MANAGING REWORKS IN A SHIPYARD INVOLVING HULL REPAIRS OF COMMERCIAL VESSEL

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ABSTRACT

Availability of many commercial vessels nowadays is prompting local shipyards to increase their revenue by offering best maintenance services in ship repair industry. Reworks, occasionally, may cause negative impact on project performance involving hull repairs that adversely affect the whole shipyard operation through unnecessary additional cost of repairs. Hence, it is vital for a shipyard to plan any repair work properly to avoid issues of project delays due to reworks caused by non-conformity on quality issues. The researcher had distributed total of 30 sets of questionnaires to employees in a shipyard located in Lumut. The questionnaire covered three (3) sections, namely section A (the demographic data of respondents), section B (scope and guideline content) and section C (suggestion and opinion). The research findings revealed that most of the respondents had indicated the main root cause contributing to reworks for commercial vessel hull repairs is due to defects found on the welding beads. The weld failures caused by hydrogen cracking is the main contributing factor causing reworks for hull repairs that result in production delays and overruns in a ship repair project and finally affecting the total profitability of the shipyard.

Keywords: reworks, delays, welding failure, hydrogen cracking

INTRODUCTION

Diverse range of commercial vessel growth has brought significant impact to the maritime industry worldwide for the past 30 years as it increases the demand for planned maintenance and ship repairs in Malaysian shipyards. Hull steel work repairs play an important role in commercial vessel maintenance due to its high costs. Therefore, proper guidelines and comprehensive planning is required to avoid the unnecessary additional costs that need to be borne due to these reworks on hull structure. Malaysian local shipyards often experience rework activities that contribute to overruns in ship repair projects. Nature and extent of repair works on hull structure may vary according to surveys carried by the ship's appointed classification surveyor.

LITERATURE REVIEW

The literatures reviewed in this research revealed various factors that contribute to reworks, the impact of reworks on shipyard operation and ship owners, the shipbuilding quality standards and procedures to avoid mishaps such as hydrogen induced cracking. These reviews helped in furthering of understanding of the research objectives, methodological approach and identifying of best approach for hull repair works on commercial vessels. Hence, relevant literatures cited are focused on issues relating to defining reworks (Enhassi et al., 2017), and measuring and classifying reworks (Fayek et al., 2003). Best practices were sought through relevant literatures that dwell on avoidance of hydrogen cracking (Bailey et al., 1993). These citations should help lend credibility to researcher's own findings on various issues that relate to managing of reworks of hull repairs in a shipyard. In a nut-shell reworks imply additional costs that deviate from the norm and these costs are actually a reflection on the actual quality standard of work whereby the actual causes of reworks may vary among countries as work culture and situation is different.

PROBLEM STATEMENT

Every repair task on a commercial vessel is required to meet the planned schedule to avoid any subsequent warranty losses on the shipyard. Hence, the problem of high cost due to reworks on hull repairs and how reworks affect project delays and reputation to shipyard are the main issues to be addressed in this research. Since, this research is focused on hull reworks caused by welding defects, the mode of most commonly adopted welding approach, namely the manual metal arc welding (MMAW) will be centrally focused in order to derive the best approach to minimize hull reworks.

SIGNIFICANCE OF RESEARCH

The research may help identify the root causes and consequential cost escalation due to reworks in steel hull repairs for commercial vessels in a Malaysian shipyard. This research would determine the cause of reworks in hull repairs and its impact on shipyard operation cost in order to keep the shipyard financial management on track by maintaining the targeted revenue through adopting the best approach in managing of hull reworks.

RESEARCH OBJECTIVES

Research objective is vital in order to resolve the stated issues. The research objectives for this study are as follows:

- To identify the root causes that contribute to reworks on commercial vessel hull repairs.
- To propose the best approach in manual metal arc welding (MMAW) operations for hull repair works onboard commercial vessel.

RESEARCH QUESTIONS

The research questions are focused on factors that contribute to reworks for commercial vessel hull repairs in shipyard located in Lumut. The research questions are as follow:

- What are the main contributing factors affecting reworks for commercial vessel hull repairs in the shipyard?
- What is the best procedure in MMAW operations for hull repairs of commercial vessel in the shipyard?

RESEARCH METHODOLOGY

The Cronbach's Alpha method is a measurement of questionnaires' internal consistency where it analyzes the relationship between sets of item in a group. Additionally, Cronbach's Alpha gives the scale measurement of reliability. Above all the purpose of providing the internal consistency is to deliver the concrete proof of the questionnaire's reliability. Thirty (30) questionnaires were provided by the researcher to employees working in hull department of the shipyard.

The data analysis was made using the SPSS. SPSS is the acronym for Statistical Package for Social Science. The SPSS is a software to perform statistical analysis. This software is widely used to conduct statistical analysis for various fields of research including economics, education, health and even engineering. The statistical analysis that can be analyzed in SPSS software consist of T-test, frequencies, ANOVA, cross tabulation and correlation.

RESULTS AND DISCUSSION

T-Test

T-Test is an independent comparative and differentiation test to identify the most significant mean or the differences of two independent groups' mean with interval data. The mentioned two groups are indicated as two unpaired groups that the data origin was derived from two different subjects.

Table 1: One-Sample Test

	Test Value = 0					
	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Material, Equipment and Environment	33.902	29	.000	3.35468	3.3456	3.3891

$$P\ Value = \frac{0.000}{2}\ (Claim) = 0.000$$

P Value = 0.000 < 0.005 (H_o Rejection Passed)

Significance level at 5%; evidence is sufficient to assert that material, equipment and environment are root causes that contribute to reworks for commercial vessel hull repair works. Thus, material, equipment and environment are the most dominant factors that contribute to reworks for commercial vessel hull repair works.

Kruskal Wallis

The test for Kruskal Wallis is a non-parametric test based on ranking that intend to identify the significant differences of two independent groups. The most dominant cause that contributes to rework in shipyard operation is rework that occurs frequently due to defects found on welding beads.

Table 2: Test Statistics

Test Statistics	
Value	Rework occurs frequently due to defects found on welding beads
P-Value	0.166
T-Test	4.200
F-Value	33

Majority of the respondents have voted that the main contributing factor that causes rework occurrence was due to frequent defects found on welding beads. As shown on Table 2, P-Value is higher than 0.05 which at 0.166 indicating that reworks occur frequently due to defects found on welding beads show excellent internal consistency. On the other hand, the value for T-test is 4.20, where data gained from SPSS analysis stated that for material, equipment and environment section the most pre-eminent cause for rework is from frequent defects found on welding beads.

Best Approach in MMAW Operations for Hull Repair Works Onboard Commercial Vessel

The most common factor that can cause welding failures for MMAW operations is due to hydrogen cracking. While the fabrication works by welding is being carried out, hydrogen induced cracking can occur within the heat affected zone (HAZ) in the steel caused by the presence of hydrogen in the welding materials. Hence, it is important to avoid hydrogen cracking in order to eliminate welding failures in MMAW operations. The approach that can be adopted in the guideline for hull repair works of manual welding in MMAW operation onboard commercial vessel comprises:

a) Low-Hydrogen Electrode

The origin of hydrogen is from moisture. Certain welding electrode consistsz of cellulose that is an active foundation of hydrogen. Hence, the use of low level hydrogen diffusion of welding electrode is compulsory for any welding operation of hull structure. When an iron-based steel material is being welded, the low hydrogen electrode is decent defense to avoid hydrogen-induced cracking. According to American Welding Society (AWS) D1.1 for carbon steel material type A36, the recommended use of low hydrogen welding electrode such as E7015 or equivalent is highly recommended to be used for MMAW operation (American Welding Society, 2008).

b) Temperature of Welding Material

Trapped hydrogen forms ductile characteristics in the HAZ region, and the material gravitate to create the residual stress within the material during cooling process after completion of welding. Thus, it is vital to carry out pre-heat on the base material within the recommended temperature between 50°C to 250°C according to AWS D1.1 procedure to assure the material is dried from any moisture.

c) Carbon Equivalent of Heat Affected Zone

Martensitic steel is a consequence of the steel phase change that contain huge amount of hardness brittle material named as a susceptible HAZ microstructure. The susceptibility of a steel microstructure for HAZ hardness is influenced by the steel chemical composition. Carbon Equivalent Content (CEV) of a steel is a formula to determine its susceptibility. The formula to determine CEV of a steel is shown in Figure 1. The CEV formula is calculated by inserting the chemical composition value contained in the mill certificate of the steel. If the calculated CEV is high, the tendency of the steel to form hydrogen cracking is greater.

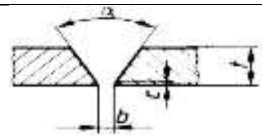
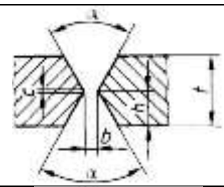
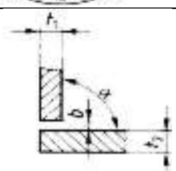
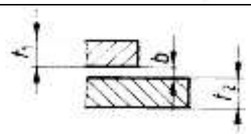
$$CEV_{IIW} = \%C + \frac{\%Mn}{6} + \frac{\%Cr + \%Mo + \%V}{5} + \frac{\%Ni + \%Cu}{15}$$

Figure 1: Carbon Equivalent Value

d) Heat Input

During welding, the cooling rate of parent metal is determined by the supplied heat input that subsequently disturb the properties of the welding bead due to changes in material microstructure. Thus, it is essential to control the heat input of welding operation to retain the quality of the welding. From the research that was conducted by the US Army Research Laboratory, for MMAW operation that using E7018 electrode, the carbon steel A36 weldment were restricted to 2.165 kJ/mm although with presence of porosity, the strength of the weldment is found to be satisfactory. However, the recommended heat input for A36 carbon steel with E7018 electrode is between 0.787 kj/mm to 2.165kj/mm (Weber, 1983). Heat input can be calculated by using the formula shown in Figure 2.

Table 3: Recommended Typical Fit-Up

Cross-section	Angle α°	Gap (b)	Root face thickness (c)
	60°	1mm to 4mm	2mm to 4mm
	60° 40° to 60°	1mm to 3mm	Less than 2mm
	70° to 100°	Less than 2mm	Nil
	Nil	Less than 2mm	Nil

$$Arc\ energy\,(kJ/mm) = \frac{Volts \times Amps}{Travel\ speed\,(mm/\sec) \times 1000}$$

Figure 2: Heat input formula

e) Tensile Stress

Tensile stress occurs on the welding bead caused by the welding residual stress. Due to high restraint in joint, that equals to the steel yield strength. The mere solution to reduce the presence of residual stress is by preparing the proper parent metal fit-up. In accordance with ISO 9692 (201 the recommended fit up and dimension for ordinary groove joint and ordinary fillet joint of parent metal are shown in Table 3.

CONCLUSION AND RECOMMENDATION

Based on the results that were analyzed in SPSS most of the respondents have indicated that the main root cause that contribute to reworks for commercial vessel hull repairs are due to defects found on welding beads. Therefore, if this factor is not managed and mitigated it may lead to consequential cost escalations or costly reworks.

Furthermore, welding failures caused by hydrogen cracking can be controlled if any of the stated variables as shown above is taken into account in the guideline for best manual welding in MMAW operation for hull repair works onboard commercial vessels. This may help reduce unnecessary repairs due to reworks and finally improve the productivity of shipyard operation.

Shipyard must practice effective monitoring for continual quality improvement by identifying immediately the root causes of any non-conformance work with regards to hull repair work and to suggest the corrective action of that particular issue. Additionally, shipyard needs to review and verify the effectiveness of the suggested corrective action to improve current work practices in the shipyard for hull repair works. By conducting work in accordance to correct practices and standards as suggested in this research may help reduce unnecessary costs that need to be absorbed by shipyard management due to the presence of reworks in welding operations onboard commercial vessels.

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