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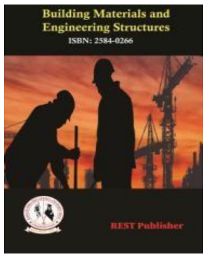

Optimization of Welding Process Parameters using the MOORA Method

*** Sathiyaraj Chinnasamy, Vimala Saravanan, Nathiya Murali, M. Ramachandran**

REST Labs, Kaveripattinam, Krishnagiri, Tamil Nadu, India

*Corresponding author: sathiyaraj@restlabs.in

Abstract: *In order to increase the overall quality and effectiveness of the welding process, it is necessary to methodically and effectively identify the ideal combination of welding factors utilising the Multi-objective Optimisation Based on Ratio Analysis technique. A multi-criteria decision-making process called MOORA assesses several welding parameters and the conditions that go along with them in order to improve welding quality, boost output, and cut down on defects. The possibility of Multi-objective Optimisation Based on Ratio Analysis to contribute to developments in the fields of welding and fabrication is what makes this study topic so important. In order to increase the overall effectiveness, efficacy, and quality of the welding process, researchers and engineers can use MOORA to systematically evaluate and optimise welding factors. An evaluation and ranking of options based on numerous criteria or objectives are done using the Multi-Objective Optimisation Based on Ratio Analysis approach of decision-making. It offers a methodical way to assess several possibilities and choose the best course of action. In Multi-Objective Optimisation Based on Ratio Analysis method, the decision problem is typically characterized by several criteria or objectives that need to be considered simultaneously. These criteria could be quantitative or qualitative & can represent various aspects of the problem, such as cost, quality, efficiency, and performance. Alternate Parameters taken as Wielding process parameters 1 to 7. Evaluation Parameters taken as Bandwidth, Reinforcement, Penetration, Width of HAZ. From the rank table in result we can get that wielding process parameters 4 has the first rank whereas wielding process parameters 1 has the last rank (seventh rank). the first ranking wielding process parameters 4 is obtained with the lowest quality of wielding process parameters 1*

Keywords: *MOORA, Bandwidth, Reinforcement, wielding process parameters*

1. INTRODUCTION

A multi-objective optimisation problem in welding was resolved using the MOORA method. In this article, six decision-making issues are discussed, including choosing the right welding parameters for a variety of welding methods, including submerged arc the welding process, gas tungsten welding, gas metal welding, CO2 laser welding, and friction stir welding. The MOORA approach almost always yields results that almost exactly match those of earlier studies, proving the method's relevance, viability, and adaptability in addressing several of challenging decision-creating issues in the modern manufacturing environment [1]. By applying a tiny amount of a second substance to the surface of a base material, the process of metal plating protects the base material. This procedure is important because it protects against corrosion and wears to the underlying material while also being economical. Different coating procedures are mostly used to lower the cost and enhance the performance of engineering components. Due to its high efficiency, dependability, high deposition rate, cheap cost, user-friendliness, and appropriateness for both a non-fer and ferrous metals, GMAW is one of the most effective techniques for cladding. The GMAW technique is used to deposit a thin film of stainless steel on an ordinary steel substrate for stainless steel cladding [2]. In the MIG welding process, an electric arc is created over the work component with the metal electrode feed, heating the piece to achieve fusion. GMAW, or Gas Metal Arc Welding, is another name for MIG. A gas shielding process that works well in every environment is gas metal arc welding. An inert gas can all be used as the shielding gas. Almost all metals, including stainless steel, carbon steel, alloy steel, and aluminium, can be utilised with it. An investigation of the use of flux gas for metal arc welding, The variety and content of inorganic composite flux materials are varied. According to reports, some fluxes work well with particular types of materials. Oxides and halides are examples of activating fluxes. It has been observed that oxide coats, which boost welding speed and efficiency [3]. By heating an ongoing metal filler electrode and working piece with a welding arc, the computerised GMA (gas metal arc) welded technique allows for the fusion of metals. Wire feed rate, arc current, and other welding parameters are controlled by a controller for welding voltage. A versatile, multi-factor metal fabricating technology is welding. Bead geometry and welding quality can be affected directly or indirectly by the intricate interactions between numerous welding factors. The reactions or welding qualities of the parameters for welding should therefore be optimised. Due to its usefulness, the multi-application optimisation by ratio analysis method has had tremendous success in designing experiments for multi-parameter issues [4]. A multi-application optimisation method called the MOORA method is employed in industrial applications to address multi-objective decision-making issues. The best choice among options with many competing objectives can be determined using multi-objective decision making techniques, a technique that combines the Taguchi and MOORA methods to identify the best factor placements [5]. In any conductive material, Wire Electric Discharge Machining (WEDM) is a form of EDM method that generates intricate shapes and profiles with extreme precision. The aerospace, nuclear, automotive, printing, and die sectors all make extensive use of the WEDM process. A series of isolated electrical sparks caught between wire electrodes erode the workpiece using this thermoelectric material removal technique. A piece of work submerged in a dielectric fluid. A less quantity of material off the surface of the workpiece can melt and vaporise because to the electrical discharge's high heat output. These vaporised substances cool down in the dielectric to generate debris, which is then eliminated by flushing the dielectric fluid. Using WEDM process is ideal for smooth parts without any mechanical stresses as no cutting forces are applied [6]. Over the past few decades, the field of composite materials has expanded quickly to involve metal matrix composite items, ceramic composites through and polymer-matrices composites. Metal grid plastic composites have received a lot of attention because of the range of microstructures and characteristics they may offer. In order to create a material with superior qualities, the primary idea behind composite design is to combine a continuous metal matrix's ductility and formability with an stiffness and load-bearing capabilities of quartz or refractory reinforcements. High specific strength, improved alloy qualities at high temperatures, little thermal expansion, excellent wear resistance, and great structural strength are all advantages that alloys have over other materials [7]. Using the MOORA approach, Kadak et al. Shows or displays the simultaneous welding process parameters, to demonstrate the usefulness of this technique, six instances were taken into consideration. This method showed that it might be used to address complex industrial decision-making issues in a mass setting. Using the Multi-Objective Optimisation Based on Ratio Analysis approach, Chaturvedi et al. evaluated the electro-chemical machining process to determine the best machining parameters. This approach was trustworthy for achieving various goals when quality improvement was taken into account for any procedure. Chakraborty created the MOORA approach to address dilemmas with decision-making in a manufacturing setting. To illustrate the MOORA approach, six charts were taken into account [8]. Adalarasan and Sundaram38 predicted the ideal size of a continual friction welding pores for Al/SiC/Al2O3 composites using a combination approach of GT-PCA. When Lahane et al employed the WPCA stroke to optimise the various WEDM process responses for high fast steel; they found that it outperformed other methods in terms of overall quality. Saha and Mondal40 all simultaneously enhanced surface roughness, and machining time, among other performance attributes [9]. Industries frequently employ unconventional production methods to attain high precision and desired product quality. As a result, choosing the right machining parameter before beginning work has become crucial. To address the loft issue, various optimisation techniques are available. In order to address numerous multi-objective issues got to in real-time manufacturing businesses; the current work develops a novel technique known as multi-objective optimisation employing ratio analysis (MOORA). The research discussed here focuses on using the MOORA approach to solve some challenges involving non-traditional machining methods and several criteria [10]. Stainless steel was used for the work piece and AiSiMg was used for the electrode. By using additive manufacturing, electrodes were made. The outcome showed that the electrode worked effectively. Process parameter optimisation has been done effectively using the MOORA approach. Liang et al. employed the Taguchi approach based on MOORA to optimise welding process parameters. The Taguchi orthogonal loop served as the planning framework for the tests. After estimating the electrical signal to noise ratio, the MOORA approach was effectively used. The outcome shown that multi-objective problems can be solved using the Taguchi approach based on MOORA [11]. The term "shape memory" refers to a plastic object's capacity to recall its original shape when subjected to magnetic, thermo mechanical or thermal pressures. Arne Olander discovered shape memory alloy, or “smart alloy" in 1932, and Vernon coined the name "shape memory" for his polymer dental materials in 1941. As William Buehler and Frederick Wang proved SME in the nickel-titanium mixture nitinol (Naval Ordnance Laboratory), the significance of shape memory materials (SMMs) became clear. Shape memory composites (SMAs), which have a distinctive shape memory effect (SME), pseudo elastic property, and super elastic property, have a wide range of applications in a variety of industries, including aerospace, automotive, robotics, biological, and civil structures [12]. When applied to conductive materials, Electrical Discharge Machining serves as a commonly utilised non-traditional machining technique that produces elaborate or complex geometries. Choosing the best control variable parameters is crucial for any manufacturing sector looking to boost productivity and other performance traits like surface integrity. When the suggestions for MOORA-PCA hybrid findings were compared to the conventional MOORA results, it was discovered that the suggested methodologies accurately predicted the responses [13]. The technique of cladding involves placing a reasonably thick filling material over carbon and less alloy steel metals in order to improve surfaces given desired qualities. Cladding is done by a variety of welding techniques. Weld cladding is a method primarily used to extend the lifespan and lower the price of engineering components. It is a technique for creating a surface that is resistant to corrosion. Due to its high dependability, cheap cost, simplicity of usage, high efficiency, and elevated deposition rate during ferrous and non-ferrous metals, GMAW are among the acceptable welding techniques used for weld cladding [14]. The three alternate arc welding procedures in this scenario are shielded metal welding with arcs, tungsten arc gas welding, and gases for metal arc welding. Weld effectiveness, operator fatigue, skill level, post-weld cleaning requirements, consumable availability, and initial preparation requirements are all factors taken into account. Weld quality and consumable availability are two of these properties that are positive, whereas the others are unfavourable. Decisions are frequently made in complicated environments where there is a requirement for flexibility, subjectivity of decision makers, and resilient and flexible manufacturing processes. Generally speaking, decisions regarding the layout of goods, facility context, power layout, your supplier, material, information, etc. must be made quickly and effectively throughout the cycle of life of a production system [15].

2. METHODOLOGY

The practise of continuously optimising two or more competing attributes while keeping in mind specific restrictions is known as multi-objective optimisation often referred to as multi-criteria and multi-attribute reference. There are many different fields, including the design of products and processes, finance, aircraft design, the petroleum and natural gas sector, manufacturing, and automobile design, where it is necessary to make the best choices possible when there are trade-offs between the objectives or competing goals. Typical instances of multi-objective optimisation challenges include increasing profits while lowering product costs, maximising vehicle efficiency while minimising fuel consumption, and minimising weight while maximising strength of a specific engineering component [16]. Designers need to have an accurate grasp of what is needed for function and in-depth knowledge of factors for just about every component when choosing the best substance from an expanding number of potential options, each with a multitude of unique uses, advantages, and limitations. Specifications for a certain engineering design. The use of the wrong material might result in significant expenditures and early component or product failure. One of the most difficult challenges in the creation and creation of products for diverse engineering applications is choosing the appropriate materials for various components. To produce intended outcome along with minimal cost involvement and precise application, designers must identify and choose the appropriate materials with defined functionalities [17]. The MOORA technique use high ratio estimation and dimensionlessness measurement to rank contractors objectively. Ratio architecture and reference point method are its two basic parts. Attributes are used to describe objectives, such as "tonnes of sulphur dioxide each year" for the goal of reducing emissions. The reporter trait and objectivity are constantly linked. As a result, allusions to objectivity entail the reporter characteristic as well [18]. There are a number of objectives connected to contractor (costs, experience, and efficiency) & ownership (quality, length, and price) in the context of application. By using dimensionless ratios, the MOORA technique overcomes the difficulty of normalising these objectives using diverse units. In the first half of the approach, these ratios are integrated, and in the second part, they are treated as distances from a reference point. A robustness test is performed using outcomes from both components, which mutually constrain one another. Additionally, MOORA's multi-objective optimisation outperforms other approaches in terms of performance. Both MOORA components yielded rankings that were comparable in the specific instance of the Lithuanian facilities sector, demonstrating the reliability of the findings [19]. The Multi-Objective Optimisation based on Ratio Analysis is a simple and computationally effective strategy that aids decision-makers in removing inappropriate options and determining the best choice. It is made to optimise different welding parameters and complements current selection processes. The MOORA approach has been investigated and used by numerous researchers in a variety of applications, proving its usefulness, viability, and adaptability [20]. The MOORA approach, which has an inbuilt machine solver for producing dimensionless numbers, is recommended to get around this problem. Additionally, this feature enables the use of an extra non-subjective reference theory. The selection & prioritisation of objectives become objective when all stakeholders agree on them, the ratio calculation-based MOORA approach satisfies the first six requirements of multi-objective optimisation. It also fulfils the seventh requirement by using two different approaches. The MOORA method, which consists of a rate systems and the point of reference approach, provides an answer to these problems [21]. The MOORA system is the decision support tool for choosing scholarship candidates who will raise their academic standing. The MOORA approach is used to help decision-making processes overcome a number of obstacles. The decision advice system approach is currently gaining popularity as a computational technique. Using a system that supports decisions gives decision-makers the ability to choose options that are easily accessible and expeditious, leading to efficient and rapid solution generation [22]. MOORA is the simultaneous improvement of several competing attributes while adhering to predetermined limitations. The production system's life cycle

includes jobs including the creation of products, design of processes, picking materials, cutting tool choice, materials handling system choice, and advanced manufacturing technique selection. These tasks all provide criteria-related issues at various phases. The input data is normalised within the result matrix in the ratio system approach to achieve dimensionless. The goal of normalisation is to ensure uniform comparability by enabling meaningful comparisons across all components of the decision matrix [23]. The establishment of a sustainable supply chain depends critically on the complex process of supplier selection. Fuzzy MOORA, a multi-objective fuzzy optimisation approach, is used in this study to evaluate suppliers' overall performance. It recognises that suppliers face a variety of risks, including natural disasters and unstable political conditions. A technique known as failure mode and effects analysis (FMEA) is used to assess supplier risk. Additionally, a fresh multi-objective mathematical model is created that simultaneously takes supplier stability and order distribution into account, providing a thorough method of supplier selection [24]. Numerous multi-criteria decision-making techniques have been created over time in the field of operational research. The recently developed MOORA method, however, stands out being a more concentrated strategy that still has opportunity for growth. Despite being a relatively new approach, MOORA has already been used to solve a variety of business, management, and construction issues. It has shown to be especially useful for selecting the best road design options. By building on past research, Brauers and Savatskas (2006) developed the multi-Objective Optimisation Based on Ratio Analysis technique, which offers a framework to multi-objective optimisation utilising ratio analysis [25].
Alternate Parameters: Welding process parameters 1 to 7. The various elements or variables that are controlled and adjusted during the wielding process in order to achieve the required weld characteristics and results are referred to as welding process parameters. These factors are very important in determining the effectiveness, integrity, and calibre of the welding process. Welders & engineers can optimise the welding process according to specific criteria and achieve the desired weld characteristics by adjusting these variables.

Evaluation Parameters:
Bandwidth: The term "bandwidth" says that to the maximum quantity of data that may be transferred across a network / communication channel in a specific quantity of time.
Reinforcement: Reinforcement, in a general sense, refers to the act of strengthening or increasing a particular behavior or response. It involves providing consequences or stimuli that enhance the likelihood of a behavior recurring in the future. Reinforcement is a fundamental concept in psychology and behavior analysis, widely used in various fields, including education, parenting, and organizational management.
Penetration: Penetration refers to the act or process of entering, piercing, or passing through a material or surface. It is commonly used in various contexts, including physical, scientific, and metaphorical domains.
Width of HAZ: The width of the Heat-Affected Zone (HAZ) refers to the distance or measurement of the region surrounding a weld where the base material has been subjected to heat during the welding process, resulting in micro structural changes. The HAZ is the area adjacent to the fusion zone or weld metal where the material experiences thermal cycles but does not undergo complete melting.

3. RESULTS AND DICUSSION

TABLE 1. Data set

welding process parameters 1	9.36	3.28	1.58	2.11
welding process parameters 2	9.04	3.14	1.84	1.62
welding process parameters 3	10.72	3.75	1.91	1.98
welding process parameters 4	13.12	3.94	1.98	2.31
welding process parameters 5	11.65	3.43	2.37	3.65
welding process parameters 6	12.47	4.16	1.88	2.59
welding process parameters 7	13.75	4.32	2.26	3.1

Table 1 shows the values like: bandwidth, reinforcement, penetration and width of HAZ for seven wielding process parameters

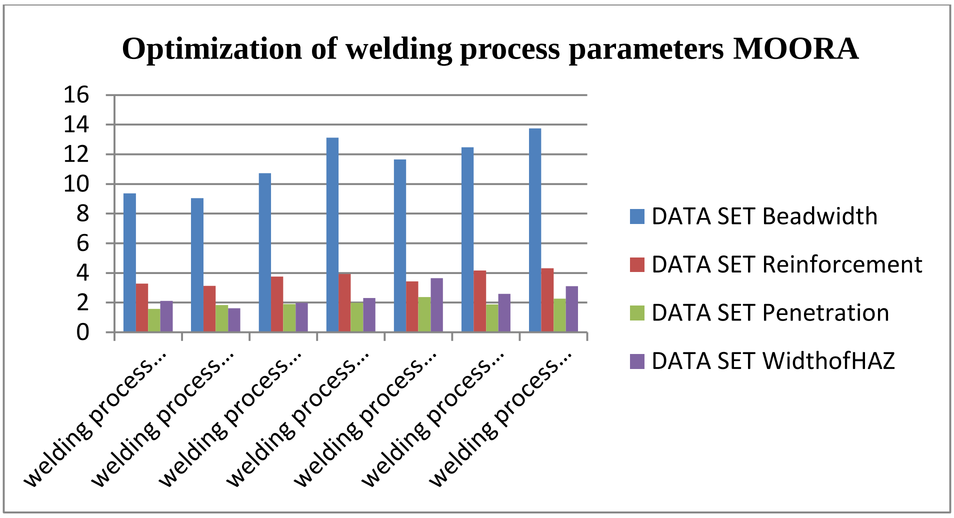

FIGURE 1. Optimization of welding process parameters MOORA

Figure 1 shows the schematic view of value for all the 7 wielding process parameters

TABLE 2. Normalized data

Bandwidth	Reinforcement	Penetration	WidthofHAZ
0.306	0.331	0.3	0.311
0.295	0.317	0.35	0.239
0.35	0.379	0.363	0.292
0.429	0.398	0.376	0.341
0.381	0.347	0.45	0.538
0.407	0.42	0.357	0.382
0.449	0.437	0.429	0.457

Table 2 provides the normalized data for the wielding process parameters

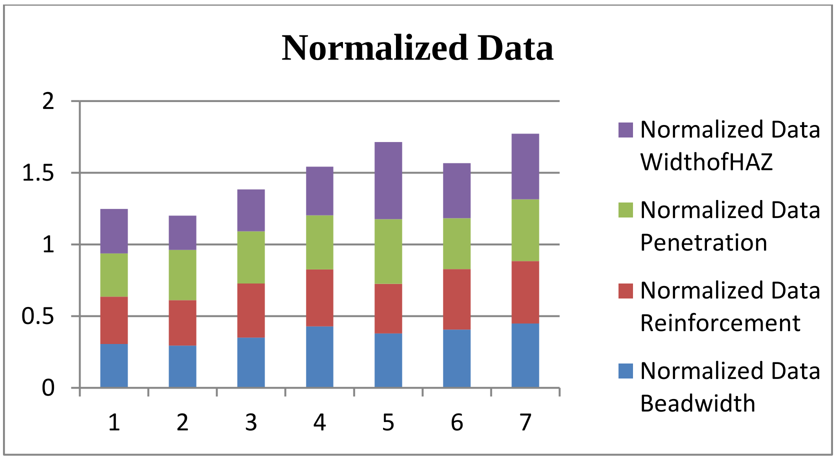

FIGURE 2. Normalized data

Figure 2 delivers a graphical view of normalized data for all 7 wielding process parameters.

TABLE 3. Weight data

Bandwidth	Reinforcement	Penetration	WidthofHAZ
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25

The weight of each wielding process parameters under for all the values: bandwidth, reinforcement, penetration and width of HAZ is displayed by Table 3.

TABLE 4. Weighted normalized decision matrix

Bandwidth	Reinforcement	Penetration	WidthofHAZ
0.076	0.083	0.075	0.078
0.074	0.079	0.087	0.06
0.088	0.095	0.091	0.073
0.107	0.1	0.094	0.085
0.095	0.087	0.113	0.135
0.102	0.105	0.089	0.095
0.112	0.109	0.107	0.114

Table four provides the weighted normalized decision data matrix for the wielding process parameters for values like: bandwidth, reinforcement, penetration and width of HAZ

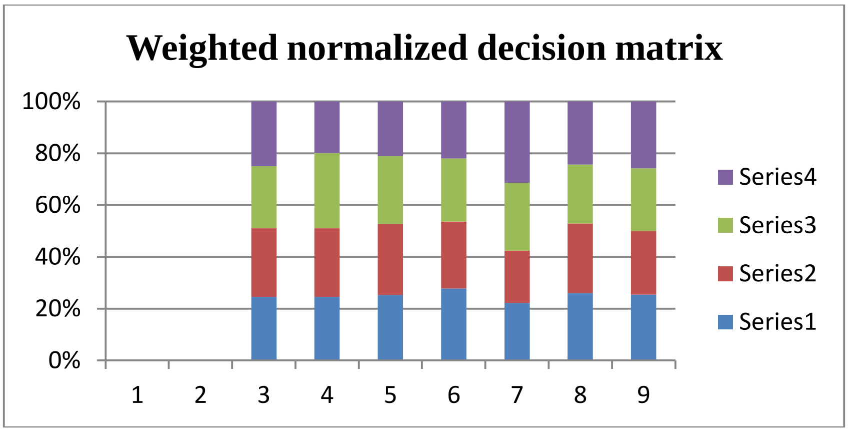

FIGURE 3. Weighted normalized decision matrix

Graph 3 displays the weighted normalized matrix for given wielding process parameters for the values like: bandwidth, reinforcement, penetration and width of HAZ.

TABLE 5. Assessment value

welding process parameters 1	0.156557518
welding process parameters 2	0.180821816
welding process parameters 3	0.200005716
welding process parameters 4	0.215567115
welding process parameters 5	0.159790612
welding process parameters 6	0.200741996
welding process parameters 7	0.214482655

Table 5 provides data of assessment value for all the seven wielding process parameters

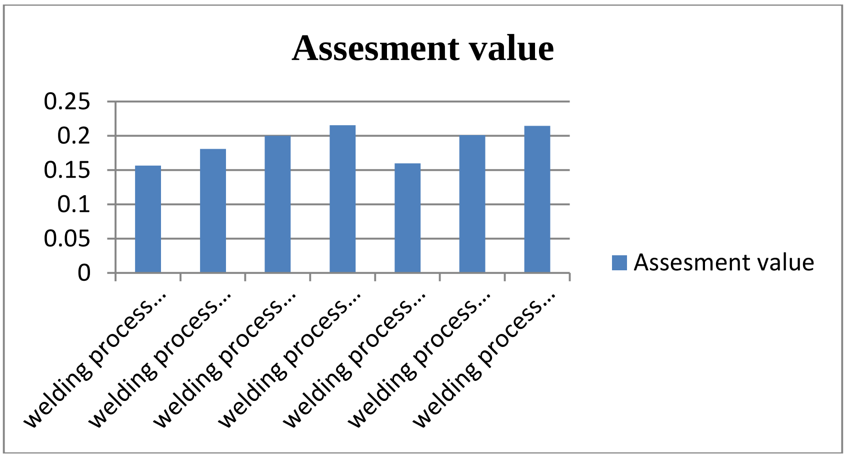

FIGURE 4. Assessment value

Figure 4 displays the assessment value for wielding process parameters 1 to 7

TABLE 6. Rank

Rank	
welding process parameters 1	7
welding process parameters 2	5
welding process parameters 3	4
welding process parameters 4	1
welding process parameters 5	6
welding process parameters 6	3
welding process parameters 7	2

Table 6 provides rank for weld process parameters 1, weld process parameters 2, weld process parameters 3, wield process parameters 4, weld process parameters 5, weld process parameters 6 and weld process parameters 7

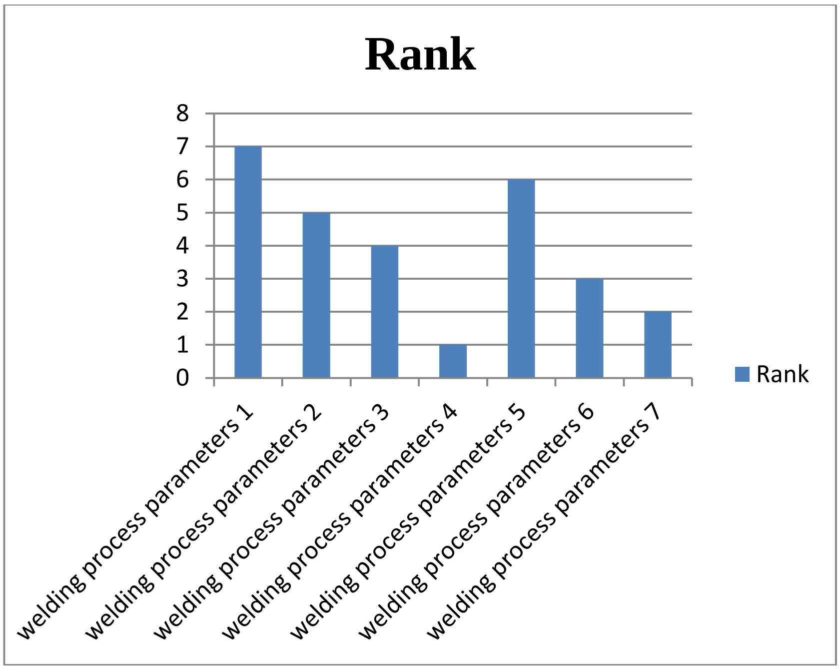

FIGURE 5. Rank

From figure 5 we can get the rank of welding process parameters 1, welding process parameters 2, welding process parameters 3, welding process parameters 4, welding process parameters 5, welding process parameters 6 and welding process parameters 7.

4. CONCLUSION

In order to handle multi-criteria optimisation issues within the welding sector, the MOORA technique was used. The six choice difficulties that arise when choosing appropriate welding parameters for different welding techniques, including submerged arc welding, tungsten gas arc welding, gas-metals arc the welding process, CO2 laser welding, & friction stir welding, are the focus of this study. The results from using the MOORA technique closely match those from earlier studies, demonstrating the system's applicability, practicality, and adaptability in addressing challenging decision-making issues in the modern manufacturing environment. When dealing with decision-making problems with many objectives, the MOORA approach is a powerful multi-objective optimisation tool used in industrial settings. The best choice can be made from options with competing objectives using multi-objective decision-making (MODM) methodologies. A technique known as multi-objective optimisation, or programming, can be used to determine the best placements for factors by combining the MOORA and Taguchi approaches. This method makes it possible to simultaneously optimise two or more references or characteristics that are in conflict while taking certain restrictions into account. In many different sectors, including the design of goods and processes, finance, aviation design, the oil and gas business, manufacturing industry, and vehicle design, optimal decisions must be made while weighing trade-offs or opposing objectives. These situations are known as multi-objective optimisation issues. Increasing profits while lowering product costs, increasing productivity while lowering fuel consumption, and balancing weight reduction and strength maximisation for engineering components are a few examples of multi-objective optimisation tasks, Designers need to have a thorough awareness of their functional needs and in-depth knowledge of the unique considerations related to each component in order to choose the best material from a broad spectrum of possibilities. These factors serve as guidelines for the current engineering design, taking into consideration the traits, applications, benefits, and drawbacks of each alternative. A poor choice of materials can have a major financial impact and hasten the early failure of products or components. Designing and creating engineering products is a significant difficulty in terms of selecting the right materials for various components. Designers must find and use materials that perform particular activities in order to produce the intended result with the lowest possible cost and the broadest possible applicability. In MCDM, Choosing the best product while taking into account several factors that frequently disagree with one another is a common difficulty

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