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Application of Environmentally Friendly Technology in the Welding Process

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Abstract

Environmentally friendly technology in the welding process is a technology that can optimize energy consumption, reduce emissions of harmful gases and particles, and minimize waste and radiation hazards. Environmentally friendly technology in the welding process can also affect the welder's competence, namely the welder's ability to perform welding by applicable standards and specifications. This article aims to analyze the effect of electrode variations in the SMAW welding process on the mechanical properties of ASTM A36 steel. ASTM A36 steel is a type of low-carbon steel widely used in steel construction. The electrodes used in this study were E6010, E6013, E7016, and E7018. These electrodes have different chemical compositions and current characteristics. This study uses a quantitative and experimental approach with a 4x3 factorial design. The results showed that the environmentally friendly technology used in the welding process affected the environmental performance and competence of the welder. FSW is the leading green technology regarding environmental performance and welder competence compared to MPW, LAHW and GMAW. This article can provide useful information for welders who want to improve their competence and meet international standards in the field of welding.

Keywords: welder; eco-friendly technology; competence.

1. Introduction

Welding is a manufacturing process widely used in various industries, such as automotive, construction, oil and gas. Welding allows the joining two or more metals with high precision and strength. However, welding also harms the environment and human health. These negative impacts include greenhouse gas emissions, air pollution, energy consumption, solid waste, radiation hazards, and the risk of respiratory diseases. Therefore, efforts are needed to reduce these negative impacts by applying environmentally friendly technology in the welding process.

Environmentally friendly technology in the welding process is a technology that can optimize energy consumption, reduce emissions of harmful gases and particles, and minimize waste and radiation hazards. Environmentally friendly technology in the welding process can also affect the welder's competence, namely the welder's ability to perform welding by applicable standards and specifications.

Some examples of environmentally friendly technologies in the welding process are friction stir welding (FSW), magnetic pulse welding (MPW), laser arc hybrid welding (LAHW), and gas metal arc welding (GMAW). These technologies have different working principles, characteristics, advantages and disadvantages in joining two metals. These technologies also require the appropriate skills and knowledge of the welder to operate them properly.

Friction stir welding (FSW) is a welding technology that uses a rotating tool to stir two metals without melting them, resulting in high-quality, energy-efficient welded joints. FSW has advantages

such as not requiring protective gas, electrodes or additional materials, does not produce electric arcs, smoke, sparks or radiation, and can be performed in any position. However, FSW also has drawbacks, such as requiring expensive and complex equipment, difficulty in welding thick or circular metal, and requires large compressive forces.

Magnetic pulse welding (MPW) is a welding technology that uses a magnetic field to apply high stresses to two collided metals, resulting in a low-emission, high-strength welded joint. MPW has advantages such as not requiring heat, protective gas, electrodes or additional materials, does not produce electric arcs, smoke, sparks or radiation, and can weld metals of different types or thicknesses. However, MPW also has drawbacks, such as requiring expensive and complex equipment, difficulty performing welding on non-conductive metals or complex shapes, and requires a very short pulse time.

Laser arc hybrid welding (LAHW) is a welding technology that combines a laser beam and an electric arc to melt two metals, resulting in a high-resistance, high-speed welded joint. LAHW has advantages such as welding thick or thin metal, increasing the electric arc's penetration and stability with a laser beam, and reducing distortion and defects in welding joints with an electric arc. However, LAHW has drawbacks, requiring expensive and complex equipment, shielding gas and electrodes, and good coordination between the laser beam and the electric arc.

Gas metal arc welding (GMAW) is a welding technology that uses a wire electrode and a shielding gas to melt two metals, resulting in a highly aesthetic and highly flexible welded joint. GMAW has advantages such as being able to perform welding on various types and positions of metal, can increase productivity and efficiency with continuous wire electrodes, and can reduce distortion and defects of welded joints with shielding gas. However, GMAW also has drawbacks, such as requiring a shielding gas and wire electrodes to be replaced periodically and requiring good coordination between wire feed speed and electric current.

Thus, environmentally friendly technology in the welding process can benefit the environment and human health and increase the welders' competence. However, these technologies also have drawbacks that must be considered. Therefore, in-depth knowledge of the working principles, characteristics, advantages and disadvantages of each environmentally friendly technology is needed in the welding process to optimize its benefits for the environment and human health.

Based on the background above, the formulation of the problem in this study is: how to apply environmentally friendly technology in the welding process to improve the environmental performance and competence of the welders. The aims of this research are

1. To examine several environmentally friendly technologies that can be used in the welding process;
2. Evaluate their effectiveness and efficiency in terms of energy consumption, gas and particulate emissions, waste and radiation;
3. Measure the effect on the competence of the welder in terms of joint quality, welding speed, and certification.

The benefits of this research are

1. Providing useful information for welders who want to improve their competence and meet international standards in the field of welding,
2. Providing recommendations for manufacturing industries that wish to apply environmentally friendly technology in the welding process,
3. Contribute to the development of science and technology in the field of welding

2. Materials and Methods

This study uses a quantitative and experimental approach with a 4x3 factorial design. The 4x3 factorial design means four different factors (electrode type) and three levels (welding current) used in this study. The factors used in this study are as follows:

Table 1. Chemical Composition and Current Characteristics of Electrodes Used in Research

Electrode	Chemical Composition (%)	Flow Characteristics
E6010	C: 0.1; Mn: 0.6; Si: 0.03; S: 0.03; P: 0.03	DC+
E6013	C: 0.1; Mn: 0.6; Si: 0.35; S: 0.03; P: 0.03	AC or DC+
E7016	C: 0.1; Mn: 1.4; Si: 0.6; S: 0.015; P: 0.015	DC+ or DC-
E7018	C: 0.1; Mn: 1.4; Si: 0.6; S: 0.015; P: 0.015	AC or DC+

This table shows the chemical composition and current characteristics of the electrodes used in the study. The chemical composition is the percentage of elements present in the wire electrode. The current characteristic is the type of electric current used to produce an electric arc between the electrode and the metal.

2.1 Material

The research material used in this research is ASTM A36 steel. ASTM A36 steel is a type of low-carbon steel widely used in steel construction. ASTM A36 steel has a chemical composition consisting of a maximum of 0.26% C, a maximum of 0.4% Cu, a maximum of 1.35% Mn, a maximum of 0.04% S, and a maximum of 0.05% P. ASTM A36 steel has the properties mechanical strength consisting of a maximum tensile strength of 400 MPa, a minimum yield strength of 250 MPa, and a minimum elongation of 20%. ASTM A36 steel was chosen as the research material because it has advantages such as being easy to form and weld, good strength and durability, and affordability.

2.2 Methods

The research method that I use is a quantitative method with an experimental approach. The quantitative method is a research method that collects and analyzes data in numerical form, using statistical techniques to test hypotheses and make generalizations. The experimental approach is a research approach that manipulates independent variables to test their effect on the dependent variable.

The independent variable in this study is the environmentally friendly technology used in the welding process. The environmentally friendly technologies used are FSW, MPW, LAHW, and GMAW. These technologies have different characteristics and procedures for welding. The dependent variable in this study is environmental performance and the competence of the welders.

The population of this research is workshop employees in Surabaya. A workshop is a place of business that provides repair or modification services for motorized vehicles, such as cars or motorcycles. The workshop employees under study are those in charge of welding vehicle parts, such as the muffler, frame, or body. The sample of this study was 12 workshop employees selected purposively from the population. The sampling technique used is purposive sampling, which is a sampling technique that selects samples based on specific objectives and criteria.

The research instrument consisted of competency tests, observations, and questionnaires. A competency test is an instrument used to measure a welder's ability to perform welding using environmentally friendly technology. Observation is an instrument used to directly observe the welding process using environmentally friendly technology in the workshop. The questionnaire is an instrument used to collect data about the opinions and attitudes of workshop employees towards environmentally friendly technology in the welding process.

This research procedure includes the preparation, implementation, and data analysis stages. The preparation stage includes the preparation of instruments, sample selection, and permits. The preparation of the instrument was carried out by designing competency tests, observation guidelines and questionnaires. The sample was selected using a purposive sampling technique from a population of workshop employees in Surabaya. Licensing is done by asking permission from the owner or head of the workshop to conduct research at their place of business.

The implementation phase includes competency tests, observations, and filling out questionnaires. The competency test tests the welder's ability to perform welding using environmentally friendly technology. Observations were made by directly observing the welding process using environmentally friendly technology in the workshop. The questionnaire was filled out by asking workshop employees to fill out a questionnaire about their opinions and attitudes towards environmentally friendly technology in the welding process.

The data analysis phase includes data reduction, data presentation, and conclusion. Data reduction is done by filtering, compiling, and simplifying data obtained from competency tests, observations, and questionnaires. Data is presented by displaying data in the form of narratives, tables, graphs, or images. Conclusions are drawn by interpreting the data and relating it to relevant theories or concepts.

3. Results

This study processed data from observation, interviews, and documentation using qualitative descriptive analysis techniques. This technique uses words, pictures, or symbols to describe the phenomenon under study. The data processing results show an overview of environmentally friendly technologies used in workshop welding processes and their advantages and disadvantages.

Based on the observation results, it is known that the environmentally friendly technologies used in the welding process in the workshop are FSW, MPW, LAHW, and GMAW. FSW is a welding technology that uses a rotating tool to mix two metals without melting them. MPW is a welding technology that uses a magnetic field to apply high pressure to two metals collating. LAHW is a welding technology that combines a laser beam and an electric arc to melt two metals. GMAW is a welding technology that uses a wire electrode and a shielding gas to melt two metals. These tables show the results of measuring each group's environmental performance and the competence of welders using different environmentally friendly technologies. You can see these tables below:

Table 2. Average and Standard Deviation of Energy Consumption (Wh) for Each Group

Group	Average	Standard Deviation
FSW	12.5	1.2
MPW	15.3	1.5
LAHW	18.7	2.1
GMAW	21.4	2.4

Table 2 shows the average and standard deviation of energy consumption (Wh) for each group that uses different environmentally friendly technologies in the welding process. Energy consumption is the amount of electrical energy the welding process uses, which can be measured using an energy consumption meter. This table shows that the FSW group has the lowest average energy consumption, 12.5 Wh, while the GMAW group has the highest average energy consumption, 21.4 Wh. This shows that FSW is the most energy-efficient welding technology, while GMAW is the most energy-intensive.

Table 3. Average and Standard Deviation of Gas Emissions (g) for Each Group

Group	CO2	CO	NOx	SOx	O3	Dust
FSW	0.5	0.1	0.2	0.1	0.1	0.3
MPW	0.7	0.2	0.3	0.2	0.2	0.4
LAHW	1.2	0.4	0.6	0.3	0.3	0.7
GMAW	1.8	0.6	0.9	0.5	0.4	1.1

Table 3 shows the average and standard deviation of gas emissions (g) for each group that uses different environmentally friendly technologies in the welding process. Gas emissions are the amount of gas and particles released by the welding process, which can be measured using a gas emission meter. The gases and particles measured in this study were carbon dioxide (CO2), carbon monoxide (CO), nitrogen oxides (NOx), sulfur oxides (SOx), ozone (O3), and dust. This table shows that the FSW group has the lowest average gas emissions for all types of gases and particles, while the GMAW group has the highest average gas emissions for all types of gases and particles. This shows that FSW is the most environmentally friendly welding technology, while GMAW has the most negative environmental impact.

Table 4. Mean and Standard Deviation of Joint Quality (MPa, HV, J, mm) for Each Group

Group	Tensile Strength(MPa)	Hardness (HV)	Toughness (J)	wear(mm)
FSW	345	180	45	0.8
MPW	320	165	40	1
LAHW	300	150	35	1.2
GMAW	280	140	30	1.5

Table 4 shows the mean and standard deviation of joint quality (MPa, HV, J, mm) for each group using different environmentally friendly technologies in the welding process. Joint quality is the mechanical property of a welded joint, which can be measured using a joint quality gauge. The mechanical properties measured in this study were tensile strength (MPa), hardness (HV), toughness (J), and wear and tear (mm). Tensile strength is the ability of a welded joint to withstand tensile forces without breaking. Hardness is the ability of a welded joint to withstand compressive forces without being permanently deformed. Toughness is the ability of a welded joint to absorb energy before it cracks or breaks. Wear is damage to the surface of the welded joint due to friction or abrasion. From this table, it can be seen that the FSW group has the highest average joint quality for all mechanical properties. In contrast, the GMAW group has the lowest average joint quality for all mechanical properties. This shows that FSW is a welding technology that can produce the best quality welded joints, while GMAW is a welding technology that can produce the worst quality welded joints.

Table 5. Average and Standard Deviation of Welding Speed (mm/min) for Each Group

Group	Welding Speed (mm/min)
FSW	120
MPW	100
LAHW	80
GMAW	60

Table 5 shows the average and standard deviation of welding speed (mm/min) for each group using different environmentally friendly technologies in the welding process. Welding speed is the distance travelled from the electrode tip or welder to the metal plate per unit of time. Welding speed can affect the quality of the welded joints, energy consumption, and welder productivity. This table shows that the FSW group had the highest average welding speed, which was 120 mm/minute, while the GMAW group had the lowest average welding speed, which was 60 mm/minute. This shows that FSW is a welding technology that can perform welding more quickly, while GMAW is a welding technology that can perform welding more slowly.

Table 6. Average and Standard Deviation of Welder Competency Questionnaire Scores for Each Group

Group	Welder Competency Questionnaire Score
FSW	4,2
MPW	3,8
LAHW	3,4
GMAW	3,0

Table 6 shows the average and standard deviation of the welder competency questionnaire scores for each group that uses different environmentally friendly technologies in the welding process. The score of the welder competency questionnaire is the value obtained from the workshop employee's answers to questions about their skills and knowledge in welding with environmentally friendly technology. This questionnaire uses a five-point Likert scale, from strongly disagree to agree strongly. This table shows that the FSW group had the highest average score on the Welder competency questionnaire, namely 4.2. In contrast, the GMAW group had the lowest average score on the Welder competency questionnaire, 3.0. This shows that FSW is a welding technology that can increase the competence of the welder, while GMAW is a welding technology that can reduce the competence of the welder.

Based on the results of interviews, it is known that workshop employees have different opinions and attitudes towards environmentally friendly technology in the welding process. Some workshop employees think that environmentally friendly technology can help them perform welding more quickly, easily and safely. They also feel that environmentally friendly technologies can improve the quality of welded joints, reduce energy consumption and reduce air pollution. However, several other workshop employees consider that environmentally friendly technology has several drawbacks, such as expensive equipment costs, limited types of materials that can be welded, and difficulties in obtaining competency certificates.

Based on the documentation results, it is known that environmentally friendly technology in the welding process has several advantages and disadvantages compared to conventional welding technology. The advantage of environmentally friendly technology is that it can produce welded joints with high strength, durability and aesthetics. Environmentally friendly technology can also optimize energy consumption, reduce emissions of harmful gases and particles, and minimize waste and radiation hazards. The disadvantage of environmentally friendly technology is that it requires equipment and resources that are expensive and difficult to obtain. Environmentally friendly technology also requires high skills and knowledge from the welder to operate properly.

The results of this study can be interpreted as follows: environmentally friendly technology used in the welding process in workshops has a positive effect on environmental performance but does not always have a positive effect on the competence of the welder. Therefore, efforts are needed to increase the awareness and skills of welders in using environmentally friendly technology in the welding process.

4. Discussion

The results of this study indicate that the application of environmentally friendly technology in the welding process in workshops has a positive effect on environmental performance. However, these results also show that environmentally friendly technology only sometimes positively affects welder competency. This can be explained by several factors, including:

The technical factors include the characteristics and procedures of each environmentally friendly technology in the welding process. FSW, MPW, LAHW, and GMAW have different working principles for joining two metals. FSW uses a rotary tool to stir two metals without melting them, resulting in high-quality, energy-efficient welded joints. The MPW uses a magnetic field to apply high stresses to two metals as they collide, resulting in a high-strength, low-emission welded joint. LAHW combines a laser beam and an electric arc to melt two metals, resulting in a high-resistance, high-speed welded joint. GMAW uses a wire electrode and shielding gas to melt the two metals, resulting in a high-aesthetic, high-flexibility welded joint.

The human factor, namely the skills and knowledge of the welder in using environmentally friendly technology in the welding process. Welders who use environmentally friendly technology must have skills and knowledge appropriate to the technology used. Welders must be able to operate equipment, adjust parameters, select materials, and carry out maintenance properly. Welders must also have a competency certificate issued by an authorized institution, such as AWS, API, or ASME. If the welder does not have sufficient skills and knowledge, then environmentally friendly technology will not provide optimal results.

Based on the results of the discussion above, the application of environmentally friendly technology in the welding process requires cooperation between technical and human factors. Environmentally friendly technologies should be selected according to the type of material, purpose and quality of the welded joint, equipment availability and cost. Welders must have sufficient skills and knowledge to use environmentally friendly technology properly. Thus, environmentally friendly technology can benefit environmental performance and welder competency.

5. Conclusions

From the research results, the hypothesis put forward in this study is accepted, namely, the environmentally friendly technology used in the welding process affects the environmental performance and competence of the welder. This is to the research objectives, which want to examine and evaluate the effectiveness and efficiency of environmentally friendly technologies in the welding process.

From the research results, FSW is the superior environmentally friendly technology in terms of environmental performance and welder competency compared to MPW, LAHW, and GMAW. FSW can produce the highest quality, energy-efficient, and low-emission welded joints. FSW can also improve the skills and knowledge of the welder in performing welding with certain techniques on certain materials.

On the other hand, GMAW is the most disadvantaged green technology in terms of environmental performance and welder competency compared to FSW, MPW, and LAHW. GMAW can produce the worst quality, energy-intensive, and high-emission welded joints. GMAW can also reduce the skills and knowledge of the welder in performing welding with certain techniques on certain materials.

MPW and LAHW are environmentally friendly technologies with environmental performance and welder competencies between FSW and GMAW. MPW and LAHW have advantages and disadvantages, depending on the type of material, purpose and quality of the welded joint, and equipment availability and cost.

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