Research Gap Finding in Shielded Metal Arc Welding of Steel

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Abstract . Shielded Metal Arc Welding (SMAW) is a commonly employed method for joining steel in general industrial applications, encompassing both similar metals (SMW) and dissimilar metals (DMW) welding, primarily due to economic considerations. However, the welding process itself can lead to a reduction in joint strength. In order to identify the parameters and testing methods that can be developed, it is possible to gather and statistically analyze previous research studies. Through the data analysis of parameter types and testing in both SM and DM welding, significant research gaps can be identified, paving the way for further research and exploration in this field. This has consequently spurred the advancement of welding research, which focuses on exploring various parameters and conducting tests to achieve high-quality welds

1 Introduction

Steel is a material that significantly influences the development of industries worldwide [1]. Carbon steel and stainless steel find widespread applications in various fields, including transportation, energy, the steel industry, and automotive sectors [2], [3]. The joining process for steel, whether it involves similar metals (SMW) or dissimilar metals (DMW), is commonly accomplished using Shielded Metal Arc Welding (SMAW) due to its cost-effectiveness and user-friendliness [4]. Dissimilar metal welding (DMW) is typically employed in the fabrication of boilers, pressure vessels, heat exchangers, nuclear reactors, and power plants [5]–[7].

The process of Shielded Metal Arc Welding (SMAW) involves joining metals in a molten state created by the heat of an electric arc. This welding process is influenced by the chemical composition, mechanical properties, and thermal characteristics of the steel being used [7]–[9]. As a result, these factors make the weld vulnerable to issues such as corrosion, fatigue cracking, grain enlargement, microstructural changes, and variations in hardness levels within the welded area. Consequently, these factors can weaken the strength of the welded joint [10]–[13]. To achieve a strong and durable weld joint, it is crucial to ensure excellent metal fusion and select appropriate welding parameters [9], [14]. The welding parameters encompass various factors, including welding current, heat input, welding speed, arc voltage, polarity, electrode diameter, electrode type, preheating, and post-heating [15]–[21]. Proper control and adjustment of these parameters are essential to obtain a high-quality weld with optimal strength.

Currently, SMAW research is being compared to other fusion welding methods, considering differences in arc efficiency and variations in the welding bead [22]–[26]. This comparison indicates that both SMW and DMW in SMAW still hold potential for further investigations. To explore this potential, a comprehensive review of previously published research studies is necessary. Employing statistical analysis can help identify any existing research gaps. This paper proposes a novel method for identifying research gaps by ranking the utilization of research parameters and tests in SMAW. The articles included in this review are selected from the past five years

2 Methods and Materials

The data was collected from 50 articles that discuss SMAW studies. These articles were classified into SMW (similar metal) in Table I and DMW (dissimilar metal) in Table II. The tables present the materials, welding parameters, and testing methods employed in each study.

Table 1. Articles of SWM

Base metal	Research Parameters	Testing	Ref.
Carbon Steel	current, electrode type	hardness	[11]

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IS 2062	current, material thickness, polarity, compared with GMAW	microstructure, hardness, tensile	[27]
IS 2062	current, welding groove, welding speed,	microstructure, hardness, tensile, distortion, impact	[28]
AISI 1018	current, material thickness, electrode diameter	tensile	[15]
AISI 1020	current, electrode angel, polarity	tensile	[16]
AISI 304	electrode type	macrostructure, tensile, microstructure. hardness,	[29]
DMR 249A	compared with GMAW	macrostructure, microstructure, hardness, tensile, impact	[10]
AISI 490M	current	microstructure, hardness, tensile, corrosion	[30]
IS 2062	polarity, hybrid with GMAW	microstructure, hardness	[25]
SA 516 Gr. 70	pre-heating, welding groove, electrode diameter, root gap	hardness, tensile, distortion, impact	[31]
AISI 1045	pre-heating	macrostructure, hardness, tensile	[32]
AISI 1018	current, electrode type, electrode diameter	microstructure, tensile, bending, impact	[14]
Mild Steel	pre-heating	macrostructure, microstructure, hardness	[33]
ASTM A36	current, electrode type	tensile	[34]
Ni-Cr-Mo HSLA	compared with SAW, GMAW, and GTAW	microstructure, tensile, impact	[22]
ASTM A36	current	microstructure, hardness	[35]
ASTM A36	compared with GMAW	microstructure, hardness, tensile, impact,	[36]
Mild Steel	current, electrode type, electrode diameter	hardness, tensile	[37]
ASTM A236-C	electrode type	microstructure, tensile	[8]
CS 32	current, electrode type	microstructure, hardness	[38]
ASTM A36	current	microstructure, tensile	[39]
AISI 1018	current, electrode diameter	tensile	[40]
EN10025	material thickness, compared with GTAW	microstructure, hardness, tensile, bending, impact	[41]
AISI 1045	compared with GMAW	tensile, bending	[42]
AISI 409 M	number of pass	microstructure, hardness, tensile, corrosion	[12]

Table 2. Articles of DWM.

Base metal	Research Parameters	Testing	Ref.
AISI 304, GCI	pre-heating, post heating	microstructure, hardness	[21]
SS 304, MS 1018	current, electrode angel, welding speed, root gap	microstructure, metal deposition rate	[18]
MS1018, SS 304	current, electrode angel, root gap	hardness, tensile	[43]
DCI, AISI 304	welding pass variation with MIG	microstructure, hardness, tensile, impact	[44]
P91, SS 304L	electrode type buttering with GTAW	hardness, tensile, impact	[26]
SS 316, ASTM A36	current, electrode type, welding speed, voltage	hardness, tensile, bending	[45]
SS 316L, ST41	electrode type	macrostructure, microstructure, tensile	[13]
Mild Steel, Stainless Steel	compared with GTAW and GMAW	tensile	[46]
SA.240 Tp.304, SA.36	heat input, welding pass	hardness, tensile	[47]
SS 304, AISI 1045	electrode type, welding groove	macrostructure, tensile	[4]

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SS 304, SS 304L	compared with GTAW and GMAW	macrostructure, microstructure, tensile	[23]
SS 304, SS 310	welding groove, compared with GTAW	hardness, tensile	[48]
AISI 304, AISI 1020	electrode type, post heating, compared with GTAW	microstructure, hardness, tensile, bending	[49]
P91, P92	electrode type	microstructure, hardness, tensile, bending	[19]
IN 718, 304L	welding pass	microstructure, hardness, tensile, impact	[50]
AISI 1020, AISI 6150	compared with GTAW and GMAW	microstructure, hardness, tensile	[24]
HY 80, DSS 2205	joint type	microstructure, hardness, impact	[51]
SA508 Gr. 1A, 316 SS / 316L SS	post heating	microstructure, hardness, tensile	[20]
AISI 304, AISI 1015	current, electrode type	macrostructure, microstructure, hardness, impact	[5]
A 335P 12, ASTM A 106 Gr C	compared with SAW	macrostructure, microstructure, tensile, bending	[6]
AISI 4340, SS304	current, electrode type, welding groove	microstructure, tensile	[52]
P91, P92	electrode type	microstructure, tensile	[53]
P22, P91	electrode type	corrosion	[54]

Based on the data presented in tables 1 and 2, the identical parameters and testing types in SMW and DMW were identified and subsequently summed up. The sum of these values is then divided by the total number of articles to determine the modus or percentag indicating how frequently a particular parameter was investigated. The calculation of this modus is formulated in Equation (1).

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where Modus is percentage of how often a parameter is studied, Amount is number of selected parameter or testing type in SMW or DMW and N is number of SMW or DMW articles. The total count and modus of each parameter and testing type in the SMAW research are presented in Table III and Table IV, respectively

Table 3. Modul of Each Parameter In SMW and DMW

Research Parameters	SMW		DMW	
	Amount	Modus	Amount	Modus
FXUUH				
HOHFW W\SH				
KHDW L				
SUHKHDW				
HOHFW DQJOH				
ZHOGL JURRYH				
PDWHU WKLFN				
SRVW K				
SRODUL				
ZHOGL VSHHG				
HOHFW GLDPHV				
URRW J				
K\EULG				
FRPSDU				
ZHOGL SDVV				
YROWD				
MRLQW				

Table 4. Modul of Each Testing Typer In SMW and DMW.

Testing	SMW		DMW	
	Amount	Modus	Amount	Modus
PDFURVV				
PLFURVW				
KDUGQH				
WHQVLO				
EHQGLQ				
GLVWRU				
LPSDFW				
GHSRVLV				
FRUURVL				

3 Result and Discussion

Table III and Figure 1 present the frequency distribution of 17 research parameters used in SMAW. The data reveals that weld current is the parameter most frequently investigated in SMW research, with a modus value of 52%, while the electrode type exhibits the highest frequency in DMW research, with a modus value of 44%. Comparative studies between SMAW and other welding methods show an equal modus value of 24% for both SMW and DMW. The majority of SMAW parameters have been explored in both SMW and DMW, exhibiting varying modus values. However, there are several parameters with a modus value of 0%, indicating their underutilization in the reviewed 50 articles as research parameters. Specifically, heat input, post-heating, voltage, and joint type have not been employed in SMW research, while material thickness, polarity, and hybridization have not been utilized in DMW research.

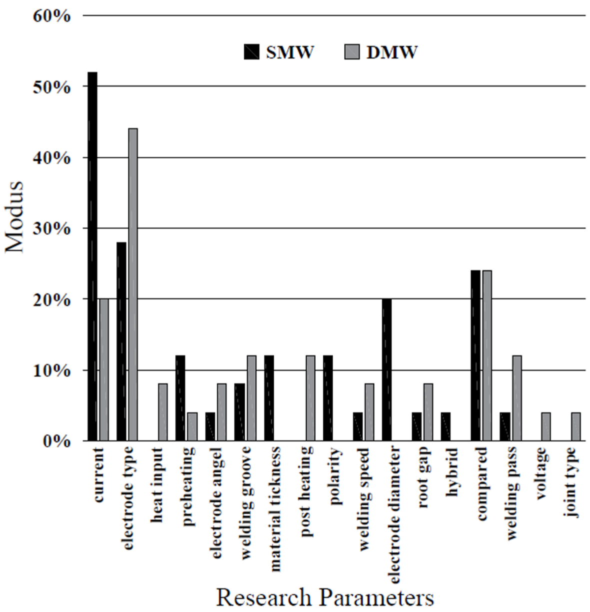

Fig 1. Modus of Parameter in SMAW Research

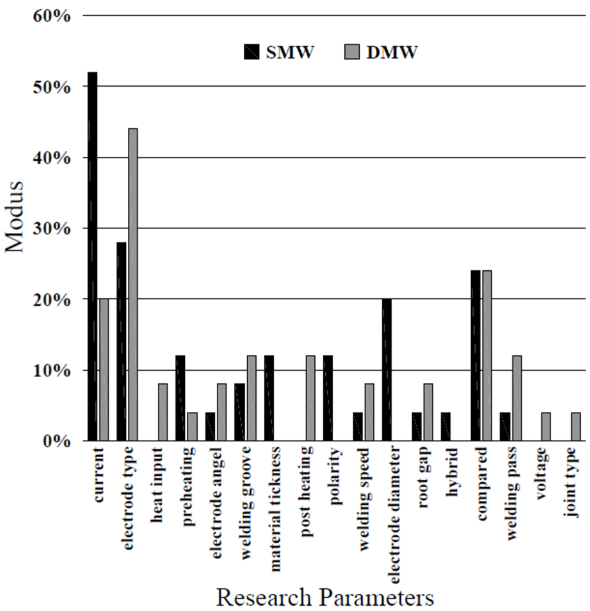

Fig 2. Modus of Testing in SMAW Research

The characteristics of welding joints are typically evaluated through macrostructure and microstructure observations, as well as mechanical property testing. Common mechanical property tests conducted on steel weldments include hardness, tensile strength, impact strength, fatigue resistance, and bending strength [56]. Table IV and Figure 2 display nine types of tests conducted on SMAW research. Tensile strength testing is the most frequently utilized in SMAW research with a modus value of 80% for SMW research, and 72% for DMW research. Microstructure observations are commonly performed in both SMW and DMW research, with an equal modus value of 64%. The third most commonly performed test type in SMAW research is hardness testing, with a modus value of 64% for SMW and 60% for DMW. Deposition rate is a test type that has not been utilized in SMW research, while distortion has not been employed in DMW research. This analysis has identified research gaps that can provide valuable references for future studies. Conducting SMAW research for SMW cases using previously unexplored parameters such as heat input, post-heating, voltage, joint type, and deposition rate would be beneficial as they can address the data gaps in those specific cases. Conversely, there is a lack of data on SMAW characteristics for DMW cases, including parameters such as material thickness, polarity, hybridization, and distortion testing. One promising avenue for SMAW research is investigating fatigue testing, as it has yet to be utilized in both SMW and DMW cases.

4 Conclusion

A research gap analysis was conducted for SMAW joints in both SMW and DMW cases, taking into account the frequency levels of parameters and testing types used in previous studies. The analysis revealed that welding current and electrode type were the parameters most frequently investigated in SMAW research. Parameters such as heat input, post-heating, voltage, and joint type have not been utilized in SMW research, while material thickness, polarity, and hybridization have not been employed in DMW research. The most commonly testing type in SMAW research include tensile strength, microstructure observation, and hardness. Deposition rate measurement has not been utilized in SMW research, while distortion measurement has not been employed in DMW research.

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