COMPARATIVE MULTI-CRITERIA OPTIMIZATION OF TUNGSTEN INERT GAS (TIG) WELDING PARAMETERS USING TOPSIS AND COPRAS TECHNIQUES

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Abstract
This study presents a comparative multi-criteria optimization of Tungsten Inert Gas (TIG) welding parameters using the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Complex Proportional Assessment (COPRAS) methods. The study aimed to identify the most suitable combination of welding voltage, current, and shielding-gas flow rate based on the combined mechanical performance of welded joints. Twenty experimental runs formulated using design exert 7.01 were evaluated using tensile strength, elongation, and hardness as equally weighted beneficial criteria. The experimental parameters included welding voltages of 16–25 V, currents of 96–213 A, and shielding-gas flow rates of 11–19 L/min. The measured mechanical properties varied across the experimental conditions, demonstrating the difficulty of selecting an optimal welding condition using a single response. TOPSIS ranked Run 6 as the best-performing alternative, with a voltage of 20.5 V, current of 154.5 A, and shielding-gas flow rate of 11 L/min. This condition achieved a tensile strength of 483.4 MPa, elongation of 16.3%, and hardness of 189.5 BHN. COPRAS also identified Run 6 as the highest-ranked alternative, indicating agreement between the two decision-making techniques regarding the preferred experimental condition. The results demonstrate the potential of integrating multi-criteria decision-making methods to balance competing mechanical responses and support systematic selection of TIG welding parameters. However, the selected condition represents the best-ranked alternative among the twenty experimental runs rather than a confirmed global optimum. Further investigations involving replicate experiments, weld microstructural characterization, and defect assessment are recommended to validate the robustness and practical applicability of the identified condition. This comparative framework provides a useful basis for evidence-based welding parameter selection and improved assessment of welded-joint performance.
Keywords: TIG welding; multi-criteria decision-making; TOPSIS; COPRAS; tensile strength; elongation; hardness; welding parameter optimization.

1 Introduction

Welding is one of the fundamental manufacturing and materials-joining process used in the fabrication of structural components, pressure vessels, automotive parts, aerospace structures, and industrial equipment. The quality and service performance of welded components depend considerably on the welding process, material characteristics, joint configuration, and process parameters (Guiqing et al., 2020; Assar et al., 2021; Mroczka et al., 2023; Ponnusamy et al., 2023; Liu et al., 2024; Uppada et al., 2025). Among the available fusion-welding techniques, tungsten inert gas (TIG) welding, also known as gas tungsten arc welding (GTAW), is valued for its controllable arc, shielding-gas protection, and ability to produce clean, high-quality welds. Nevertheless, achieving satisfactory weld characteristics requires appropriate control of welding current, welding speed, arc length, and shielding-gas flow rate (Sonar et al., 2023; Thangavel et al., 2024; Yelamasetti et al., 2024; Schilling et al., 2025; Zai et al., 2025).

The relationship between TIG welding parameters and weld performance is complex because changes in operating conditions influence heat input, molten-pool behaviour, solidification, microstructure, and the resulting mechanical properties. Excessive or insufficient heat input can contribute to undesirable weld geometry, defects, and variations in joint strength (Santhosh et al., 2026; Satheesh et al., 2026; Wei et al., 2026). Consequently, recent investigations have examined experimental design, statistical modelling, and optimization techniques to determine welding conditions that improve joint performance. For example, Thangavel et al. (2024) investigated automated TIG welding of SS304 using the Taguchi technique, while Yelamasetti et al. (2024) optimized TIG welding parameters for dissimilar AA5083 and AA7075 aluminium alloys. Karthick et al. (2025) further investigated welding parameters and filler-rod selection for dissimilar aluminium alloy joints. These studies demonstrate the continuing importance of systematic parameter selection in improving TIG welding performance.

Although conventional optimization techniques, including the Taguchi method, response surface methodology (RSM), grey relational analysis (GRA), Combined Compromised Solution (CoCoSo) and Multi-Objective Optimization Ratio Analysis (MOORA), have been applied to welding processes, selecting the best experimental condition becomes more complicated when several performance responses must be considered

simultaneously. The selection of appropriate welding parameters is essential for achieving desirable mechanical properties, sound weld geometry, and reliable joint performance. However, the simultaneous optimization of multiple welding responses remains challenging because improving one response may adversely affect another (Omprakasam et al., 2022; Thangavel et al., 2024; Karthick et al., 2025; Ghosh and Roy, 2026). A parameter combination that produces high tensile strength, for instance, may not necessarily produce the most desirable hardness, weld penetration, or bead geometry. This creates a multi-criteria decision-making problem in which alternative welding conditions must be evaluated against several criteria that may have competing objectives. manufacturing processes, including TIG–MIG hybrid welding and machining operations (Srivastava et al., 2021; Abima et al., 2022; Waheed et al., 2022; Thangavel et al., 2024).

Multi-criteria decision-making (MCDM) methods provide a systematic framework for ranking alternative process conditions according to their performance across multiple evaluation criteria. Two relevant methods are the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Complex Proportional Assessment (COPRAS). TOPSIS ranks alternatives according to their relative proximity to an ideal solution and distance from a negative-ideal solution, whereas COPRAS evaluates alternatives using their relative significance based on beneficial and non-beneficial criteria. Their application to manufacturing optimization offers a means of comparing experimental alternatives using a common decision framework (Varatharajulu et al., 2022; Umamaheswarrao et al., 2021; Krishna et al., 2022; Waheed et al., 2022; Sristi et al., 2024). For example, Varatharajulu et al. (2022) applied both TOPSIS and COPRAS to the selection of drilling parameters for AZ91 magnesium alloy, illustrating their suitability for evaluating competing manufacturing criteria.

Recent developments also indicate continued interest in improving TIG welding through statistical optimization, alternative process configurations, and data-driven methods. Schilling et al. (2025) investigated the effects of electrical and geometric parameters on process stability and seam quality in double-electrode TIG welding. Ghosh and Roy (2026) examined the optimization of microstructure and mechanical properties in dissimilar TIG welding of AISI 304L and AISI 409M stainless steels. Other 2026 studies have investigated pulsed TIG welding of AZ91 magnesium alloy and the optimization of TIG welding conditions for AISI 316L stainless steel (Kanan, 2026; Satheesh & Thanikodi, 2026). These investigations reinforce the need to understand parameter–response relationships and establish suitable operating conditions for different materials and welding configurations.

Despite these advances, the choice of an optimum TIG welding condition remains dependent on the material, experimental design, and performance criteria under consideration. Furthermore, identifying the best condition using a single response or optimization technique may not provide sufficient evidence that the selected condition represents a balanced solution across competing objectives. A comparative application of TOPSIS and COPRAS to the same experimentally obtained TIG welding dataset can therefore provide an additional basis for evaluating alternative welding conditions and examining the consistency of their rankings. The extent to which the two methods agree, however, must be established using experimental results rather than assumed in advance.

Accordingly, this study aims to evaluate and rank TIG welding parameter combinations using TOPSIS and COPRAS multi-criteria decision-making techniques. The study considers the selected welding parameters and measured weld-performance responses to determine the relative suitability of the experimental alternatives. By comparing the rankings obtained from the two methods, the investigation seeks to establish a transparent, reproducible approach to selecting appropriate TIG welding conditions. The intended contribution is a comparative decision-making framework that complements conventional welding optimization methods and supports evidence-based selection of welding parameters.

2 Methodology

2.1 Materials

American Iron and Steel Institute 1020 (AISI 1020) mild steel of 10 mm thickness was cut into two of dimension 60mm by 30mm for each specimen, with each steel plate chamfered to an angle of 30^0 and 2.5mm depth using a vertical milling machine. The chemical properties of the AISI 1020 mild steel was determine using optical emission spectroscopy (spectrolab LAVM 11A, Kleve, Germany) (Table 1). Tungsten inert gas welding machine (dynastic 210 DX) with 2% thoriated tungsten type, pro-torch and using100% argon was used while the filler material is ER 70 S-6. A K-type thermocouple was used to measure the temperature as the arc progresses.

Table 1: Average Chemical Composition of AISI 1020

Elements	C	Si	Mn	P	Cu	Al	S	Cr	Ni	Fe
Composition (%)	0.099	0.215	0.667	0.381	0.199	0.005	0.172	0.257	0.415	97.54

2.2 Experimental Procedures

The welding surface was clean using acetone. Design expert 7.01 was used to generate the welding input parameters for 20 runs with variable voltage of range 16-25V, current of 96-213A and gas flow rate of 11-

19L/min. The plates were properly clamped and the welding torch passed over the plate at a height of 2.5 mm from the workpiece at constant velocity of 1.75 m/s with filler rod angle of $15^0$and welding torch angle of 45^0. The welded part used for the mechanical testing were cut using water jet cutting to prevent thermal modification of the weld affected zone.

Table 2: Welding Input Variables for the Experiments

Run	Voltage (V)	Welding Current (A)	Gas Flow Rate (L/min)
1	16	96	11
2	25	213	19
3	20.5	154.5	15
4	16	213	19
5	25	96	11
6	20.5	154.5	11
7	20.5	154.5	19
8	16	154.5	15
9	25	154.5	15
10	20.5	96	15
11	20.5	213	15
12	16	96	19
13	25	213	11
14	20.5	125.25	15
15	20.5	183.75	15
16	18.25	154.5	15
17	22.75	154.5	15
18	18.25	125.25	13
19	22.75	183.75	17
20	20.5	154.5	15

2.3 Mechanical Properties of Welded Joints

The surface preparation of the specimen were don according to ASTM E3-11 (ASTM, 2016) on the cross section of the weld for tensile test. The tensile test was conducted using a 1200kN universal testing machine (MTS BIONIX) according to ASTM 8 (ASTM, 2016) equipped with elite software at a strain rate of 5mm/min. The tensile strength and elongation were measured for each specimen. Figure 1 showed the dimension of the prepared specimen.

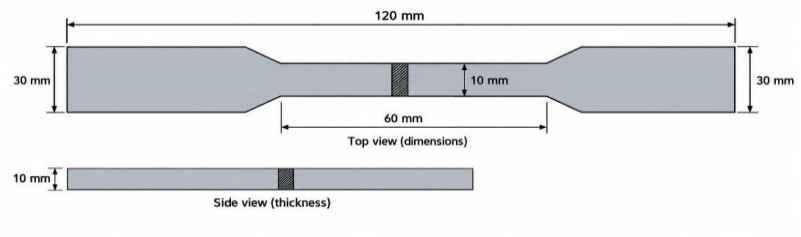


Figure 1: Tensile |Test Dimension

The hardness test was conducted according to ASTM E384 (ASTM, 2017) standard using Zwick Vickers hardness tester (Zwick Roell, Ulm, Germany). A puncturing sweep was performed with a load of P = 4 N with a duration time of 15 seconds of application, each indentation was performed with a separation of 0.4 mm,

2.4 Optimization using TOPSIS and COPRAS

Both multi-criteria optimization tool follows the same steps from step 1 to 3

Step 1: Normalization of the decision matrix using Equation (1) (Sabry et at., 2024)

$$\gamma_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}} \quad (1)$$

Where γ_{ij} is the normalized value, $a_{ij}$is original value and m is numbers of alternative=20

Step 2: Construction of decision matrix using Tensile Strength, Elongation and Hardness

$$D_m = \begin{bmatrix} a_{11} & a_{12} & a_{1n} \\ a_{12} & a_{22} & a_{2n} \\ . & \dots & \dots \\ . & \dots & \dots \\ a_{m1} & a_{m2} & a_{mn} \end{bmatrix} \quad (2)$$

Where n=3 is numbers of columns which are the optimization criterion (tensile strength, elongation and hardness)

Step 3: Construction of the weighted normalized matrix

$$\varphi_{ij} = w_j \Upsilon_{ij} = \begin{bmatrix} w_1\Upsilon_{11} & w_2\Upsilon_{12} & w_n\Upsilon_{1n} \\ w_1\Upsilon_{21} & w_2\Upsilon_{22} & w_n\Upsilon_{2n} \\ . & \dots & \dots \\ . & \dots & \dots \\ w_1\Upsilon_{m1} & w_2\Upsilon_{m2} & w_n\Upsilon_{mn} \end{bmatrix} \quad (3)$$

Where $\sum_{j=1}^{n} w_j = 1$

$$w_{ij} = \frac{w}{\sum_{j-1}^{i=0} w} \quad (4)$$

Where w_{ij} is the rating weight of data (tensile strength, elongation and hardness)

2.4.1 Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) for Determination of Optimal Weld Parameters

Step 4: determination of positive (φ^+) and negative (φ^-) ideal solution

$$\varphi^+ = (\varphi_1^+, \varphi_2^+ \dots \dots \varphi_{ni}^+ = \{(max\varphi_{ij} j \epsilon j_1), (min\varphi_{ij} j \epsilon j_2, i = 1, 2, \dots n)\} \quad (5)$$

$$\varphi^- = (\varphi_1^-, \varphi_2^- \dots \dots \varphi_{ni}^- = \{(max\varphi_{ij} j \epsilon j_1), (min\varphi_{ij} j \epsilon j_2, i = 1, 2, \dots n) \quad (6).$$

Step 5: Calculation of separation distance (S)

$$S_i^+ = \sqrt{\sum_{i=1}^{n} (\varphi_{ij} - \varphi^+)^2} \quad (7)$$

$$S_i^- = \sqrt{\sum_{i=1}^{n} (\varphi_{ij} - \varphi^-)^2} \quad (8)$$

A smaller S_i^+ indicates that the blend was closer to the ideal performance whereas a larger S_i^-indicated that the blend was farther from the undesirable condition

Step 6: Determination of relative closeness to the ideal solution

$$CC = \frac{S_i^-}{S_i^+ - S_i^-} \quad (9)$$

Step 7: Ranking of alternatives based on CC

2.4.2 Complex Proportional Assessment for Determination of Optimal Weld Parameters

Step 4: Calculate the Relative Significance of each Alternative

$$Q_i = \sum_{j=1}^{n} \varphi_{ij} \quad (10)$$

Step 5: Calculate the Relative Performance of each Alternative

$$U_i = \frac{Q_i \times 100}{Q_{max}} \quad (11)$$

Where U_i=utility degree of each alternative, Q_I=relative significance of each alternative and Q_{max}=highest relative significance among alternatives

Step 5: Ranking of Alternatives Based on Relative Performance

2.5 Correlation Between TOSIS and COPRAS Optimization Method

The degree of agreement between the two method was evaluated using spearman rank correlation coefficient in other to establish whether the two methods produce similar ranking. The spearman coefficient was obtained using equation (12)

$$r = 1 - \frac{6 \sum D_i^2}{n(n^2-1)} \quad (12)$$

Where r=Spearman rank correlation coefficient., D_i= difference between the TOPSIS and COPRAS ranks for each run and n = number of experimental runs (20)

3 Results and Discussion

3.1 Mechanical Properties of Welded Joint

The experimental results revealed variations in all three mechanical properties across the investigated welding conditions. Tensile strength ranged from 465.6 to 497.5 MPa, elongation ranged from 12.5 to 16.3%, and hardness ranged from 168.7 to 192.3 BHN. These ranges indicate that the tested welding conditions were associated with differences in mechanical performance. The results showed that the experimental condition producing the highest tensile strength did not produce the highest elongation or hardness. Similarly, the condition with the highest elongation did not correspond to the highest tensile strength. This indicates that selecting welding parameters based on a single mechanical property may not adequately represent the overall performance of the welded joint. The results show that the three responses do not identify a single experimental condition as the best in every respect.

Run 1 offers the highest tensile strength and nearly the highest hardness, whereas Run 6 provides the highest elongation. Run 11 provides the highest hardness, but its tensile strength and elongation are lower than those of Run 1. tThis pattern illustrates the importance of multi-response optimization. A welding condition that maximizes tensile strength alone may not maximize ductility, and a condition that maximizes hardness may not

provide the best balance of mechanical properties. The engineering significance of these results depends on the intended application. For a component subjected to high tensile loading, tensile strength may receive greater importance. Where deformation capacity is essential, elongation may be equally or more important. Hardness should be interpreted in relation to the base material, service conditions, wear requirements, and susceptibility to brittle behaviour.

The observed variation in mechanical properties is consistent with the findings of Abima et al. (2022), who investigated multi-objective optimization of TIG–MIG hybrid-welded AISI 1008 steel. Their study employed the Taguchi method and grey relational analysis to optimize ultimate tensile strength and yield strength simultaneously. The authors reported that the combined optimization approach improved the grey relational grade by 0.0489, demonstrating the usefulness of evaluating multiple mechanical responses rather than optimizing an individual response in isolation. This agrees with the present study, in which Run 1 produced the highest tensile strength of 497.5 MPa, whereas Run 6 achieved the highest elongation of 16.3%. Consequently, the experimental condition that maximized tensile strength was not the same condition that maximized elongation. Both studies therefore demonstrate the relevance of multi-response evaluation when selecting welding parameters, although Abima et al. investigated a hybrid welding process and two mechanical responses, whereas the present study considers TIG welding and three responses.

Further comparison can be made with Yelamasetti et al. (2024), who investigated TIG welding parameters for dissimilar AA5083 and AA7075 aluminium alloy joints. Their investigation evaluated tensile strength, yield strength, hardness, and impact energy using the Taguchi experimental design. The inclusion of several mechanical responses in their investigation supports the approach adopted in the present study, where tensile strength, elongation, and hardness are assessed together. However, the materials and experimental conditions differ, meaning that the numerical results cannot be compared directly. The relevance of their study lies in its demonstration that welding parameter selection should account for several characteristics of the welded joint rather than relying on a single mechanical response.

Similarly, Ghosh and Roy (2026) investigated the influence of TIG welding parameters on the mechanical properties and microstructure of dissimilar AISI 304L–409M stainless-steel joints. They reported tensile strengths ranging from 522 to 644 MPa, with their highest-performing specimen achieving 644.5 MPa tensile strength and 30.6% elongation. These values are higher than the corresponding maximum values of 497.5 MPa and 16.3% obtained in the present investigation. Nevertheless, this difference should be interpreted in relation to the different steel grades, joint configuration, and welding conditions used in the two studies. Ghosh and Roy also associated mechanical performance with microstructural development, emphasizing the importance of considering the relationship between welding conditions, microstructure, and mechanical behaviour. Their findings provide a basis for further investigating the microstructural characteristics responsible for the differences in tensile strength and elongation observed across the present experimental runs.

Table 3: Experimental Results

Run	Voltage (V)	Welding Current (A)	Gas Flow Rate (L/min)	Tensile Strength (MPa)	Elongation (%)	Hardness (BHN)
1	16	96	11	497.5	12.5	192.2
2	25	213	19	496.3	14.2	190.4
3	20.5	154.5	15	495.4	13.8	189.6
4	16	213	19	496.2	15.2	189.5
5	25	96	11	489.9	15.5	173.6
6	20.5	154.5	11	483.4	16.3	189.5
7	20.5	154.5	19	465.6	14.8	178.8
8	16	154.5	15	483.4	13.2	185.9
9	25	154.5	15	490.4	14.5	171.3
10	20.5	96	15	483.0	15.6	191.2
11	20.5	213	15	478.2	12.5	192.3
12	16	96	19	486.4	12.8	187.2
13	25	213	11	472.4	14,6	190.6
14	20.5	125.25	15	494.6	15.0	187.1
15	20.5	183.75	15	496.0	14.1	178.9
16	18.25	154.5	15	475.7	16.2	168.7
17	22.75	154.5	15	480.4	14.8	190.0
18	18.25	125.25	13	486.7	15.5	180.6
19	22.75	183.75	17	482.3	14.9	182.3
20	20.5	154.5	15	488.1	12.9	187.6

3.2 TOPSIS Optimization of the Weld Parameters

The TOPSIS results showed that Run 6, with a TOPSIS closeness coefficient of 0.8979 is the best combined condition. Its parameters were 20.5 V, 154.5 A, and 11 L/min, producing a tensile strength of 483.4 MPa, elongation of 16.3%, and hardness of 189.5 BHN. Run 10 is the second, with a coefficient of 0.8133. followed by Run 4, with a coefficient of 0.7452. Lowest-ranked: Run 12, with a coefficient of 0.3120. The identification of Run 6 as the highest-ranked experimental condition agrees with the general application of multi-criteria optimization in welding research. Rojas et al. (2024) combined the Taguchi method, Grey Relational Analysis, and analysis of variance to optimize TIG welding parameters for the mechanical performance of Al-6061 T6 alloy. Their study demonstrates the applicability of integrating experimental design and multi-response optimization to identify welding conditions that provide improved overall performance. The distinction is that the present study uses the relative distances of the experimental alternatives from positive and negative ideal solutions to determine their preference order. Therefore, the leading position of Run 6 represents its overall performance under the adopted criteria and weighting scheme, rather than its superiority in every individual mechanical property.

The results also relate to the investigation by Sabry et al. (2024), who applied a Taguchi–TOPSIS approach to optimize welding parameters for metal inert gas welding of AA6063 aluminium alloy pipes. Their study considered welding current, voltage, and travel speed and evaluated the mechanical performance of the resulting joints. However, their study involved MIG welding of aluminium alloy pipes, whereas the present investigation concerns TIG-welded joints. Accordingly, the agreement is methodological rather than a direct equivalence between the optimum parameter values. A further comparison can be made with Omprakasam et al. (2022), who investigated TIG welding parameter optimization for AA5052 aluminium alloy using the Taguchi method, analysis of variance, signal-to-noise ratio analysis, and regression modelling. Their study identified a preferred combination of welding current, voltage, and speed for the investigated material and responses. Although their optimization procedure differs from TOPSIS, both investigations address the same general problem: selecting welding conditions from multiple experimental alternatives based on measured performance.

Table 4: TOPSIS Ranking of the Experimental Runs

Run	Tensile Strength (MPa)	Elongation (%)	Hardness (BHN)	S^+	S^-	CC	TOPSIS Ranking
1	497.5	12.5	192.2	0.01955	0.01066	0.3528	16
2	496.3	14.2	190.4	0.01083	0.01323	0.5499	11
3	495.4	13.8	189.6	0.01291	0.01168	0.4751	13
4	496.2	15.2	189.5	0.00577	0.01689	0.7452	3
5	489.9	15.5	173.6	0.00866	0.01600	0.6487	7
6	483.4	16.3	189.5	0.00244	0.02144	0.8979	1
7	465.6	14.8	178.8	0.01063	0.01251	0.5406	12
8	483.4	13.2	185.9	0,01630	0.00827	0.3367	17
9	490.4	14.5	171.3	0.01259	0.01102	0.4667	14
10	483.0	15.6	191.2	0.00425	0.01854	0.8133	2
11	478.2	12.5	192.3	0.01977	0.00970	0.3292	18
12	486.4	12.8	187.2	0.01820	0.00825	0.3120	20
13	472.4	14,6	190.6	0.00958	0.01399	0.5935	10
14	494.6	15.0	187.1	0.00702	0.01549	0.6882	5
15	496.0	14.1	178.9	0.01254	0.01031	0.4513	15
16	475.7	16.2	168.7	0.01009	0.01909	0.6542	6
17	480.4	14.8	190.0	0.00820	0.01479	0.6433	8
18	486.7	15.5	180.6	0.00647	0.01648	0.7180	4
19	482.3	14.9	182.3	0.00857	0.01375	0.6159	9
20	488.1	12.9	187.6	0.01765	0.00861	0.3279	19

3.3 COPRAS Optimization of the Weld Parameters

From Table 5, run 6 ranked first, with a COPRAS significance value of 0.052466 and a utility degree of 100%. Its welding parameters voltage is 20.5 V, current is 154.5 A and gas flow rate is 11 L/min. The corresponding mechanical properties were 483.4 MPa tensile strength, 16.3% elongation, and 189.5 BHN hardness. This ranking indicates that Run 6 provided the strongest overall compromise among the three selected mechanical responses under the adopted equal-weighting scheme. Although it did not produce the highest tensile

strength or hardness, its comparatively high elongation and satisfactory hardness contributed to its leading overall assessment. Run 10 ranked second, with a COPRAS significance value of 0.051798 and a utility degree of 98.73%. It produced 483.0 MPa tensile strength, 15.6% elongation, and 191.2 BHN hardness. Run 4 ranked third, with a significance value of 0.051635 and a utility degree of 98.42%. It produced 496.2 MPa tensile strength, 15.2% elongation, and 189.5 BHN hardness. Run 11 ranked twentieth, with a COPRAS significance value of 0.048155 and a utility degree of 91.78%. It produced 478.2 MPa tensile strength, 12.5% elongation, and 192.3 BHN hardness. Although Run 11 recorded the highest hardness among the 20 runs, its comparatively low elongation and moderate tensile strength reduced its overall ranking. This illustrates why a multi-criteria method is useful: the best result for one mechanical property does not necessarily represent the best overall combination of properties.

The COPRAS results can be compared with those of Varatharajulu et al. (2022), who applied both TOPSIS and COPRAS to the optimization of drilling parameters for magnesium AZ91 alloy. Their investigation considered several response characteristics, including drilling time, burr height, burr thickness, and surface roughness, and reported an identical sequencing order from the two optimization methods. This finding demonstrates that TOPSIS and COPRAS can produce consistent rankings when applied to the same multi-response decision problem. In the present study, both methods identify Run 6 as the preferred welding condition, providing agreement on the highest-ranked alternative. However, the intermediate rankings reported in the present tables are not identical. This difference is consistent with the fact that TOPSIS and COPRAS evaluate alternatives using different mathematical procedures. Consequently, agreement on the leading experimental condition is important, but the complete ranking sequences must be examined separately.

Krishna et al. (2022) also applied COPRAS, integrated with the entropy method, to multi-criteria decision-making in the dry turning of Nimonic C263. Their study illustrates the application of COPRAS to engineering decisions involving several performance criteria. In the present investigation, COPRAS combines tensile strength, elongation, and hardness to calculate the relative significance and utility degree of each welding condition. Run 6 achieved the highest reported utility degree of 100%, while Run 11 achieved the lowest reported utility degree of 91.78%. This contrast illustrates the ability of a multi-criteria method to distinguish between alternatives that perform differently across several responses. In particular, Run 11's hardness of 192.3 BHN, although the highest among the experimental runs, did not compensate for its lower elongation of 12.5% and tensile strength of 478.2 MPa. The ranking therefore emphasizes the combined performance of the selected criteria rather than the maximum value of one response.

The results further support the relevance of multi-objective optimization in welding research, as demonstrated by Abima et al. (2022), who used grey relational analysis to combine tensile strength and yield strength in TIG–MIG hybrid welding. Although their method differs from COPRAS, both approaches convert multiple response characteristics into an overall assessment that can be used to compare experimental conditions. The present results contribute to this broader approach by assessing three mechanical properties simultaneously and by comparing the outcome of COPRAS with the independent ranking produced by TOPSIS. The identification of Run 6 by both methods provides a consistent indication of its suitability within the tested experimental conditions, subject to verification of the underlying calculations

Table 5: COPRAS Ranking of Experimental Results

Run	Tensile Strength (MPa)	Elongation (%)	Hardness (BHN)	Q_i	U_i (%)	COPRAS Ranking
1	497.5	12.5	192.2	0.04808	93.03	16
2	496.3	14.2	190.4	0.050566	96.38	7
3	495.4	13.8	189.6	0.050002	95.30	12
4	496.2	15.2	189.5	0.051635	98.42	3
5	489.9	15.5	173.6	0.050332	95.93	8
6	483.4	16.3	189.5	0.05266	100.00	1
7	465.6	14.8	178.8	0.049160	93.70	14
8	483.4	13.2	185.9	0.048564	92.56	17
9	490.4	14.5	171.3	0.048988	93.37	15
10	483.0	15.6	191.2	0.051798	98.73	2
11	478.2	12.5	192.3	0.048155	91.78	20
12	486.4	12.8	187.2	0.048323	92.10	19
13	472.4	14,6	190.6	0.050226	95.73	9
14	494.6	15.0	187.1	0.051133	97.46	4
15	496.0	14.1	178.9	0.049404	94.16	13
16	475.7	16.2	168.7	0.050211	95.70	10

Run	Tensile Strength (MPa)	Elongation (%)	Hardness (BHN)	Q_i	U_i (%)	COPRAS Ranking
17	480.4	14.8	190.0	0.050677	96.59	6
18	486.7	15.5	180.6	0.050853	96.93	5
19	482.3	14.9	182.3	0.050164	95.61	11
20	488.1	12.9	187.6	0.048533	92.50	18

3.4 Correlation Between TOPSIS and COPRAS Optimization Methods

The Spearman correlation coefficient of 0.5414 indicates a very strong positive correlation between TOPSIS and COPRAS. Their rankings follow a very similar pattern across the 20 experimental runs. Five runs (Runs 1, 4, 6, 8, and 10) received exactly the same rank from both methods. Run 6 ranked first in both TOPSIS and COPRAS, while Run 10 ranked second and Run 4 ranked third. This agreement provides evidence that the preferred condition is not an isolated result of using only one ranking method. Differences remain among some intermediate-ranked runs. For example, Run 2 ranked eleventh under TOPSIS but seventh under COPRAS, while Run 16 ranked sixth under TOPSIS but tenth under COPRAS. These differences demonstrate that the methods do not produce identical rankings for every experiment.

The differences arise because TOPSIS evaluates the relative distance of each alternative from positive and negative ideal solutions, whereas COPRAS assesses the alternatives through their relative significance based on normalized and weighted criteria. The correlation analysis revealed a very strong positive relationship between the TOPSIS and COPRAS rankings, with a Spearman rank correlation coefficient of 0.5414 ($p>0.001$). This finding indicates that both multi-criteria decision-making methods produced highly consistent rankings of the 20 welding experimental runs based on tensile strength, elongation, and hardness. The use of rank-based comparisons to examine agreement between optimization methods is relevant to the work of Varatharajulu et al. (2022), who compared TOPSIS and COPRAS rankings when optimizing magnesium AZ91 drilling parameters.

4 Conclusion

This study evaluated and ranked 20 TIG welding experimental conditions using the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Complex Proportional Assessment (COPRAS) methods, considering tensile strength, elongation, and hardness as equally weighted beneficial criteria. The experimental results demonstrated variations in mechanical performance, confirming that no single welding condition simultaneously produced the highest values for all three responses. According to TOPSIS, the ranking are run 6 > 10 > 4 > 18 >14 >16 >5 >17 >19 >13 >2 >7 >3 >9 >5 >1 > 8 >11 >20 >12 while COPRAS ranking were run 6 >10 >4 >14 >18 >16 >5 >17 >19 >13 >2 >7 >3 >9>15 >1 >8 >20 >12 >11. Both optimization methods independently identified Run 6, corresponding to a voltage of 20.5 V, welding current of 154.5 A, and shielding-gas flow rate of 11 L/min, as the preferred experimental condition. This combination produced a tensile strength of 483.4 MPa, elongation of 16.3%, and hardness of 189.5 BHN, demonstrating a favourable balance of the selected mechanical properties. Furthermore, the Spearman rank correlation coefficient of 0.5414 indicated a very strong positive association between the TOPSIS and COPRAS rankings, supporting the consistency of the comparative optimization results. These findings demonstrate the usefulness of integrating multiple decision-making techniques to evaluate competing welding responses and reduce dependence on single-response optimization. Nevertheless, the selected condition represents the best-ranked alternative among the experimental runs investigated rather than a confirmed global optimum. Further validation through replicate welding trials, microstructural examination, and assessment of weld defects is recommended to establish its reliability and suitability for practical engineering applications. The study provides a reproducible multi-criteria framework for selecting TIG welding parameters based on balanced mechanical performance. Further investigations involving replicate experiments, weld microstructural characterization, and defect assessment are recommended to validate the robustness and practical applicability of the identified condition. This comparative framework provides a useful basis for evidence-based welding parameter selection and improved assessment of welded-joint performance**.**

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Conflict of Interest

The authors declare there are no conflicts of interest regarding the publication of this article.

Authorship contribution statement

Oboh, J.I. was involved in the conceptualization, investigation, and writing of the manuscript. Olorunrokan, O.C. and Akeni, O.C. were involved in the conceptualization, supervision, analysis of results and review of the manuscript draft. All authors read and approved the manuscript

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