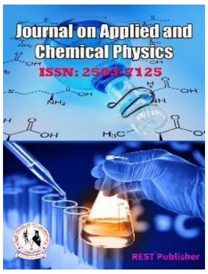
Journal on Applied and Chemical Physics

Vol: 4(3), September 2025

REST Publisher; ISSN: 2583-7125

Website: https://restpublisher.com/journals/jacp/

DOI: https://doi.org/10.46632/jacp/4/3/4



Applying The WASPAS Method For Optimal Material Selection in Cryogenic Storage Tank Design

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Abstract: *Cryogenic storage tanks are designed to store liquefied gases at very low temperatures, typically below -150°C (-238°F) Common materials used for cryogenic storage tanks include stainless steels, aluminium alloys, and certain low-temperature carbon steels. Additionally, specialized materials such as nickel alloys or composite materials may be utilized for specific applications where enhanced properties are required. The material selection process for cryogenic storage tanks involves a comprehensive evaluation of the aforementioned factors, often utilizing material databases, testing, and simulation tools. It is essential to consult with experts in cryogenic engineering and consider the specific requirements of the intended application to ensure the optimal material choice for cryogenic storage tanks. the Weighted Aggregated Sum Product Assessment (WASPAS) methodology is a multi-criteria decision-making (MCDM) technique used to solve problems where multiple criteria need to be considered for decision-making. It provides a structured approach for decision-making that takes into account the preferences and priorities of the decision-maker. The weights assigned to the criteria play a crucial role in determining the final ranking of the alternatives. 2024 aluminium in the T6 temper, 2024 aluminium in the O temper, 301 Full Hard Tempered Stainless Steel, Stainless Steel 310, TC4, Ti64, or ASTM Grade 5, nickel-chromium-molybdenum superalloy, Brass. Yield Strength, Elastic Modulus, Toughness Index, Density, Specific Heat, Thermal Expansion. from the result we can see that ss301-FH got 1st rank and AL5052-0 got last rank .by using waspas method we obtained that ss301-FH got 1st rank and AL5052-0 got last rank*

Key words: *Yield Strength, Elastic Modulus, Toughness Index, Density, Specific Heat, Thermal Expansion.*

1. INTRODUCTION

Selecting materials inappropriately can lead to serious consequences, including increased expenses and premature failure of components or products. Therefore, designers must carefully assess the characteristics, benefits, and limitations of various materials to make informed choices. It is crucial to identify and evaluate materials that possess the specific functionalities required for the desired outcome. This involves considering factors like mechanical properties, thermal properties, chemical compatibility, manufacturability, and environmental considerations. Since material selection often involves conflicting criteria, it can be treated as a multi-criteria decision-making (MCDM) problem. Designers must weigh and prioritize different criteria based on their relative importance to the application. This necessitates a systematic and efficient approach to ensure the selection of the best material alternative. Various methods and tools can aid in the material selection process, such as material property databases, decision matrices, and computer-aided design software. These resources help designers evaluate and compare different materials based on their performance against specific criteria. Additionally, knowledge of industry standards, regulations, and past experiences with similar applications can also contribute to effective material selection To sum up, the process of selecting suitable materials for engineering applications is a crucial task that requires careful consideration of functional requirements, adherence to criteria, and a systematic approach. By utilizing appropriate methods and tools, designers can make informed decisions that optimize performance, minimize costs, and ensure desired functionality. Material selection significantly impacts the quality and cost of the end product, making it a challenging task. It is an ongoing process that aims to identify the most suitable material to meet specific requirements, typically done during the initial design stage or during component redesigns. Choosing the wrong material can lead to premature failure and unnecessary expenses. However, advancements in materials and production methods have expanded the range of options available to designers, enabling innovation and improved performance at lower costs. The presence of substitute materials and a wide variety of engineering materials further complicates the selection process, necessitating consideration of technological, economic, and environmental factors. To make well-informed decisions, designers must possess a comprehensive understanding of material properties and behaviour under various working conditions Key considerations for the selection of materials include the functional requirements of the engineering component. Qualitative and Quantitative Criteria: When selecting the best material, designers need to evaluate both qualitative and quantitative criteria. This involves considering subjective factors, such as aesthetics or environmental impact, as well as objective measurements and data, such as material properties or cost. Material Knowledge: Designers must possess knowledge about material properties to make informed decisions. Understanding how different materials behave under various conditions can help in selecting the most appropriate material for a given application. Exploring Alternatives: The material selection process involves navigating through numerous alternatives. Designers need to explore different material options, comparing their properties, performance, and cost to identify the most suitable choice. Impact on Design and Functionality: The material chosen for an engineering component significantly influences its design and proper functioning. The selected material can have a substantial impact on the component's performance, durability, reliability, and overall functionality. In conclusion, the material selection process is crucial for achieving desired product outcomes. Designers must consider a wide range of criteria, possess knowledge about material properties, and carefully evaluate alternatives to identify the most suitable material for a given application. The material must fulfil the functional requirements of the component. This includes factors such as mechanical strength, dimensional stability, thermal properties, electrical conductivity, corrosion resistance, and compatibility with other materials or fluids in the system. Load and Stress Considerations: The material needs to be able to withstand the expected loads, stresses, and environmental conditions that the component will encounter throughout its operational lifespan. When selecting a material, it is important to consider factors such as tensile strength, yield strength, fatigue resistance, and toughness. Manufacturing and fabrication processes are also important considerations. The chosen material should be suitable for processes like casting, forging, machining, welding, and forming. Cost and availability are significant factors to take into account. This includes considering the overall cost of the material, including sourcing, processing, and any required treatments. Availability and sourcing constraints become particularly important for large-scale production. Environmental and sustainability factors should be considered as well. The material's impact on the environment, such as its recyclability, energy consumption during production, and potential for pollution, should be evaluated from a sustainability perspective. Longevity and maintenance are key considerations. The chosen material should ensure the desired lifespan of the component and minimize the need for frequent maintenance or replacement. Factors such as resistance to wear, corrosion, and degradation over time should be assessed. Compliance with relevant industry standards, regulations, and safety requirements is crucial. The material should meet the necessary certifications and specifications for its intended application, ensuring regulatory and standards compliance. Designers must thoroughly assess various factors in order to choose the most appropriate materials, often employing material databases, testing, simulations, and expertise in the field. Collaborating with material scientists, engineers, and suppliers can also offer valuable insights and support in the decision-making process. The historical and ongoing impact of materials on society is undeniable, and their significance is expected to endure. Engineering materials such as concrete, steel, and plastics have played a pivotal role in the advancement of modern civilization. The ongoing development of advanced materials with exceptional properties is crucial for addressing the significant challenges faced by humanity. The selection of the right material is a vital aspect of engineering design and product development. Designers must identify the necessary material properties for a specific product and assess potential materials based on those properties. However, material selection can be challenging due to insufficient or unavailable material data. Traditionally, manual methods involving handbooks, rules of thumb, and heuristics have been used for material selection. Ashby's material selection charts have proven to be a valuable graphical tool for initial screening, providing insights into property trade-offs. Furthermore, tools like the Cambridge Engineering Selector (CES) have been developed to assist in the material selection process. CES is an advanced web-based tool that grants designers access to valuable materials and design information, enabling them to make well-informed choices, identify potential issues, and reduce turnaround time. Having extensive material databases readily available would greatly simplify the process of selecting materials. By storing knowledge about the properties of numerous materials in a database, the laborious task of searching through handbooks would be eliminated. The progress in computing, communication, and data acquisition technologies has made it possible to collect and store vast amounts of material property data. These databases can be regularly updated to accommodate the evolving landscape of new material options and meet the needs of modern manufacturing. In conclusion, materials have a vital role in shaping society, and their selection is a crucial aspect of engineering design. The existence of comprehensive material databases and sophisticated selection tools can significantly assist designers in making informed decisions, enhancing efficiency, and fostering innovation in material selection and product development.

2. MATERIALS AND METHOD

In 2024 aluminium is a high-strength aluminium alloy that is commonly used in aerospace applications. When in the T6 temper, 2024 aluminium undergoes a specific heat treatment process to enhance its mechanical properties.

specific properties of 2024 aluminium in the T6 temper may vary depending on the exact processing, heat treatment, and manufacturing methods 2024 aluminium in the O temper: 2024 aluminium in the O temper refers to the annealed condition of the alloy. When in the O temper, 2024 aluminium has not undergone any specific heat treatment to enhance its mechanical properties. It's important to note that the O temper of 2024 aluminium is primarily used when the alloy needs to be formed, shaped, or machined. If higher strength is required, the material can be heat treated to achieve the desired mechanical properties in other tempers such as T3, T4, or T6. The specific properties and applications of 2024 aluminium in the O temper may vary depending on the exact composition and manufacturing processes used. 301 Full Hard Tempered Stainless Steel is a type of austenitic stainless steel that has been cold rolled and then fully hardened through a process known as tempering. the full hard temper of 301 stainless steel is achieved through a specific cold rolling and annealing process. The resulting material is characterized by its high strength and hardness. The specific properties and applications of 301 Full Hard Tempered Stainless Steel may vary depending on the exact composition, processing, and intended use. Stainless Steel 310: Stainless Steel 310 is a high-temperature austenitic stainless steel that offers excellent resistance to oxidation and high-temperature corrosion. It's important to note that the specific properties and performance of Stainless Steel 310 may vary depending on the manufacturing process, heat treatment, and environmental conditions TC4, Ti64, or ASTM Grade 5: C4, Ti64, and ASTM Grade 5 are different designations for the same titanium alloy. Here's some information about this alloy: TC4, Ti64, or ASTM Grade 5 refers to a titanium alloy composed of approximately 90% titanium, 6% aluminium, and 4% vanadium (hence the name Ti64). It is a widely used titanium alloy known for its excellent strength, low density, and corrosion resistance. the specific mechanical properties and performance of TC4/Ti64/ASTM Grade 5 can be further tailored through heat treatment and alloy modifications. Nickel-chromium-molybdenum superalloy: A nickel-chromium-molybdenum superalloy is a type of alloy that contains nickel as the primary element, along with significant amounts of chromium and molybdenum. These alloys are known for their exceptional strength, heat resistance, and corrosion resistance, making them suitable for high-temperature applications. there are different grades and variations of nickel-chromium-molybdenum superalloys, each with its specific composition and properties. These alloys are often tailored for specific applications, and their performance can be further enhanced through specialized heat treatments and alloy modifications. One well-known example of a nickel-chromium-molybdenum superalloy is Inconel, which encompasses a range of alloys (e.g., Inconel 600, Inconel 625, Inconel 718) with slightly different compositions and characteristics.

3. WASPAS METHOD

The Weighted Sum Model (WSM) and Weighted Product Model (WPM) are two techniques commonly used in Multi-Criteria Decision Making (MCDM). However, in 2012, Zavadskas, Turskis, Antucheviciene, and Zakarevicius introduced a new approach called Weighted Aggregated Sum Product Assessment (WASPAS), which combines the WSM and WPM methods. They argued that both WSM and WPM are less accurate compared to the WASPAS approach. Since its development, the WASPAS technique has been applied in various research projects. For instance, Bagoius, Zavadskas, and Turskis utilized WASPAS to select a deep-water port, while Staninas, Medineckien, Zavadskas, and Kalibatas used WASPAS for the ecological-economic assessment of multi-dwelling home modernization [161]. The robustness of the methodology in evaluating different solutions was examined using WASPAS [163], and Zavadskas, Antucheviciene, Saparauskas, and Turskis used WASPAS to evaluate facade options [162]. Additionally, Bitarafan, Zolfani, Arefi, Zavadskas, and Mahmoudzadeh employed WASPAS to assess real-time intelligent sensors for monitoring the structural health of bridges [164]. Djus and Antucheviien utilized WASPAS to evaluate health and safety precautions on building sites [165 To explore decision-making strategies for addressing commercial challenges from a foresight perspective, researchers Hashemkhani Zolfani, Aghdaie, Derakhti, Zavadskas, and Morshed Varzandeh employed the WASPAS method [166]. WASPAS has gained popularity and proven effective in enhancing decision-making processes across various fields [1]. In their work, the authors propose an extended WASPAS approach that incorporates interval type-2 fuzzy sets (IT2FSs) to handle multiple criteria decision-making (MCDM) concerns. By utilizing IT2FSs, the proposed approach increases the level of knowledge about factors, thereby improving decision-making intelligence and choice evaluation accuracy. To expand the WASPAS technique, the researchers integrate the normalization and weighted product model with the concepts and arithmetic operations of IT2FSs. They also introduce a novel method for determining criteria weights by combining subjective weights provided by decision-makers with objective weights obtained through an entropy method. This combination ensures more realistic criteria weights and enhances the stability of criterion weights during the decision-making process. Overall, the upgraded WASPAS method with IT2FSs offers a superior approach for addressing MCDM problems, enabling a more comprehensive evaluation of available options and facilitating more precise decision-making [2]. The objective of the study is to propose a strategy for selecting process improvement initiatives that considers unpredictability and dynamic assessments based on crucial continuous improvement criteria. The study employs the Weighted Aggregated Sum Product Assessment (WASPAS) method, which extends Zadeh's fuzzy sets approach by utilizing ordered fuzzy numbers (OFNs). The study conducted by Slezak, Kosinski, and [author's name] aims to achieve this objective. The authors of the study recommend using the Weighted Aggregated Sum Product Assessment (WASPAS) approach, which was developed by Zavadskas et al. in 2012, as a strategy that considers both qualitative and quantitative criteria. The WASPAS approach is known for its ability to provide highly accurate estimates through weighted aggregation function optimization. It has been successfully applied in various decision-making scenarios, such as selecting construction techniques, remodeling residences, and determining the location of shopping malls. Previous studies by Zavadskas and Turskis (2011) and Kapliski and Tupenaite (2011) have demonstrated the value of Multiple Attribute Decision Making (MADM) techniques, including the WASPAS method, in economic applications. The current study aims to rank and analyze outsourcing choices using the WASPAS method, which takes into account multiple variables and facilitates more informed decision-making. The WASPAS method combines the advantages of the weighted sum model (WSM) and the weighted product model (WPM) to improve ranking accuracy. An ideal combination parameter is calculated throughout the process, details of which can be found in the literature. Overall, the WASPAS method offers a valuable solution to MADM problems and aims to enhance the accuracy of rankings for decision-making purposes. In the essay's main focus, the planning of waste incineration plant construction sites is examined, considering ecological, technological, and urban factors. The primary objective is to demonstrate how multi-criteria decision methods (MCDM) can be applied to address the specific issue of waste management. The authors explore the usefulness and applicability of the WASPAS method for determining the optimal locations for waste incineration facilities. To address this challenge, they propose an adaptation of the original WASPAS method called WASPAS-SVNS, which incorporates the concept of single-valued neutrosophic sets into the decision-making process. The overall aim of this study is to demonstrate how the WASPAS-SVNS method can be applied to tackle the complexities of site planning for waste incineration plants while considering various criteria and incorporating sustainability considerations. his research paper proposes an integrated methodology that combines the Weighted Aggregated Sum Product Assessment (WASPAS) method with information measures to evaluate multi-criteria decision-making (MCDM) problems using hesitant fuzzy sets (HFSs). To incorporate HFSs into the WASPAS technique, the authors introduce HF-aggregation operators and modify the normalization and weighted product algorithms. The effectiveness of the developed method is demonstrated by applying it to a group support system (GSS) scenario, where the answers to the GSS problem are provided along with a sensitivity analysis that modifies the parameters and weights of the existing WASPAS approach. By comparing the results with previous methods, the paper highlights the advantages of the proposed method. The study aims to offer a comprehensive and reliable approach for assessing MCDM challenges using HFSs, combining the WASPAS method with information measures, and showcasing its superiority over existing approaches in real-world situations. The focus of the study is on sustainable perspectives in Uttarakhand, India. The remaining sections of the paper are organized as follows: "Earlier works": This section provides an in-depth analysis of relevant prior research and literature related to the subjec"Preliminaries": This part covers the fundamental concepts and principles of Fermatean fuzzy sets (FFSs). It will provide you with the background information necessary to understand the sections that come next. The phrase "improved score function and entropy measure within FFSs" alludes to the presentation of a brand-new Fermatean fuzzy score function as well as brand-new entropy measures within the framework of FFSs. These improvements are made to improve the precision and effectiveness of the decision-making process. "Proposed FF-WASPAS method for MCDM problems" This section will introduce the unique Fermatean fuzzy weighted aggregate sum product assessment (FF-WASPAS) model. The FF-WASPAS method incorporates the score function and entropy measures within the FFSs framework to handle MCDM difficulties. The case study "selection of the healthcare waste disposal location (HCWDLThis work's potential research directions will also be highlighted. This preset framework will be followed throughout the study in order to analyse the sustainable perspectives of Uttarakhand, India, and to provide a special FF-WASPAS approach for MCDM difficulties with FFSs. The case study and comparisons with other methods will be used to discuss the applicability and stability of the suggested procedure.[9] Since its creation by Zavadskas et al. (2012),.In order to evaluate real-time smart sensors for a fundamental health assessment of bridges, Bitarafan et al. (2014) expanded the WASPAS approach and the SWARA (Step-wise Weight Assessment Ratio Analysis) method. Chakraborty and Zavadskas (2014) utilized the WASPAS approach to tackle various multi-criteria manufacturing issues. These included selecting an electroplating system, cutting fluid, arc welding procedure, and baking condition.

4. ANALYSIS AND DISCUSSION

TABLE 1. Material selection problem of cryogenic storage tank

	Yield Strength	Elastic Modulus	Toughness Index	Density	Specific Heat	Thermal Expansion
Al2024-T6	420	74.2	75.5	2.8	0.16	21.4
Al5052-O	91	70	95	2.68	0.16	22.1
SS301-FH	1365	189	770	7.9	0.08	16.9
SS310-3AH	1120	210	187	7.9	0.08	14.4
Ti6Al4V	875	112	179	4.43	0.09	9.4
Inconel718	1190	217	239	8.51	0.07	11.5
70Cu-30Zn	200	112	273	8.53	0.06	19.9

Table 1 showing WSM alternative parameters Al2024-T6, Al5052-O, SS301-FH, SS310-3AH Ti6Al4V, Inconel718,70Cu-30Zn and evaluation parameters yield strength, elastic modules, toughness index, density, specific heat, thermal expansion.

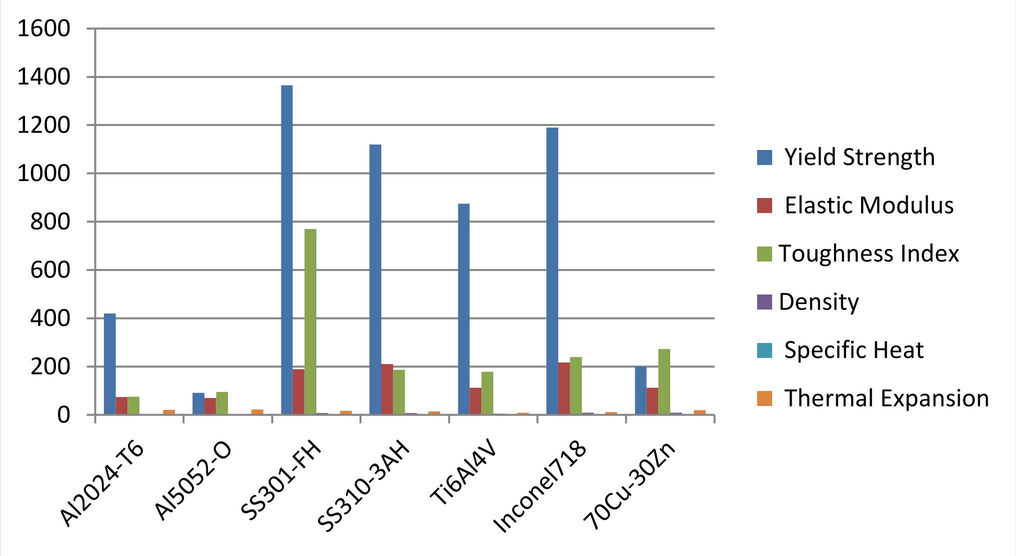

FIGURE 1. Material selection problem of cryogenic storage tank

figure 1 showing WSM alternative parameters Al2024-T6, Al5052-O, SS301-FH, SS310-3AH Ti6Al4V, Inconel718,70Cu-30Zn and evaluation parameters yield strength, elastic modules, toughness index, density, specific heat, thermal expansion.

TABLE 2. Performance Value

	Yield Strength	Elastic Modulus	Toughness Index	Density	Specific Heat	Thermal Expansion
Al2024-T6	0.307692	0.341935484	0.098051948	0.957143	0.375	0.439252
Al5052-O	0.066667	0.322580645	0.123376623	1	0.375	0.425339
SS301-FH	1	0.870967742	1	0.339241	0.75	0.556213
SS310-3AH	0.820513	0.967741935	0.242857143	0.339241	0.75	0.652778
Ti6Al4V	0.641026	0.516129032	0.232467532	0.604966	0.66666667	1
Inconel718	0.871795	1	0.31038961	0.314924	0.85714286	0.817391
70Cu-30Zn	0.307692	0.516129032	0.354545455	0.314185	1	0.472362

Table 2 showing WSM alternative parameters Al2024-T6, Al5052-O, SS301-FH, SS310-3AH Ti6Al4V, Inconel718,70Cu-30Zn and evaluation parameters yield strength, elastic modules, toughness index, density, specific heat, thermal expansion.

TABLE 3. Weight

	Yield Strength	Elastic Modulus	Toughness Index	Density	Specific Heat	Thermal Expansion
Al2024-T6	0.166	0.166	0.166	0.166	0.166	0.166

Al5052-O	0.166	0.166	0.166	0.166	0.166	0.166
SS301-FH	0.166	0.166	0.166	0.166	0.166	0.166
SS310-3AH	0.166	0.166	0.166	0.166	0.166	0.166
Ti6Al4V	0.166	0.166	0.166	0.166	0.166	0.166
Inconel718	0.166	0.166	0.166	0.166	0.166	0.166
70Cu-30Zn	0.166	0.166	0.166	0.166	0.166	0.166

Table 3 shows the weight of the waspas method

TABLE 4. Weighted Normalised Decision Matrix

	Yield Strength	Elastic Modulus	Toughness Index	Density	Specific Heat	Thermal Expansion
Al2024-T6	0.822294	0.836825	0.680114	0.992755	0.849746	0.87235
Al5052-O	0.637924	0.82877	0.706553	1	0.849746	0.867701
SS301-FH	1	0.977328	1	0.835727	0.953367	0.907215
SS310-3AH	0.967694	0.994572	0.790621	0.835727	0.953367	0.931646
Ti6Al4V	0.928841	0.89602	0.784903	0.919957	0.934908	1
Inconel718	0.977482	1	0.823487	0.825471	0.974736	0.967082
70Cu-30Zn	0.822294	0.89602	0.841871	0.82515	1	0.882937

Table 4 presents the weighted normalised decision matrix for selected engineering materials based on key thermo-mechanical properties. The values reflect relative performance in yield strength, elastic modulus, toughness, density, specific heat, and thermal expansion, enabling objective comparison and informed multi-criteria material selection decisions.

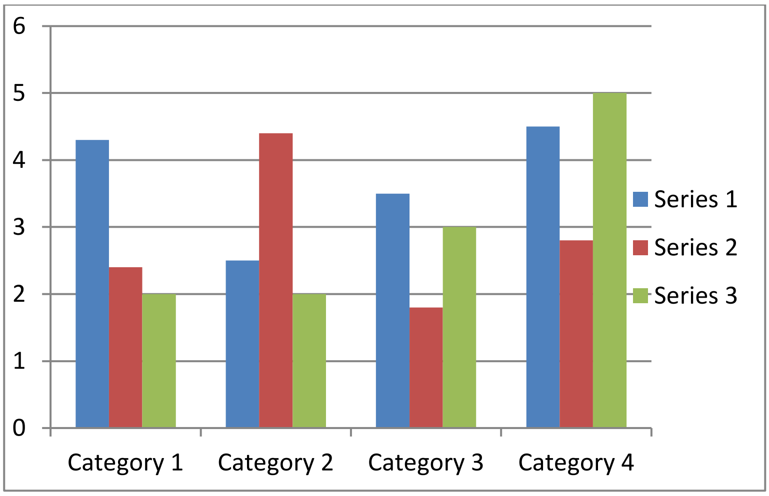

FIGURE 2. Weighted Normalised Decision Matrix

Figure 4 presents the weighted normalised decision matrix for selected engineering materials based on key thermo-mechanical properties. The values reflect relative performance in yield strength, elastic modulus, toughness, density, specific heat, and thermal expansion, enabling objective comparison and informed multi-criteria material selection decisions.

TABLE 5. Rank

Rank
6
7
1
3
4
2
5

Table 3 presents a comparative ranking pattern across seven positions. Rank 1 indicates the highest priority, followed by 2 and 3, showing strong performance. Ranks 4 and 5 represent moderate standing, while 6 and 7 reflect comparatively lower performance among the evaluated criteria.

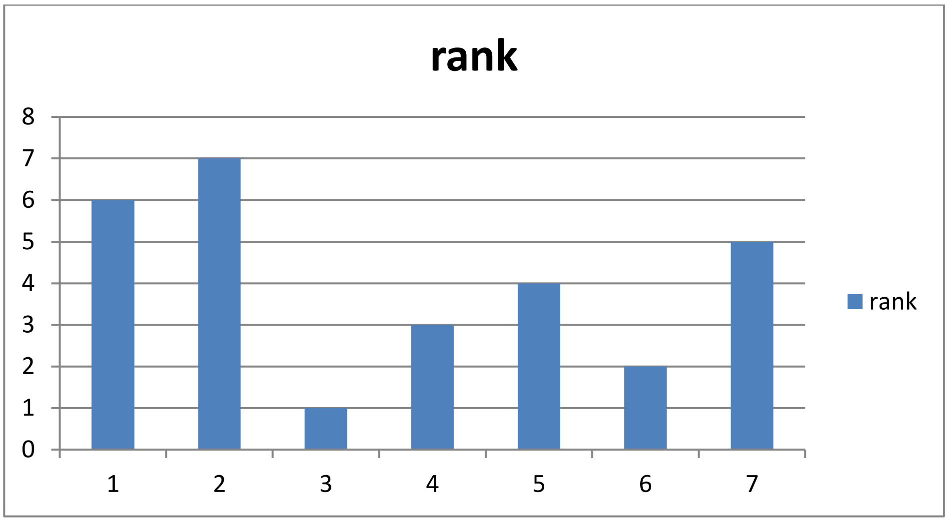

FIGURE 3. Rank

Figure 3 presents a comparative ranking pattern across seven positions. Rank 1 indicates the highest priority, followed by 2 and 3, showing strong performance. Ranks 4 and 5 represent moderate standing, while 6 and 7 reflect comparatively lower performance among the evaluated criteria.

5. CONCLUSION

Performance, safety, and cost-effectiveness of the tank are all impacted by the material selection. Due to their high mechanical strength and resistance to corrosion, stainless steel alloys like 304L and 316L are frequently utilised. Their ductility at very low temperatures, however, may restrict their usage in several cryogenic applications. Aluminium alloys with good cryogenic characteristics, including 5083 and 6061, provide lightweight choices. They are appropriate for non-pressurized cryogenic storage tanks, such as LNG tanks, however they have less mechanical strength than stainless steel. Although carbon steel, such ASTM A516 Grade 70, offers affordable solutions, it needs more insulation and corrosion protection. At cryogenic temperatures, it provides enough strength and hardness but is more prone to corrosion. At cryogenic temperatures, nickel-based alloys with exceptional corrosion resistance and high strength, such as Inconel 600 and Incoloy 825, are available. Despite being more expensive, they are chosen in specialised applications with harsh cryogenic conditions or corrosive surroundings.Composite materials, such carbon fibre reinforced polymers (CFRP), hold promise due to their ability to reduce weight and withstand corrosion. However, before to deployment, significant consideration is required due to their high cost and long-term durability. In the end, the choice of material for cryogenic storage the material selection problem for cryogenic storage tanks is a complex task that requires careful consideration of multiple factors. The choice of material directly impacts the tank's performance, safety, and cost-effectiveness. Based on the analysis of various materials, the following key points can be summarized: Stainless steel, such as 304L and 316L, is a popular choice due to its good mechanical properties, corrosion resistance, and reasonable cost. It is suitable for moderate cryogenic temperatures and offers a balance between performance and affordability.Aluminum alloys, Lightweight choices that thrive in non-pressurized cryogenic applications like LNG storage tanks include 5083 and 6061. They have reasonable low-temperature embrittlement resistance and cryogenic qualities, although they are less strong mechanically than stainless steel. For cryogenic storage tanks, carbon steel, such as ASTM A516 Grade 70, offers affordable solutions. Although it provides enough strength and toughness at cryogenic temperatures, its sensitivity to corrosion necessitates additional corrosion prevention measures. Extremely cold or corrosive situations favour nickel-based alloys, such as Inconel 600 and Incoloy 825. Although they have strong strength at low temperatures and excellent corrosion resistance, their more expensive price may prevent them from being widely used. For cryogenic storage tanks, composite materials like carbon fibre reinforced polymers (CFRP) show potential.

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