Journal of Optimization in Industrial Engineering
Vol.16, Issue 1, Winter & Spring 2023, 249–254
DOI: 10.22094/JOIE.2023.1973923.2019

Research Article

Types of Welding Process and Relationship with Defective Rate in Structural Fabrication for Oil & Gas Project

Mohd Amran Mohd Daril [a], Abd. Rahim Sidek [a,*], Mohamad Ikbar Abdul Wahab [a], Khairanum Subari [a], Sobia Irum [b], Nohman Khan [c]

[a] *Quality Engineering Research Cluster, Quality Engineering Section, Universiti Kuala Lumpur, Malaysian Institute of Industrial Technology, Johor Bahru, Johor, Malaysia.*

[b] *Department of Management and Marketing, College of Business Administration, University of Bahrain, Sakhir, Kingdom of Bahrain.*

[c] *UniKL Business School Universiti Kuala Lumpur*

Received 20 November 2022; Revised 01 April; Accepted 16 April 2023

Abstract

This research sought to identify the best welding processes with the lowest defective rate. It is important to select the most appropriate welding process for a certain condition, such as welding, taking into consideration technical and economic viability. This study will help the key person in the organization make the right decision on the selection welding process. The existence of many welding processes on the market, each with their own sets of advantages and disadvantages, makes determining the optimal welding process for a given situation challenging. As a result, selecting which welding process would provide the best welding quality at the lowest cost is critical to the success of any company's market strategy. There are three (3) variables that will be further investigated, which are: welding process (WP), defective rate (DR), and types of welding defect (WD). This study will analyze welder data from the welding department in MMHE, Pasir Gudang, Johor. The software that is going to be used is Minitab and SPSS. The research methodology starts with data collection, data screening, description analysis, inferential statistical analysis, independent sample t-test, correlation analysis, and regression analysis. The result of the analysis shows that there is a correlation between WP versus DR and WP versus WD, but it is a weak correlation. The results also show that SAW is the best welding process and contributes almost no defects. The SAW process is the right choice for fabricators to use in the structural fabrication industry. However, due to time constraints, probably the cost factor of SAW process is slightly higher than other welding processes not discussed in this study.

Keywords: Welding Process; Defective Rate; Welding Defect; Oil and Gas

1. Introduction

Welding is a common process for joining metals using various applications. Welding is a fabrication process whereby two or more parts are fused together using heat, pressure, or both, forming a join as the parts cool (Shankar & Wu, 2002). Welding is widely used across all industries, such as automobiles, aviation, shipbuilding, power plants, oil and gas, and others. There are many factors to be considered in the selection of a welding process (Öberg & Åstrand, 2018). The low defective rate, welding deposition rate, cost, and welding position restriction are all factors. The most important factor to take into consideration in the selection of a welding process is that the welding can contribute to a low defective rate (Anderson & Kovach, 2014). In the oil and gas industry, especially in MMHE, Pasir Gudang, Johor, most of the welding processes are manual, such as SMAW, or semi-automatic, such as SAW, due to the complexity of the structure, high altitude of weld (Hassan, Awan, & Jalil, 2012).

Several types of welding are used today. The most common types in industrial environments are shielded metal arc welding (SMAW), gas tungsten arc welding location, and space limitation. It is different in comparison to the manufacturing industry, where the welding process can be programmed and controlled by robots. The process is also repeatable and not complex. Therefore, automatic welding processes and programmable robotic control are suitable for the manufacturing industry. (GTAW), submerged arc welding (SAW), flux-cored arc welding (FCAW), and stick welding.

In the oil and gas industry, welding plays a very important role due to the very complex infrastructure to be fabricated, such as pile and jacket, topside, living quarters, bridges, flare booms, and other facilities. The manual welding process and semi-automatic welding process are still preferred in the oil and gas industry. All these infrastructures are created using welding processes and technologies.

2. Research Methodology

This chapter discusses the research methodology used to achieve the research objectives. The data was obtained from Archival Data from the past project in MMHE. The Archival Data in form of Welder Performance consist of types of welding processes, types of Defective and Defective rate. The data will be analyzed for further investigation. There are seven (7) projects are involved in this study which is: a) Bekok AA& BB Jacket & Topside-Year 2020 b) Kasawari Gas Development Project-Year

*Corresponding author Email address: rahim.sidek@s.unikl.edu.my

2016 c) Pluto Water Handling Unit Project- Year 2019 d) Bergading CPP MRU Project- Year 2020 e) BokorPhase3 Redevelopment Project-Year 2018 f) Sepat Phase 2A Facilities Topside-Year 2017 g) Tembikai Non-Associated Gas (TNAG)- 2018. The Defective for the completed weld will be obtained using Ultrasonic Testing (UT) scanning, one of the best NDT methods for structural fabrication. The data were compiled and submitted to Welding Section for analysis. The data were analysed using Minitab Software. There are a few processes involved in data analysis such as Data Screening, Description Analysis, and Inferential Statistical analysis. The details are discussed in this chapter.

Research Design. The research design is very important to guide the researcher along the research, primarily in the collection, analysis, and interpretation of data collected in the study (Chua, 2012), (Yin, 2013). In this study, the Archival Data from the past project are analyzed, investigate, and interpret. The research philosophy is able to help the researcher to provide the justification for the research will be carried out (Flick, 2015). Research philosophy can be defined as a system of beliefs and assumptions about the development of knowledge (Sekaran & Bougie, 2016). The method of data collection, data analysis, tools are going to use are discussed in this chapter. It specifies the data required for this study, the process for gathering and analyzing it, and how it addressed the Research Questions.

Table 1

Interconnection between R.O. and R.Q. of this study

No.	Research Objective (RO)	Research Questions (RQ)
1.	RO1- To investigate the relationship between Welding Processes (WP) and Defective Rate (DR).	RQ1-What is the relationship between Welding Processes (WP) and Defective Rate (DR)?
2.	RO2- To investigate the relationship between Type of Welding Prcesses (WP) and Welding Defect (WD).	RQ2- What is the relationship between Type of Welding Process (WP) and Welding Defect (WD)?
3.	RO3- To show the relationship between Welding Processes (WP), Defective Rate (DR) and types of Welding Defect (WD).	RQ3- How does the Welding Processes (WP) and types of Welding Defect (WD) related to the Defective Rate (DR)?

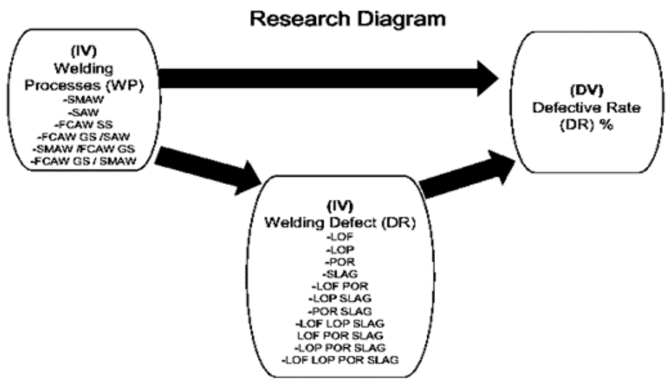

Fig. 1. Relationship IV and DV

2.1. Data collection method

Data collection is defined as the procedure of collecting, measuring, analyzing accurate data and data evaluation. The existing archival data collected from the Welding department based on Weekly Welder Performance. These data will be updated progressively once NDT report from welding activity at site is obtained.

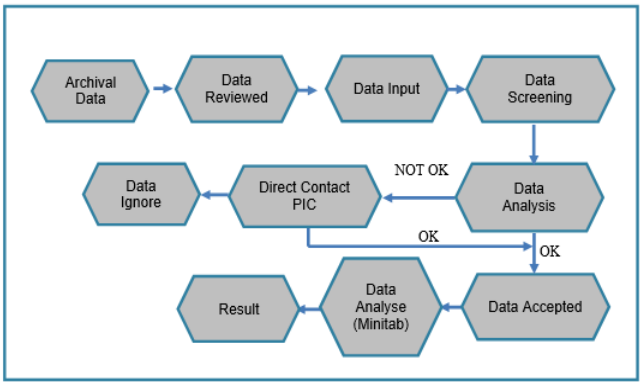

Fig. 2. Data Process Flow

2.2. Data analysis

The data analysis has been obtained from seven (7) projects in MMHE based on research scope. There are (3) main subjects to further analyse which is welding processes (WP), Defective Rate (DR) and types of Welding Defect (WD). Welding processes and Welding Defect are directly getting from Welding data. While Defective rate is defined as total Defective length welding of a particular welder divide by total length welding for the entire project duration. The common KPI (Key Performance Indicator) for structural in MMHE is 1% (maximum). This KPI is stated in Project Quality Plan (PQP) for every project and has been developed prior to project execution. There are three (3) method data analysis will be used: i) Data Screening ii) Descriptive Analysis iii) Inferential Analysis (Kothari, 2004).

2.3. Data screening

Data screening was conducted to ensure the data have been correctly entered and the distribution of data is normal (Field, 2009). Screening for missing data were conducted as the first step in the data analysis. For Treatment of Missing Data unusable data due to more than 10% of incomplete data can be ignored (Henn, Weinstein, & Foard, 2005) and were removed from the list. Data screening is important while checking data for errors and fixing or removing the error. Screening of missing data, assessment of outliner, assumption of normality and multicollinearity were part of data analysis and were determine whether the data is complete or incomplete

2.4. Descriptive analysis

Descriptive statistical analysis was used provided a basic summary of each variable by showing a proportionate breakdown of the categories for each variable (Henn, Weinstein & Foard, 2006). In this analysis, it was involved the processing and manipulation of raw data and subsequently transformed it into a finding that represents the situation for the set of factors (Sekaran & Bougie, 2016). In this study, the descriptive statistic was also used to tabulated and analyzed the data from a survey in the form of frequency, percentage, cumulative frequency, and cumulative percentage, to describe the characteristic of the sample with respect to the demographic variables. There are two types of data category which is complete data and incomplete data, if data is incomplete, we will get the extra information through direct communication with Welding Department or direct communication with the welder based on the contact detail welder list provided by Welding Department. All data will identify as coding and text will change to numbering for further analysis. Minitab software will be used for analysis (Rasli, 2006).

2.5. Inferential statistical analysis

Archival welder data consist of welding processes, Defective rate and Welding Defect will be analysed using the Inferential Statistical Analysis technique which is a sample of data taken from a population to describe and make inferences about the population. The data will analyse using Minitab and make generalizations about the larger population of subject. All inferential statistics have an important underlying assumption. Each replication in a condition is assumed to be independent. There are four (4) method will be used for statistical analysis: i) Independent Sample T-test ii) Regression Analysis iii) Correlation Bivariate- Pearson iv) Correlation Bivariate – Spearman

2.6. Independent sample T-Test

In this study, the independent sample t-test is used for testing differences between 4 types of Welding Processes and Defective Rate (ACC or NOT). The independent sample t-test useful when the study requires the comparison of variables obtained from two independent samples (Welding Process and Defective Rate) (Field, 2009). Thus, the independent sample's t-test can be used to test the hypothesis on differences of mean ranking of related to the demographic variables that contains only two groups. The null hypothesis (Ho) and the alternative hypothesis (HA) can be described as below. If a p-value is less than 0.05, then reject the null hypothesis.

2.7. Regression analysis

Regression analysis is a set of statistical methods to estimate relationships between a dependent variable and more independent variables (Tang, Goh, Lam, & Zhang, 2007). QTTs by Tang et al. (2007). It can be utilized to assess the relationship between variables and model the future relationship between them. In this study, this test was mainly used to analyze the relationship (if any) between all variables (WP, WD, and DR) as in Para 1.6-Research Objective No.3 (RO-3). To investigate to develop the model of the relationship between Welding Processes (WP), Defective Rate (DR) and types of Welding Defect (WD). The overall relationship can be presented as the regression formula below:

$Y=AX1 + BX2 + C$, Whereby, Y is Welding Processes (WP), X1 is Defect Rate (DR Value), X2 is Welding Defect (WD), and whereby constant value from the equation can be obtained from the Minitab software.

The Alphabet, A is unknown

The Alphabet B is unknown

The Alphabet C is an error

The result for this analysis is near to 1.0 is considered acceptable.

2.8. Correlations bivariate- pearson

The statistical hypothesis test for this p-value is: H0: There is no significant relationship between Optimism and Life Satisfaction. QTTs by Tang et al. (2007). Ha: There is a statistically significant relationship between Optimism and Life Satisfaction. Because $p < .05$, reject the null of no relationship and conclude that the relationship is statistically significant. Pearson – Evaluation of the linear relationship between two continuous variables. Analysis as below: a) WP Vs DR Range b) WP Vs WD

2.9. Correlations bivariate – spearman

The statistical hypothesis test for this p-value is: H0: There is no significant relationship between Optimism and Life Satisfaction. QTTs by Tang et al. (2007). Ha: There is a statistically significant relationship between Optimism and Life Satisfaction. Because $p < .05$, reject the null of no relationship and conclude that the relationship is statistically significant. Spearman- Evaluation of the relationship between two variables can be described using a monotonic function. Analysis as below a) WP Vs DR Range b) WP Vs WD

3. Results and Discussion

This chapter shows the finding obtain from data analysis. The outcome from the analysis result based on the Research Objective and the Research Hypothesis and the relationship will give positive outcome or not.

3.1 Descriptive analysis of WP- graphical summary

Descriptive Analysis of DR Value by Project-Graphical Summary, Based on Table 2 shows that all the P-values for all Projects are less than 0.05. As the result is to reject the Ho and to accept the HA. The result indicates that WP code 2 (SAW) is the best welding process for CI median.

Table 2

Summary of Welding Process (WP) by Project

Project	**N**	**P-value**	**Median**	**95% CI Mean**
Bokor	222	<0.005	3	2
Begading	27	<0.005	3	2
Kasawari	104	<0.005	3	2
Pluto	71	<0.005	3	2
Sepat	53	<0.005	3	3
Tembikai	32	<0.005	3	2
Bekok	61	<0.005	2	2

3.2. Descriptive analysis of DR value by project-graphical summary

Descriptive Analysis of DR Value by Project-Graphical Summary, Based on Table 3 shows that all the P-values for all Projects are less than 0.05. As the result is to reject the Ho and to accept the HA. The result indicates that the median for the best DR Value is 0 and the highest is 0.63 the abnormal data. Results show Bekok Project is lowest defective rate which is almost 0% defect contribution.

Table 3
Summary of Defective Rate (DR) Value by Project

Project	N	P-value	Median	95% CI Mean	95% CI Median
Bokor	222	<0.005	0.02	0.14~0.27	0~0.05
Begading	27	<0.005	0	0.04~0.22	0~0.09
Kasawari	104	<0.005	0.06	0.21~0.46	0~ 0.16
Pluto	71	<0.005	0.14	0.20~0.60	0~ 0.23
Sepat	53	<0.005	0.07	0.10~0.20	0.02~ 0.14
Tembikai	32	<0.005	0.02	0.02~0.11	0~ 0.06
Bekok	61	<0.005	0	0.02~0.63	0

3.3. Descriptive analysis of WP- graphical summary

Based on table no.4 shows that all the P-values for all Projects are less than 0.05. As the result is to reject the Ho and to accept the HA. The result indicates that WD code 1 (No defect) and Code 1 (LOF) common defect found in the project for the median and the data is abnormal.

Table 4
Summary of Welding Process (WP) by Project

Project	**N**	**P-value**	**Median**	**95% CI Mean**	**95% CI Median**
Bokor	222	<0.005	1	3~4	0~1
Begading	27	<0.005	0	0~2	0~1
Kasawari	104	<0.005	1	1~2	0~1
Pluto	71	<0.005	1	2~4	0~4
Sepat	53	<0.005	1	3~6	1~7
Tembikai	32	<0.005	1	1~3	1~7
Bekok	61	<0.005	0	0~1	0~6

3.4. Correlation bivariate- pearson-WP Vs DR Range.

Based on table 6, the P-value Sig. (2-tailed) for WP versus DR Range is .434, which is more P-value >0.05. Therefore, accept the H0. Due to r ≠ 0, the correlation is significant. Due to r = .033, which is r<0.5, thus the correlation is weak a) Weak correlation between WP and DR Range, r=0.033, N_{WP}= 570 b) Weak correlation between DR Range and WP, r=0.085, $N_{DR\ Range}$=570.

Table 5
Data Interpretation for SPSS

Positive	**Negative**	**Result**
Strong	r≥0.8	r≤-0.8
Moderate	0.5≤r<0.8	-0.5≥r>-0.8
Weak	r<0.5	r>-0.5
None	r≥0.05	r≥-0.05

Table 6
Pearson Correlation between WP versus DR Range

		WP	DR Range
WP	Pearson Correlation	1	.033
	Sig. (2-tailed)		.434
	Sum of Squares and Cross-products	652.526	11.895
	Covariance	1.147	.021
	N	570	570
DR Range	Pearson Correlation	.033	1
	Sig. (2-tailed)	.434	
	Sum of Squares and Cross-products	11.895	201.221
	Covariance	.021	.354
	N	570	570

3.5. Correlation bivariate- spearman-WP Vs DR range

Based on table 7, the P-value Sig. (2-tailed) for WP versus DR Range is .491, which is more P-value >0.05. Therefore, accept the H0. Due to r ≠ 0, the correlation is significant. Due to r = .029, which is r<0.5, thus the correlation is weak a) Weak correlation between WP and DR Range, r=0.029, N_{WP}= 570 b) Weak correlation between DR Range and WP, r=0.029, $N_{DR\ Range}$=570.

Table 7
Spearman Correlation between WP versus DR Range

			WP	DR Range
Spearman's rho	WP	Correlation Coefficient	1.000	.029
		Sig. (2-tailed)	.	.491
		N	570	570
	DR Range	Correlation Coefficient	.029	1.000
		Sig. (2-tailed)	.491	.
		N	570	570

3.6. Correlation bivariate- pearson-WP Vs WD

Based on table 8, the P-value Sig. (2-tailed) for WP versus WD is .210, which is more P-value >0.05. Therefore, accept the H0. Due to r ≠ 0, the correlation is significant. Due to r = .053, which is r<0.5, thus the correlation is weak a) Weak correlation between WP and WD, r=0.053, N_{WP}= 570 b) Weak correlation between WD and WP, r=0.053, N_{WD}=570.

Table 8
Pearson Correlation between WP versus WD

		WP	WD
WP	Pearson Correlation	1	.053
	Sig. (2-tailed)		.210
	Sum of Squares and Cross-products	652.526	118.211
	Covariance	1.147	.208
	N	570	570
WD	Pearson Correlation	.053	1
	Sig. (2-tailed)	.210	
	Sum of Squares and Cross-products	118.211	7743.551
	Covariance	.208	13.609
	N	570	570

3.7. Correlation bivariate- spearman-WP Vs WD

Based on table 9, the P-value Sig. (2-tailed) for WP versus WD is .379, which is more P-value >0.05. Therefore, accept the H0. Due to $r \neq 0$, the correlation is significant. Due to r = .037, which is r<0.5, thus the correlation is weak a) Weak correlation between WP and WD, r=0.037, N_{WP}= 570 b) Weak correlation between WD and WP, r=0.037, N_{WD}=570.

Table 9
Spearman Correlation between WP versus WD

			WP	WD
Spearman's rho	WP	Correlation Coefficient	1.000	.037
		Sig. (2-tailed)	.	.379
		N	570	570
	WD	Correlation Coefficient	.037	1.000
		Sig. (2-tailed)	.379	.
		N	570	570

3.8. Regression analysis - WP with WD and DR value

Regression analysis will show an equation to describe the statistical relationship between one or more predictor variables and the response variable Research Objective No.3 (RO3, the Regression Equation between WP, WD, and DR Value as below equation. Conclusion for WP shows that there is relationship with WD and DR Value and the value of WP more than 1. Refer to table 10.

Table 10
Regression Analysis between WP with WD and DR Value

Regression Equation

WP = 2.2279 - 0.0349 DR Value + 0.0171 WD

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	2.2279	0.0553	40.26	0.000	
DR Value	-0.0349	0.0725	-0.48	0.630	1.09
WD	0.0171	0.0127	1.34	0.181	1.09

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
1.07107	0.32%	0.00%	0.00%

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	2	2.071	1.0356	0.90	0.406
DR Value	1	0.267	0.2666	0.23	0.630
WD	1	2.061	2.0615	1.80	0.181
Error	567	650.455	1.1472		
Lack-of-Fit	198	249.925	1.2622	1.16	0.109
Pure Error	369	400.530	1.0854		
Total	569	652.526			

4. Recommendation

Observation from this study and the findings is the welding data is abnormal and tabulation is scatter, for future improvement, we need to have more individual data by project for analyse and it will represent all population equally. Firstly, this data also just includes Ultrasonic Testing (UT) result and without any consideration for other Non-Destructive Testing (NDT) method such as Magnetic Particle Inspection (MPI). Secondly at site only Complete Joint Penetration (CJP), butt weld joint configuration including single bevel joint and double bevel joint to be recorded in welding data, while for Partial Joint Penetration (PJP) including Lap Joint, Corner Joint, Tee Joint and fillet joint does not consider in welding data collection. If this will be considered on welding data recorded, we may have more population of the data to be analyse.

4.2. Research limitation

There are some limitations that should be worked out in this study. The welder data collected from the department is a measure based on ultrasonic testing (UT) for groove weld complete joint penetration (CJP), while incomplete joint penetration (IJP) and fillet weld were not considered in the study since there is no such information reported in the welder performance report. This is due to these joints being tested using Magnetic Particle Inspection (MPI) and the total welding length for the MPI report not being reported in the Welder Performance Report. The total welding length for each welder is higher than reported in the welder performance report. The more total welding length tested, the lower the defective rate compared to the total defect length produced by the same welder. If this can be considered a result, the defective rate might be getting lower. Some of the information received from the welding department is incomplete since the data is kept by a different person in charge.

5. Conclusion

From this study's conclusion, it is shown that WP contributes to the almost no defect, which is the SAW welding process for the Bekok Project (Refer to table No.3). However, the sample data population for the Bekok Project is only 47 samples of data and may not represent the overall population of the data. This study shows that the SAW process is the low defective rate. This finding is useful to Fabricator to select the SAW process as prefer welding process, however this consideration only applicable for low defective rate without consideration on other factor such as cost, complexity of welding position, deposition rate and welding speed. The common welding process used for every project is FCAW. GS. This is because this type of welding process is faster. Compared to others, for WD, the most common defect found for every project is LOF. This study shows there is a weak correlation between Based on Pearson Correlation analysis, both WP versus DR Range and WP versus WD based on Pearson Correlation analysis, both the results show that the P-value is greater than 0.05. Based on Regression Analysis in Minitab WD and DR Value show that WP has a relationship with WD and DR. and a P value greater than 0.05

Acknowledgment

Authors are grateful to corresponding authors Ts. Dr. Hj. Mohd Amran Mohd Daril and Ts. Dr. Sallaudin Bin Hassan for their guidance and support. Not to forget to Ts Dr. Sabariah Binti Mohd Yusoff, and Dr. Nur Farah Hafizah Binti Mukhtar for input given to increase the understanding toward the topic. Authors wish to thank to the Quality Engineering Department, Universiti Kuala Lumpur, Malaysian Institute of Industrial Technology (MITEC) for their cooperation.

References

Anderson, N. C., & Kovach, J. V. (2014). Reducing welding defects in turnaround projects: A lean six sigma case study. *Quality Engineering, 26*(2), 168-181.

Chua, Y. P. (2012). *Mastering research methods*: Mcgraw-Hill Education.

Field, A. (2009). 20093: Discovering statistics using SPSS. *Los Angeles*, 170-179.

Flick, U. (2015). *Introducing research methodology: A beginner's guide to doing a research project*: Sage.

Hassan, J., Awan, A. M., & Jalil, A. (2012). *Welding defect detection and classification using geometric features.* Paper presented at the 2012 10th International Conference on Frontiers of Information Technology.

Henn, M., Weinstein, M., & Foard, N. (2005). *A short introduction to social research*: Sage.

Kothari, C. R. (2004). *Research methodology: Methods and techniques*: New Age International.

Öberg, A. E., & Åstrand, E. (2018). Variation in welding procedure specification approach and its effect on productivity. *Procedia Manufacturing, 25*, 412-417.

Rasli, A. (2006). *Data analysis and interpretation-A handbook for postgraduate social scientists (+ CD)*: Penerbit UTM.

Sekaran, U., & Bougie, R. (2016). *Research methods for business: A skill building approach*: john wiley & sons.

Shankar, K., & Wu, W. (2002). Effect of welding and weld repair on crack propagation behaviour in aluminium alloy 5083 plates. *Materials & design, 23*(2), 201-208.

Tang, L. C., Goh, T. N., Lam, S. W., & Zhang, C. W. (2007). Fortification of Six Sigma: expanding the DMAIC toolset. *Quality and Reliability Engineering International, 23*(1), 3-18.

Yin, R. K. (2013). Validity and generalization in future case study evaluations. *Evaluation, 19*(3), 321-332.

This article can be cited: Mohd Daril, M. A., Sidek, A. R., Abdul Wahab, M. I., Subari, K., Irum, S., & Khan, N. (2023). Types of Welding Process and Relationship with Defective Rate in Structural Fabrication for Oil & Gas Project. *Journal of Optimization in Industrial Engineering*, *16*(1), 249-254. doi: 10.22094/joie.2023.1973923.2019