergonomik di stesen kerja SMAW yang mempengaruhi postur pengimpal dan kualiti kimpalan dikenal pasti melalui pemerhatian dan soal kaji selidik di antara 40 orang staf dan pelajar di UTeM. Kesan-kesan daripada faktor-faktor ergonomik ke atas postur pengimpal dan kualiti kimpalan dianalisa menggunakan analisis RULA dan Design of Experiment (DoE). Keperluan pengimpal dipindah masuk ke dalam keperluan teknikal menggunakan House of Quality (HOQ). Kaedah Pugh telah digunakan untuk memilih reka bentuk baru stesen kerja SMAW. Berdasarkan analisis RULA, stesen kerja SMAW yang sedia ada dan reka bentuk stesen kerja SMAW yang baru menyediakan postur kerja yang selamat. Manakala DoE telah mengoptimumkan reka bentuk stesen kerja SMAW yang baru yang akan meningkatkan kualiti kimpalan. Kajian ini membuat kesimpulan bahawa mengaplikasi ciri-ciri reka bentuk ergonomik di stesen kerja SMAW dengan postur kerja yang selamat kepada pengimpal dan memastikan kualiti kimpalan. Kajian ini mencadangkan sisatan lanjut terhadap kesan-kesan pencahayaan di stesen kerja SMAW untuk meningkatkan penglihatan pengimpal dan kualiti kimpalan.

ABSTRACT

In manufacturing industry, shielded metal arc welding (SMAW) process is a precise job that requires the welders to maintain their postures in a long period of time to ensure the welding product in a good quality. However, the welders are exposed to ergonomics risk factors such as prolonged standing, heat stress, and repetitive task during performing the SMAW process. In acknowledging the importance of these issues, the aim of this study is to apply ergonomics improvement on SMAW workstation. The ergonomics factors presented at SMAW workstation that influenced the welder's posture and weld quality were determined through observation and questionnaire survey among 40 staffs and students in UTeM. The effects of ergonomics factors on the welder's posture and weld quality were analysed by RULA analysis and Design of Experiment (DoE). The welders' requirements were transferred into technical requirements using House of Quality (HOQ). The Pugh method was used to select the new design of SMAW workstation. Based on the RULA analysis, the existing and the new design of SMAW workstation provide safe working posture. While DoE optimised the new design of SMAW workstation that can improve the weld quality. This study concluded that application of ergonomics design features in the SMAW workstation provides safe working posture to the welders and enhance the weld quality. This study suggests further investigation on effects of lighting in SMAW workstation to improve welder's visibility and weld quality.

DEDICATION

For my beloved family, lecturers and friends that always believe in me to complete this project and report.

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST ABBREVIATIONS, SYMBOLS AND NOMENCLATURES

AC	–	Alternate Current
ANOVA	–	Analysis of Variance
CATIA	–	Computer Aided Three-dimensional Interactive Application
cm	–	centimetre
CNC	–	Computer Numerical Control
CO_2	–	Carbon Dioxide
DC	–	Direct Current
DoE	–	Design of Experiment
EMG	–	Electromyography
ESW	–	Electro Slag Welding
FCAW	–	Flux-Cored Arc Welding
FKP	–	Faculty of Manufacturing Engineering
GMAW	–	Gas Metal Arc Welding
GTAW	–	Gas Tungsten Arc Welding
HOQ	–	House of Quality
MMA	–	Manual Metal Arc Welding
MSD	–	Muscular Disorder
OCT	–	Optical Coherence Tomography
QFD	–	Quality Function Deployment
RULA	–	Rapid Upper Limb Assessment
SAW	–	Submerged Arc Welding
SMAW	–	Shielded Metal Arc Welding
TIG	–	Tungsten Inert Gas
UTeM	–	Universiti Teknikal Malaysia Melaka
WLBD	–	Work-Related Back Disorder
WMSDs	–	Work-Related Musculoskeletal Disorder

CHAPTER 1
INTRODUCTION

This chapter introduces the background of the study, problem statements, objectives of the study, and scope of the study. The background of the study is focused on the principles of Shielded Metal Arc Welding (SMAW) process, and the ergonomics risk factors associated with SMAW process. The problem statements reveal the impacts of ergonomics risk factors to the welder of SMAW process. In the objectives, the intentions of the study are stated to improve the SMAW workstation. At the end of this chapter, the scope of study highlights the focus and limitation of the study.

1.1 Background of Study

The manufacturing processes are the steps where the raw materials are transformed into final products (Kalpakjian, 2009). The manufacturing processes are including casting, moulding, forming, joining and machining. In joining process, there are welding, brazing, soldering, adhesive bonding and mechanical joining.

Welding is the joining process that joins materials by causing conjoining. The work piece will be molten and a filler material will be added to form a pool of molten material that becomes a strong joint when the work piece cools. There are many

welding methods in manufacturing process, including shielded metal arc welding (SMAW), gas tungsten arc welding (GTAW), gas metal arc welding (GMAW), flux-cored arc welding (FCAW), submerged arc welding (SAW) and electro slag welding (ESW).

Basically the SMAW process uses electric current to strike an arc between the parent material and consumable electrode rod. The place or space to enable the welders to perform SMAW process is called SMAW workstation. In a SMAW workstation, it consists of a table, cables and clamps, torch and electrodes, and a conventional welding machine. In the design of SMAW workstation, the anthropometry of welders and their capabilities must be considered. Occupational injuries can occur if the welding task and the workstation exceed the capabilities of the welders. In certain cases, the ergonomics risk factors cannot be eliminated due to unavoided constraints. Therefore, the SMAW workstation design plays an important role to enhance occupational health of welders and the weld quality.

In the SMAW workstation, the welders are exposed to various ergonomics risk factors. The common ergonomics risk factors in the SMAW workstation are the static working position, heavy lifting, awkward body postures and heat stress. These ergonomics risk factors can lead to work-related musculoskeletal disorder (WMSDs). The WMSDs are injuries and illness that affect muscles, nerves, tendons, ligaments, blood vessels and bones (Jaffar *et al.*, 2011). As consequences of these ergonomics risk factors, the welders may experience low motivation, fatigue, stress and injuries. Consequently, if the welder is not in good condition to perform the tasks, the weld quality can be affected. The weld quality is poor when there is a defect on the welded area such as porosity, excessive spatter, incomplete fusion, lack of penetration, excessive penetration, burn through, waviness of bead and distortion (Kalpakjian, 2009). Figure 1.1 shows the examples of poor SMAW quality. Hence, a good SMAW workstation must have sufficient lighting, proper table height and surface, safe working position and arm rest.

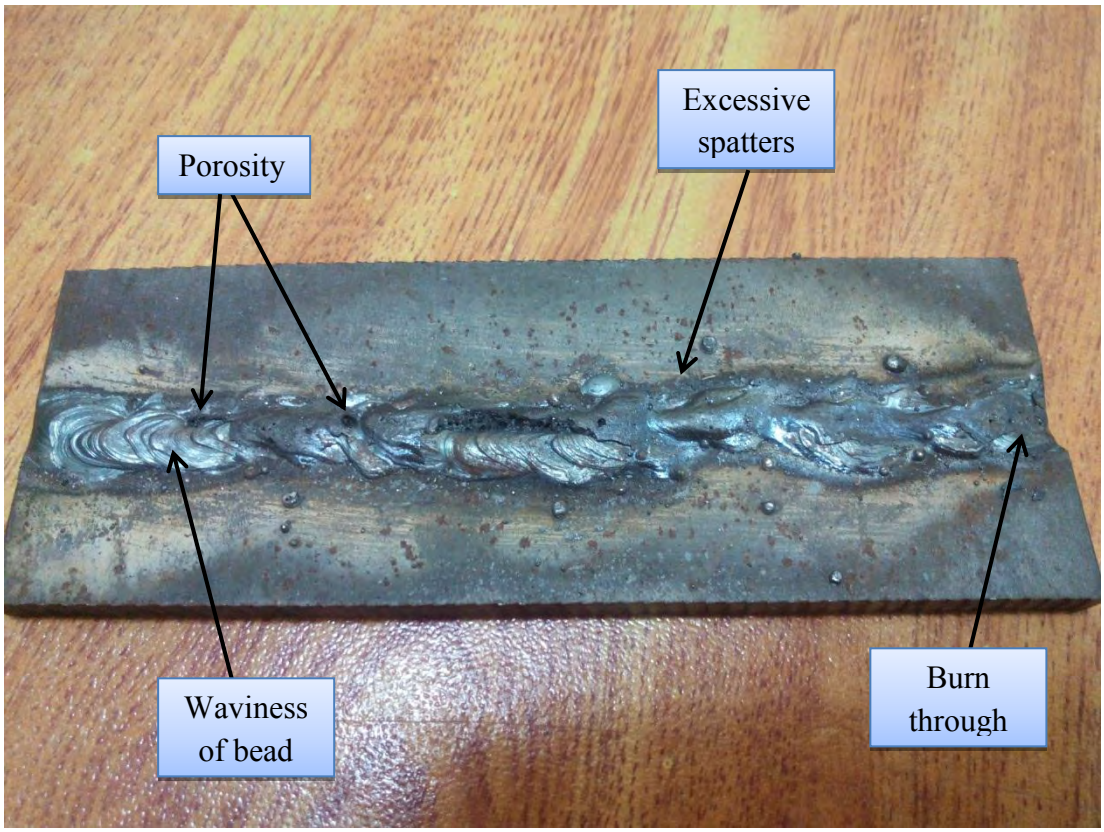

Figure 1.1: Poor welding quality in SMAW process.

Thus, the aim of this study is to design a SMAW workstation for safe work posture and improve the weld quality. Specific attention should be paid to working position, table height, table surface, lighting and arm rest.

1.2 Problem Statement

SMAW process is a precise task that requires the welders to maintain their postures to ensure the welding product in a good quality. The SMAW process may expose the welders to physical workplace risk factors. Most of the cases welding in the SMAW workstation requires the welders to adapt to the workstation, rather than adapting the workplace to welders. If the SMAW process is performed for relatively long periods of time, they can lead to fatigue, discomfort and injury to the welder. Figure 1.2 shows the welders perform the SMAW process in awkward working posture.

Figure 1.2: Welders perform the SMAW process in awkward postures.

The main physical workplace risk factors related to the development of WMSDs in welding tasks including awkward body postures, heavy lifting and static position. Figure 1.3 shows the causes and effects of the problem occurred, illustrated in Ishikawa Diagram.

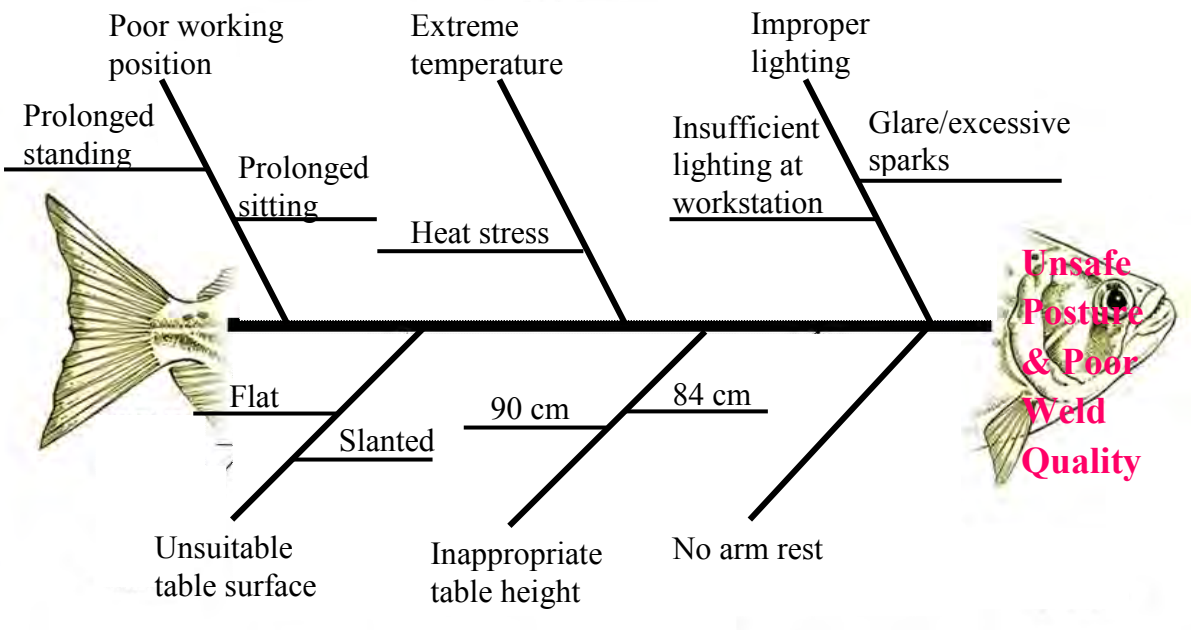

Figure 1.3: The causes and effects of the problem related to SMAW workstation.

The causes of unsafe posture of welders and poor weld quality can be summarized as follow:

a) Lighting

The welders need to wear a welding helmet with a fixed shade which remains darkened at all time. Even though the spark from the arc welding provides the illumination that can help welders vision under the helmet, however the weld quality is still cannot be maintained because they cannot examine the weldment and joint. A high level of lighting is necessary in order to make an inspection of the welding joint easy and efficient (Achten *et al.*, 2000). Consequently, the poor weld quality can be reduced.

b) Arm rest

Usually, the welder performs the arc welding without any support for their arm. A long time welding and repetitive task will make the arm feel fatigue (muscle fatigue). The arm rest is one of the supportive devices that invented to provide support welder's arm during SMAW process. Besides decreased the muscle fatigue of welder's arm, arm rest also can maintain the position of the welder's arm and improve the weld quality.

c) Table surface

Most of the table surfaces are designed as flat surfaces. However, Eastman and Kamon (1967) and Bridger (1988) found that slant surface improves body posture, involve less trunk movement, require less bending of the neck, and produce less worker fatigue and discomfort. However, according to Wickens *et al.* (2004), a slanted surface is suitable for reading tasks and a flat surface suitable for writing. Thus, an investigation of the table surface factor is highlighted in the study.

d) Working position

Prolonged standing is a stressful posture that puts excessive load on the body and may lead to body fluid accumulation in the legs. Meanwhile, prolonged sitting can be harmful to the lower back. (Wicken *et al.*, 2004). The best

working position to perform SMAW process is alternating the position such as sitting and standing.

e) Table height

The SMAW process is a coarse work that requires suitable table height to ensure the weld quality and the welders can practice a safe working posture. The available table height at SMAW workstation is 84 cm. A previous study suggested that a suitable table height is 75 – 90 cm for men and 70 – 85 cm for women (Wicken *et al.*, 2004).

f) Extreme temperature

Welders who are performing SMAW process are exposed to heat stress. Exposure to extreme heat can result in occupational illnesses and injuries. Heat stress can result in heat stroke, heat exhaustion, heat cramps, or heat rashes.

Hence, the purpose of the study is to provide safe posture in SMAW process and improve weld quality by eliminating the discussed risk factors.

1.3 Objectives

The objectives of this study are:

(a) To determine the ergonomics factors of workstation that influenced the posture of the welder and weld quality in SMAW process.
(b) To analyse the effects of the ergonomics factors on the welder's posture and weld quality.
(c) To propose a design of workstation for SMAW process to improve work posture and weld quality.

1.4 Scope of Study

This study applies ergonomics improvement on a SMAW workstation at the Faculty of Manufacturing Engineering (FKP) laboratory, Universiti Teknikal Malaysia Melaka (UTeM). As opposed to previous studies, the current study does not investigate the effects of welding parameters such as current, electrode size and work piece materials to posture and weld quality.

However, the study is limited to the analysis and design process for a SMAW workstation by using computer aided design, such as CATIA software. There is no fabrication of the workstation during the study. Moreover, only three parameters are study due to the time constraint. There are table height, table surface and working position. In this study, only butt joint welding is studied.

CHAPTER 2
LITERATURE REVIEW

This chapter continues with the literature reviews that provide information related to objectives of this study. This chapter covers the following subjects: determine the ergonomics factors that influenced the posture of the welder and weld quality in SMAW process; analyse the effect of ergonomic factors on the welder's posture and weld quality; and redesign the SMAW workstation. The information was obtained from the books, online journals, relevant articles and reference text.

2.1 The Ergonomic Factors that Influenced Posture of the Welder and Weld Quality in SMAW Process

2.1.1 Ergonomics Risk Factors

Ergonomics is a combination of the words ergo, a Greek word meaning "work" and nomics means "study". Thus, ergonomics is the study of work (Te-Hsin & Kleiner, 2001). Ergonomics is a broad science with a wide variety of working conditions that can affect worker's comfort and health.

Meanwhile, risk factors are defined as actions or conditions that can increase the injury to the musculoskeletal system (Bongers *et al.*, 2002). There are three categories of risk factors; biomechanical exposures, psychosocial stressors and individual risk factors. Biomechanical exposures related due to the poor design of workstation that caused repetitive motion, high forces and deviations from neutral

body alignments. Whereas psychosocial stressors at work include factors such as workplace stress, social support, job control, and time pressure. Meanwhile, individual risk factors are state of health, fitness and casual addictions.

Ergonomics risk factors are situations that happened on purpose or accident that could contribute to results that disregard or against the principles or philosophy of ergonomics that could or might harmful to the health of workers or users at work or after work (Jaffar *et al.*, 2011). Thus, understanding and awareness on the negative aspects of ergonomics risk factors are essential for countermeasures the negative effect before the solution of the problems can be found. There are eight commons of ergonomics risk factors that happens in workstation which are awkward body posture, contact stress, vibration, force, repetition, extreme temperature, noise and lighting or vision. Some of the ergonomics risk factors can lead to the WMSDs while some of it can affect the health of workers.

Awkward body posture happens when workers are exposed to extreme awkward postures where the positions of their shoulders, elbows or back deviate significantly from more neutral positions as shown in Figure 2.1. Repeatedly performing tasks in such positions poses increased stress on the joints or spinal discs. The other aspect that contributes to WMSDs is holding the neck and the shoulders in a fixed position. During performing any controlled movement with the arm, muscles in the shoulder and the neck contract and stay contracted for as long as the task requires. While contact stress is the injury by hard, sharp objects, equipment or instruments when grasping, balancing or manipulating. Contact stresses are encountered when working with forearms or wrists against the edge of a desk or work counter as illustrated in Figure 2.2. The contracted muscles squeeze the blood vessels, which restricts the flow of blood all the way down to the working muscles of the hand.

Figure 2.1: Awkward posture

Figure 2.2: Contact stress

Vibration affects tendons, muscles, joints and nerves. Workers can be exposed to either whole body vibration or localized vibration. The example of the whole body is vibration experienced by truck and bus drivers. Meanwhile localized vibration exposure can be caused by power tools. Common symptoms are numbness of the fingers, loss of touch and grip, and pain. In addition, the worker may use more force and awkward body positions because vibration hand tools are harder to control. Too much exposure of vibration can also cause us to lose the feeling in our hands and arms. As a result, misjudging the amount of force that need to control and use too much the tools can increase fatigue. Figure 2.3 illustrates the work that contributes vibration to the body.