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Informational of Qualification in Welding for SMAW Process: A Meta-Analysis

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Abstract - Informational of qualification and known as reference providing the instruction, guidance and support to any organization or personnel for the purpose of qualification test in welding. Currently, the requirement of qualification in welding is available in both sectors of government technical institute (TVET) and industries. The most common welding process, versatile and normally conducted in both sectors is Shielded metal Arc Welding (SMAW). This isimportant that the execution of processes is to be addressed in detail and this information will be a pillar in making the qualification test successful. The aim of this meta-analysis is to determine, investigate and further encompass the best practices together with the suggestions which can be implemented during the qualification test session.

Keywords: - Informational, Meta-Analysis, Qualification Test, Welding, SMAW,

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1.0 INTRODUCTION

Welding is one of the processes used to permanently join two or more solid components. This can be achieved by heating the material to the welding temperature, with or without the application of pressure, and with or without the use of filler material. Alternatively, welding can be defined as a fabrication process where two or more parts are fused together by means of heat, pressure, or both, forming a joint as the parts cool. Welding is typically used on metals and thermoplastics, but it can also be applied to wood. The completed welded joint may be referred to as a weldment (TWI, 2020)

The qualification test in welding is a crucial part of Quality Assurance. In accordance with the requirements of ISO 9001 for product quality, the compliance and conformity of products involving welding are highlighted topics for implementation. Compliance and conformity in welding are interpreted as ensuring that all welding activities are performed according to established guidelines, codes, and regulations. These established guidelines and references set out the requirements for any organization and its responsibilities to provide qualifications through applicable procedures and performance tests in welding. There are several international references of codes and standards, such as American Standards, European Standards, and Japan Industrial Standards, which are commonly used in both local and global markets (Prajadhiana et al., 2018).

2.0 IMPORTANT INFORMATION

Qualification Test Environment

A qualification test in welding refers to the initial and essential scope of work that validates the abilities and weldability of the test results, thereby providing acceptance of the overall work process. The work activities are primarily based on instructional references such as:

1) Welding Procedure Specification (WPS) - This is based on supporting Procedure Qualification Records (PQR), which are initially established from preliminary documents.

2) Welding Qualification Test (WQT) - This is conducted as per the reference of a certified WPS.

Both above qualifications have their own targets, which can be finalized within the qualified range. If a qualification is found to be out of range, a new qualification will be required. The process of completing a qualification test involves various parties who verify, test, and witness the entire activities.

This study aims to:

1. Compare single-phase and three-phase welding machines.

2. Examine the characteristics of SMAW electrodes with the same classification but from various brands.

3. Determine the cumulative duration of experience and knowledge required to perform the process.

4. Identify potential forms of support needed for success.

From the above items 1, 2, and 3, further studies and findings will be determined to elaborate on the results.

Table 1. shows the summaries of studies

No.	Description	Study for
1	Welding machines	Comparison between single and three phase- to include advantages and disadvantages from the perspective for qualification purposes. - Frequency and long-term duty of operational. - Stability, control and handling. Recommended current and polarity use for welding.
2	Selection of Material and Consumables	Specification and Grade of Steels and condition of supply. Manufacturer/ brand-named of SMAW electrodes and its characteristic Specification and Grouping number of SMAW electrode. Test result of quality and its properties.
3	Knowledge and experiences	Body of knowledge and skills required. Cumulative traveling time (hours, days, months and years) as required prior to performing the qualification.

Table 1 summarizes several studies related to welding machines, the selection of materials and consumables, and the required knowledge and experiences in the welding field.

The first part of the table focuses on welding machines. It compares single-phase and three-phase welding machines, discussing their advantages and disadvantages, particularly for qualification purposes. This comparison includes considerations of operational frequency, long-term use, stability, control, and handling. Additionally, the study offers recommendations on the appropriate current and polarity settings for welding.

The second part of the table addresses the selection of materials and consumables. It details the specifications and grades of steel, including their supply conditions. The study also lists the manufacturers or brand names of Shielded Metal Arc Welding (SMAW) electrodes, describing their characteristics. Further, it specifies and groups the numbers of these electrodes, and includes test results concerning their quality and properties.

The third part of the table covers the necessary knowledge and experiences for welding. It outlines the essential body of knowledge and skills required for the field. Moreover, it specifies the cumulative time

needed for travel (measured in hours, days, months, and years) before one can qualify to perform welding tasks.

Overall, the table provides a detailed overview of important studies that are crucial for understanding various aspects of welding, from machine types and material selection to the knowledge and experience needed for effective welding practices.

Table 2: Show for the Studies of Qualification in Welding

No.	Study	Research Purposes	Type of References	Support Form of Informational to The Qualification in Welding for SMAW Process.							
				Welding Machine		Selection of Material and Consumables				Knowledge and experiences	
				Welding Machine; Single and Three Phase	Durability of use; stability, frequency and long-term duty of operation.	Steels and condition of supply	Manufacturer/ brand name and its characteristics.	Grouping number of SMAW electrode.	Test result of quality and properties.	Body of knowledge and skills required.	Cumulative duration of experiences (hours, days, months, and years) as required prior to performing the qualification.
1	M. PITA1 & M. MAUMELA 2, 2021	The Effect of Different Brands of Welding Electrode on The Mechanical Properties of Welded Joints in Mild Steel.	Research Paper				√				
2	P Hargiyarto, K Syauqi, S Sugiyono, A Ardian, S Sianipar and LA Nadjib, 2020	Analysis of quality student practice results in shielded metal arc welding.	Research Paper							√	√
3	American Society of Mechanical Engineer (ASME) IX	Part QW Article IV Welding Data-P-Number (Assigned Group of Basemetal)	International Code and Standard			√					
4	American Society of Mechanical	Part QW Article IV Welding Data F-Number	International Code and Standard					√			

	Engineer (ASME) IX	(Assigned Group of Filler Metal)									
5	American Welding Society (AWS) D1.1- Structural Welding Code_Steel	Section 6, Table 6.8 & Table 5.9 of Listed and Unlisted Base Metal	International Code and Standard			√					
6	American Welding Society (AWS) D1.1-Structural Welding Code Steel	Section 6, Table 6.5 of PQR Essential Variable and Table 6.13 Electrode Classification Group	International Code and Standard					√			
7	American Society of Mechanical Engineer (ASME) II	Part A- Ferrous Material Specification.	International Code and Standard			√					
8	American Society of Mechanical Engineer (ASME) II	Part C- Specification for Welding Rods, Electrodes and Filler Metals.	International Code and Standard					√	√		
9	Sijil Kemahiran Malaysia (SKM)	SKM Level 1, Level 2, Level 3, Level 4	National Occupational Skills Standard (NOSS)							√	√
10	CIDB Malaysia	Certification Scheme for Welding Level 1, Level 2, Level 3	CIDB-Book_Cs01-Welding							√	√
11	S.Farrukh Haider 1, M.M. Quazi 2, Jahanzeb Bhatti 3, M Nasir Bashir4*, Imran Ali 5, 2019	Effect of Shielded Metal Arc Welding (SMAW) Parameters on mechanical properties of	Research Paper							√	
12	Adino Amare, Arumugam Balasuadhaka	Performance analysis of a low power	Research Paper	√	√						

	r*, and Hailemichael Solomon, 2023	consumption electric arc welding machine constructed using cost effective materials.									
13	Kobelco Welding Handbook, 2016	Suitable current and polarity for SMAW electrode.	Welding Handbook (Manufacturer)			√	√	√	√		
14	Megmeet Welding Technology	Three-phase Welding machine VS. Single-phase Inverter Welding Machine	News	√	√						
Total Frequency				**2**	**2**	**4**	**2**	**4**	**3**	**4**	**3**

Table 2 provides a comprehensive overview of various studies related to qualification in welding, focusing on the Shielded Metal Arc Welding (SMAW) process. Each study is categorized by its purpose, type of reference, and the specific support it provides for different aspects of welding qualification, such as welding machines, material selection, and the required knowledge and experience.

The first study by M. Pita and M. Maumela (2021) explores the effect of different brands of welding electrodes on the mechanical properties of welded joints in mild steel. It is a research paper that supports the use of specific welding machines. The study by P. Hargiyarto and colleagues (2020) analyzes the quality of student practice results in SMAW, focusing on knowledge and experiences required for welding, and is also a research paper.

Several international codes and standards are included in the table, such as those from the American Society of Mechanical Engineers (ASME) and the American Welding Society (AWS). These documents provide specifications and grouping numbers for materials and electrodes, and test results of quality and properties. For instance, ASME IX and ASME II parts A and C provide detailed welding data and material specifications, while AWS D1.1 details structural welding codes and essential variables for procedure qualification records (PQR).

The table also references national standards and certification schemes, such as the Sijil Kemahiran Malaysia (SKM) and the Construction Industry Development Board (CIDB) Malaysia, which outline the levels of certification and the body of knowledge and skills required for welding.

Other studies and resources, like the Kobelco Welding Handbook and news from Megmeet Welding Technology, offer practical information on suitable currents, polarity for SMAW electrodes, and comparisons between different types of welding machines.

Overall, the table lists various types of references, including research papers, international codes and standards, national occupational skills standards, and manufacturer handbooks. These references collectively support the qualification process for SMAW by providing critical information on welding machines, material selection, and the necessary knowledge and experiences.

Welding Machine

1) Single phase and three phase of welding machine.
2) Durability of use; stability, frequency and long-term duty of operation.

A three-phase welding machine is a type of equipment that uses a three-phase electrical power supply to generate the required welding current and voltage. This machine, known for its high-power output, stability, and efficiency, is ideal for heavy-duty welding applications in industries such as construction, shipbuilding, and large-scale fabrication. Its robust design, superior heat control, consistent arc stability, and ability to handle prolonged operations without overheating make it a staple in industrial workshops.

Conversely, a single-phase inverter welding machine uses a single-phase electrical power supply and employs inverter technology to convert this input power into a controlled output. This technology allows for better control over the welding arc and output characteristics. These machines are compact, portable, and energy-efficient, making them suitable for a wide range of welding tasks, including light to medium-duty applications. They are favored for their versatility, ease of use, and ability to produce high-quality welds with improved arc stability(Dagmar & Suseno, 2023).

A recent study by Adino Amare (2023) serves as a comprehensive reference for both single-phase and three-phase power supply arc welding machines (Das et al., 2020). The study was conducted to address power and cost-related issues. The findings revealed that under welding conditions, there were no additional losses. The efficiency of the local arc welding machine, characterized by its compact transformer construction, optimal material selection, and fan cooling system, was evaluated while operating on a single-phase supply. The machine demonstrated superior performance, providing significant value in terms of power output and durability for long-term operation.

Manufacturer/ brand name and its characteristics.

- Comparison of SMAW electrode with the same classification and various brand-named.

A comparison of SMAW electrodes with the same classification but different brand names was conducted by researcher (Hafni, 2021) The study found that the brand name of the SMAW electrode significantly impacts the welding outcome, even when the process parameters and handling remain the same. This was particularly evident when welding a 10.0mm thick base metal (mild steel) with an E6013 electrode of size 3.2mm. The study also noted differences in the width of the Heat- Affected Zone (HAZ) and weld metal when comparing hardness curve results.

The characteristics of a welding electrode are crucial in selecting the appropriate welding method for any type and specification of pipe or steel structure. As per the Kobelco Welding Handbook (KOBE STEEL, LTD., Welding Business Marketing Department) (KOBELCO, 2022) each electrode is specifically designed for a target welding position. For instance, the commonly used SMAW electrode E7018 is suitable for all kinds of welding positions. The handbook also provides recommended current and polarity based on the size of the electrode, serving as a guideline for organizations to develop welding procedures and qualification tests

Knowledge and experiences.

According to a study by (Hargiyarto et al., 2020) an analysis of the SMAW process practiced by 18 Diploma III Mechanical Engineering students from the Faculty of Engineering, Yogyakarta State University, revealed that none passed the visual test. The assessment results, with a rate below 50%, highlighted the importance of experience, knowledge, and welding competence in meeting industry standards.

Meanwhile, The National Occupational Skills Standard (NOSS)(“Benchmarking Analysis of Occupational Standards for The Malaysia’s National Occupational Skills Standard (NOSS) Approach

Towards New-Collar Jobs Era," 2022), under the Sijil Kemahiran Malaysia (SKM) and Jabatan Pembangunan Kemahiran (JPK), provides guidelines based on the needs of skilled personnel in Malaysia. A review by the TVET institution ILPIPOH (2023) (5) indicated that NOSS addresses work needs and career structures in specific fields, prepared by a pool of industry specialists, experts, and skilled workers. For instance, the Welding Technology course for SKM level 3, which lasts about 2 years and 3 months, exposes students to theoretical and practical knowledge about workshop practices, fabrication drawing, SMAW, FCAW, GTAW, GMAW process fundamentals, hands-on welding for plate and pipe, basic entrepreneurship, and industrial training sessions.

Other than that, The Construction Industry Development Board (CIDB, 2016) also offers a welding training course under its Certification Scheme for Welding. The course covers training, assessment, and examination for Welding Levels 1, 2, and 3. CIDB provides further training and examination for personnel with a minimum of six months of work experience or a valid Level 3 welding certificate from other training agencies. The certificate has a maximum validity of three years, with a revalidation process available.

In contrast, a study by (Chiong et al., 2019) investigated the effect of SMAW parameters on the mechanical properties of low-carbon steel, mild steel, and stainless-steel welded joints. The research showed that varying the welding parameters significantly affected the mechanical properties of different steel joints. Higher hardness values necessitated further heat treatment to prevent brittle fracture. The study concluded that more consideration should be given to input and output parameters to improve the material properties during welding.

Selection of Material and Consumables

According to the international standard stated in The American Society of Mechanical Engineers ("AMERICAN SOCIETY OF MECHANICAL ENGINEERS," 1899; Z., 1940) Section IX of ASME contains requirements for the qualification of various operators and the material joining processes they use during operations for the construction of components under the rules of the ASME Boiler and Pressure Vessel Code, the ASME B31 Codes for Pressure Piping, and other codes, standards, and specifications. The cross-section reference QW-420 in ASME IX addresses the listed material and assigns it a 'P' number, an alphanumeric designation used to reduce the number of qualifications required when materials or steel are involved in welding. Materials produced under various standards can be defined in Table QW/QB-422 and are considered equivalent using the Unified Numbering System (UNS) number.

Another reference available for the selection of steel for qualification purposes based on the application of steel structural is as per American Standards (American Welding Society (AWS) D1 Committee on Structural Welding, 2020) (2). This code, developed by the AWS D1 Committee on Structural Welding, is used for any steel thickness with a minimum of 3.0mm and specified minimum yield strength of 100 ksi (690 Mpa) or less. The cross-reference and section available for material under the 2020 edition is as per Section 6, Table 6.8 & Table 5.9 of Listed and Unlisted Base Metal. Approved base metals are grouped under various groups with references to material specification, grade, minimum yield strength, and tensile range. However, the range of qualifications for the use of unlisted steel is specifically accepted only based on the unlisted steel itself. AWS D1.1 also addresses engineer's approval for auxiliary attachment when the use of unlisted steel falls within range based on the result of chemical composition.

The American Society of Mechanical Engineers (ASME) Section II- Part A, as outlined by the ASME Boiler and Pressure Vessel Committee on Material in 2019, provides material specifications. ASME and the American Society for Testing and Materials (ASTM) have collaborated for over half a century to develop these specifications, ensuring safety in the pressure equipment field for ferrous materials.

For instance, the ASTM A106 Gr. B carbon steel pipe has defined criteria that include process product form, heat treatment information, chemical analysis, heat and product analysis, tensile requirements,

bending requirements, and other testing results such as flattening and hydrostatic tests. It also includes permissible dimensions, workmanship and finish appearance, certification, and product marking.

In a similar vein, the characteristics and criteria of filler metal to the material and welding position are supported by one of the most recognized consumable manufacturers, KOBE STEEL, LTD., Welding Business Marketing Department (6). They provide material information based on the selection of welding consumables for welding purposes. Kobelco has simplified this process by creating a summary of welding consumables versus the material. The criteria were adapted based on the selection of filler metal for API grade pipes.

Grouping Number of SMAW Electrode, Test Result of Quality and Properties.

The American Society of Mechanical Engineers (ASME) 2021 reference, Part QW Article IV Welding Data, provides information on filler metal through designated F-Numbers, which are essentially groups of electrodes and welding rods. These groups are based on usability characteristics, which fundamentally determine the ability of welders to make satisfactory welds with a given filler metal. This group aims to reduce the number of welding procedures and performance qualifications where possible.

On the other hand, the American Welding Society (AWS) D1 Committee on Structural Welding's 2020 reference, AWS D1.1, addresses filler metal in Section 6, Table 6.5 of PQR Essential Variable and Table

6.13 Electrode Classification Group. Information provided includes maximum classification strength and below, changing any low hydrogen to non-low hydrogen type of electrode, and any classification not covered by AWS A5.1 and AWS 5.5. The maximum size increase is 0.8mm from the actual. These selection requirements of SMAW electrode can be applied for qualification purposes.

Similarly, the ASME Boiler and Pressure Vessel Committee on Material's 2019 reference in Section II-Part A provides the requirement and guideline in manufacturing the said products. An example given for SMAW electrode under the specification of SFA 5.1 and classification E7018, selection of consumable may take place and focus based on type of electrode, tensile and any other properties result, position, type of coating and current. Other retrievable information includes ability under low temperature services and the result of hydrogen level.

Kobelco, one of the best references and electrode manufacturers commonly used in the local market for welding works, regularly updates the product and technology through versions of Kobelco Welding Today. The welding handbook reference, KOBELCO Welding Handbook (6), is considered user-friendly, providing information on welding electrode and filler metal based on material information. Besides the information of classification, the references also detail and completely summarize the grouping number according to both American and European standards, weld metal chemical composition group number, test result of properties, and data sheet of electrode.

Suggestion/Recommendation

There are numerous types of welding qualifications available, and these are subject to changes in technology. Therefore, before undertaking welding qualifications, researchers should consider several suggestions such as (1) preparing a checklist of necessary equipment, tools, and facilities, (2) developing a process flow and test plan, and (3) preparing relevant support forms and preliminary documents.

The qualification process in welding for both Welding Procedure Specification (WPS) and Welding Qualification Test (WQT) requires the following considerations:

For WPS: i. A competent and certified individual (such as a QAQC/Engineer/Welding Inspector) with knowledge of inspection and testing should supervise, monitor, record, evaluate, and report on weld quality and test results. ii. A qualified individual (welder) with experience and a history of records in the same welding process should perform welding on the test specimen and be able to follow instructions.

For WQT: i. A competent and certified individual (such as a QAQC/Welding Inspector) with similar knowledge to the above should be involved. ii. A trained individual (welder), who is ready, fit, and able to follow instructions, should perform the qualification test.

In addition to the use of technology for welding, such as machinery, equipment, and tools, it's important to emphasize that accuracy, stability, and validity are the main concerns. Therefore, calibration should be maintained to ensure there are no errors during the welding qualification process. The involvement of competent or qualified personnel is required to meet industrial and international requirements. This study also prefers personnel with extensive knowledge and familiarity with applicable international codes and specifications related to welding, inspection, and testing. This can assist the organization in achieving a precise and accurate qualification range, ultimately meeting expectations and needs.

5.0 DISCUSSION AND CONCLUSION

In summary, the support forms of information provided for the welding qualification test, along with the suggestions mentioned, are crucial for the successful completion of both WPS and WQT tests. With With the fast-paced changes in technology, this informational knowledge and requirements need to be continuously updated to stay relevant to industry needs. A proper setup, thorough preparation, and well-laid plans form the fundamental basis for initiating any welding qualification test.

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