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APPLICATION OF THE SREM METHOD IN FILLER MATERIAL SELECTION FOR REPAIR WELDING

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Abstract: The selection of filler metal for reparatory welding in this study is addressed through the application of the Square Root Based Evaluation Method (SREM). The aim of the paper was to examine the reliability of the method on a case that has already been solved using a Multi-Criteria Decision-Making (MCDM) approach in the relevant literature. Three filler metals, ABRADUR 58, E DUR 600, and CrWC 600, were considered and ranked based on four important criteria: wear trace width, cost, mass loss, and hardness of welded layers. All the experimental data, required for implementing the SREM method, were taken from a relevant literature source. The results of the study showed that E DUR 600 is the optimal filler metal. In addition, the results obtained using the SREM method are completely identical to those obtained using existing approaches, which confirms the applicability of this method to the considered problem. The sensitivity analysis showed that the ranking of filler metals may differ only in extreme cases, which indicates that the obtained results are sufficiently reliable.
Keywords: filler metal, reparatory welding, SREM, MCDM

1. INTRODUCTION

One of the most important technologies used in modern industries, transportation, construction, shipbuilding, and other, is reparatory welding of the damaged and/or broken parts or assemblies. This process objective is to extend the service life of machine components and parts and depends on a number of factors, among which the selection of the filler metal is particularly important, especially since failures of welded structures in heavy-duty machinery may result from the combined influence of service loads, dynamic excitation, stress concentration and weld imperfections (Arsić et al., 2026; Nikolić et al.2021). The materials from which the electrodes are made should satisfy various requirements, both in terms of mechanical properties and economic feasibility.

The selection of the filler metal can be classified as a Multi-Criteria Decision-Making (MCDM) problem, i.e., a multi-criteria optimization problem. The problem is formulated in such a way that the optimal filler metal is selected based on multiple criteria that are often

conflicting and mutually dependent. In this paper, a methodological extension and a comparative analysis of the results obtained in study (Arsić et al., 2025), on which this paper is based, have been carried out.

In the referenced study, the Best–Worst Method (BWM) (Rezaei, 2015) was used to determine the weights of the criteria, while the alternatives, i.e., filler metals, were ranked using the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) (Hwang and Yoon, 1981) and the RAnking based on the Distances And Range (RADAR) (Komatina, 2024) methods. However, given that both in the field of operations research and multi-criteria decision-making there is a continuous development of new methods, with different mathematical foundations and approaches, the need arose to examine the robustness and precision of newer approaches. The idea was to assess the robustness of one such method – the Square-Root Based Evaluation Method (SREM) (Komatina et al., 2026), in solving the particular problem that was previously solved using two other methods, the TOPSIS and RADAR methods.

One of the important characteristics of the SREM method is that it employs a specific mathematical mechanism that offers decision-makers different perspectives for analyzing the problem. This method has the ability to favor alternatives that perform extremely well with respect to important criteria, while at the same time it can favor solution stability across a larger number of criteria, reducing the influence of extreme values. As the third option, it provides a compromise solution between these two approaches, as well. In addition, the method enables the fine-tuning and balancing between these approaches.

Since the SREM method is relatively new and has not yet been applied in this domain, the aim of this study was to examine and validate the reliability of the SREM method by comparing its results to those obtained in the previous study (Arsić et al., 2025). In the research were used the experimental data and criteria weights presented in the referenced study. The objective was to compare the results and identify the potential differences, as well as to determine whether the method confirms the previously obtained ranking of the filler metals.

2. METHODOLOGY OF RESEARCH

The methodology of this research is divided in three phases. In the first phase, the experimental data, i.e., the input data used from the study by (Arsić et al., 2025), were defined. In the second phase, the procedure for applying the SREM method is explained, while in the third phase, the procedure of comparative analysis of the obtained results to the results of the previous study is presented.

2.1. Problem statement

Although the repair welding (also classified as hard-facing) is a frequently studied topic in the relevant literature (Arsić et al., 2016, 2021; Lazic et al., 2015, 2014; Tanaskovic et al., 2021a, 2021b), the problem of filler metal selection using an MCDM approach has not been considered so far, except in the referenced study on which this research is based. A similar problem was addressed only in the study (Bachchhav et al., 2023), where the authors used an MCDM approach for the selection of the spot-welding electrode materials. The problem is formulated by considering three filler metals, which, in mathematical terms, are denoted as: ABRADUR 58 ($i = 1$), E DUR 600 ($i = 2$), and CrWC 600 ($i = 3$). Their evaluation and ranking are performed according to the following criteria: wear trace width ($j = 1$), cost ($j = 2$), mass loss ($j = 3$), and hardness of welded layers ($j = 4$). For the

wear trace width, cost, and mass loss, lower values are preferred, meaning that these criteria are of the cost type. For the criterion hardness of welded layers, higher values are preferred, so this criterion is considered as being of the benefit-type.

The weights of the criteria, ω_j, are also taken from the referenced study and can be expressed as follows: $\omega_1 = 0.30$; $\omega_2 = 0.18$; $\omega_3 = 0.40$, and $\omega_4 = 0.12$. This means that the first criterion accounts for 30%, the second for 18%, the third for 40%, and the fourth for 12%, respectively.

2.2. The Square Root Based Evaluation Method – SREM

The standard SREM method is carried out through seven steps, which can be formulated as follows (Komatina et al., 2026):

Step 1. The decision matrix is constructed, $\left[D_{ij}\right]_{I\times J}$, where the value of each alternative with respect to each criterion is defined.

Step 2. The normalized decision matrix is constructed, $\left[M_{ij}\right]_{I\times J}$.

Normalization of values for the benefit-type criteria is performed according to the following expression:

$$m_{i,j} = \frac{d_{i,j}}{\sum_{i-1}^{I} d_{i,j}} \cdot 100 \,. \tag{1}$$

Normalization of values for the cost-type criteria is performed according to the following expression:

$$m_{i,j} = \frac{\frac{1}{d_{i,j}}}{\sum_{i-1}^{I} \frac{1}{d_{i,j}}} \cdot 100 \,. \tag{2}$$

Step 3. The squared-transformed normalized matrix, $\left[S_{i,j}\right]_{I\times J}$, is constructed as:

$$S_{i,j} = \frac{m_{ij}^2}{\sum_{i=1}^{I} m_{ij}^2} \,. \tag{3}$$

Step 4. The root-transformed normalized matrix, $\left[R_{i,j}\right]_{I\times J}$, is constructed as:

$$R_{ij} = \frac{\sqrt{m_{ij}}}{\sum_{i-1}^{I} \sqrt{m_{ij}}} \,. \tag{4}$$

Step 5. The α-fused matrix, $\left[A_{i,j}\right]_{I\times J}$, is constructed as:

$$a_{ij} = \alpha \cdot S_{ij} + (1-\alpha) \cdot R_{ij} \,. \tag{5}$$

Step 6. The weighted α-fused matrix, $\left[N_{ij}\right]_{I\times J}$, is constructed as:

$$n_{ij} = a_{ij} \cdot \omega_j \,. \tag{6}$$

Step 7. The final ranking index, F_i, is calculated according to:

$$F_i = \sum_{j=1}^{J} n_{ij} \,. \tag{7}$$

Based on the values of the final ranking index, the filler metals are ranked. The best-ranked alternative is the filler metal that has the highest value of this parameter.

2.3. Comparative analysis
As the final, but important, segment of this research, a comparison is made between the results obtained using the SREM method and those obtained in the previous study using the TOPSIS and RADAR methods. In addition, the aim of this analysis was to examine whether rank changes occur under different decision-making conditions, i.e., for different values of the parameter α.

3. RESULTS
The study on which this research is based was conducted in a construction machinery facility (Arsić et al., 2025). Heavy-duty machines with large metal components exposed to wear and cracking are used in the facility. The machine parts were welded using the manual metal arc welding procedure (Figure 1).



Fig. 1. Loader bucket teeth welded (hard-faced) with different patterns

As already stated, the input data were taken from the study by (Arsić et al., 2025) and are presented in Table 1.

Table 1
Decision matrix

	Wear trace width [mm]	Costs [€/kg]	Mass loss [%]	Hardness of welded layers [HV1]
ABRADUR 58	0.445	8.32	20	740
E DUR 600	0.467	7.49	14	600
CrWC 600	0.675	12.4	22	660

Based on the application of the proposed SREM procedure, it was determined that the E DUR 600 electrode is the optimal material for reparatory welding. Even with changes in the parameter α, the result remains unchanged. ABRADUR 58 is ranked in the second place, while CrWC 600 is ranked as the third. The values of the coefficient F_i for different values of the parameter α, as well as the ranking of the filler metals, are presented in Table 2.

Table 2
Rank of filler metals

	$F_i\ (\alpha = 0)$	$F_i(\alpha = 0.25)$	$F_i(\alpha = 0.5)$	$F_i\ (\alpha = 0.75)$	$F_i\ (\alpha = 1)$
ABRADUR 58	0.339	0.341	0.343	0.345	0.347
E DUR 600	0.361	0.381	0.402	0.422	0.442
CrWC 600	0.300	0.277	0.255	0.233	0.210

4. DISCUSSION

When the results obtained in (Arsić et al., 2025) are compared to results obtained in this study, it can be concluded that, for the filler metals considered in his case, the TOPSIS, RADAR, and SREM methods produce identical rankings. Even changes in the parameter α did not affect the ranking results. In addition, in this research the case was considered in which the criteria have equal weights. In that case, no change in the ranking of the alternatives occurred either. It can therefore be concluded that the E DUR 600 is definitely the optimal choice for repair welding according to the defined parameters, i.e., criteria.

To further test the model, an inversion of the criteria weights was performed, such that the weights were defined in the opposite order. The original weights: $\omega_1 = 0.30$; $\omega_2 = 0.18$; $\omega_3 = 0.40$, and $\omega_4 = 0.12$, were modified so that the most important criterion became the least important one, while the second most important criterion became the third most important. Accordingly, the weights were changed to: $\omega_1 = 0.18$; $\omega_2 = 0.3$; $\omega_3 = 0.12$, and $\omega_4 = 0.4$.

Only in the case when α=0, ABRADUR 58 becomes the top-ranked alternative, while E DUR 600 moved to the second place. This ranking remains valid approximately up to α=0.121. In all the other cases, E DUR 600 remains unequivocally in the first place. Therefore, it can again be concluded that this filler metal is the optimal choice.

5. CONCLUSION

In this paper, the applicability of the SREM method to the problem of filler metal selection for reparatory welding was investigated. The research was based on data taken from the literature. It was determined that, in the considered case, the SREM method provides identical results to the methods previously used for solving this problem, namely TOPSIS and RADAR. In all the analyzed situations, E DUR 600 proved to be the best filler metal. This was additionally confirmed through sensitivity analysis. Based on the conducted analysis, it was concluded that the SREM method represents a highly reliable and robust MCDM tool that can be used not only for material selection problems, but also for other engineering optimization problems. In future research, the SREM method will be extended through the application of different approaches for determining criteria weights, as well as approaches for modelling uncertainty and imprecision, such as fuzzy logic and rough set theory.

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