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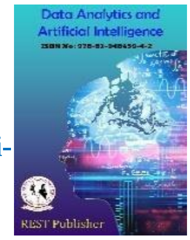


# Assessment of Materials Selection Problem in Cryogenic Tank Using COPRAS Method

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**Abstract:** Materials are well-known for their function in product creation and development. There are numerous materials with various qualities on the market right now. Before deciding on the best material for a type of product, the architect must give it some thought. Research Significance: Before making a final decision, the design engineer must also consider a wide range of material eligibility requirements; otherwise, the product could fail before it should while in use. The choice to choose a material for a particular product is an example of a "multi-criteria decision-making" dilemma because it involves several competing criteria and a limited number of candidate options. Research Methodology: In this study, the "COPRAS (COmplex PRoportional ASsessment) technique" is used to address some typical issues with material choice. " Al2024-T6, Al5052-O, SS301-FH, SS310-3AH, Inconel718 and 70Cu-30Zn" are further materials chosen for the cryogenic storage tank. "Toughness Index, Elastic Modulus, Yield Strength, Specific Heat, Thermal Conductivity, and Density" are the material properties used as evaluation criteria. Result: The rank of alternatives using the COPRAS method for Al2024-T6 is fifth, Al5052-O is sixth, SS301-FH is first, SS310-3AH is second, Inconel718 is third and 70Cu-30Zn is fourth. Conclusion**:** The outcome demonstrates that "301 Full Hard Tempered Stainless Steel" and "Stainless Steel 310" are the best materials for cryogenic tanks.
**Keywords:** Material selection. Cryogenic, Elastic Modulus, Yield Strength, Specific Heat, Thermal Conductivity, MCDM.

## 1. Introduction

The developers should have a straightforward comprehension of the functional prerequisites for each different component and in-depth knowledge of the analyzed criteria for a particular engineering design when choosing the most appropriate material from an ever-increasing arrangement of available solutions, and each has its attributes, applications, potential benefits, and limitations [1]. A poor choice of material can frequently result in significant expenditures and ultimately hasten component or product failure. One of the most difficult challenges in the creation and manufacture of products for various engineering applications is choosing the appropriate materials for various components. Therefore, to achieve the required outcome with minimal cost involvement and specialized applicability, the designers must identify and choose appropriate materials with certain capabilities [2]. A classic "multi-criteria decision-making (MCDM)" dilemma is choosing the best material in the presence of many, typically contradictory criteria. Thus, to choose the optimum option for a given application, a methodical and effective strategy for the selection of materials is required [3]. The finest selections regarding the choice of the most sustainable material for various engineering purposes have been effectively derived by historical scholars using a variety of mathematical methodologies. "Chatterjee et al." described the effectiveness of the "complex proportional assessment (COPRAS) and evaluation of mixed data (EVAMIX)" approaches [4,5]. The study of previous studies demonstrates that while much work has already been done on the choice of materials using various MCDM techniques, very little has been done to compare the rating efficiency of these techniques while addressing material selection issues [6]. The "science of cryogenics" examines how comparatively low temperatures behave (nearly 123 K). The goal is to create systems and components that make use of these temperatures. " Liquid nitrogen gas" is kept and moved in the cryogenic container. These refrigerated tanks require specialized approaches for their design [7]. The material of the tank should be adequately hard and rigid. Also, weldability and machinability must be high. Lower density and thermal properties are the other desired properties. The tank material should not be suffered from a ductile/brittle transition at the operating temperature "- 196 °C" [8,9]. In this paper " Al2024-T6, Al5052-O, SS301-FH, SS310-3AH, Inconel718 and 70Cu-30Zn" are further materials chosen for the cryogenic storage tank. "Toughness Index, Elastic Modulus, Yield Strength, Specific Heat, Thermal Conductivity, and Density" are the material properties used as evaluation criteria.

## 2. Materials and Methods

Among the most difficult challenges in the development of merchandise for various engineering, purposes are choosing the appropriate materials for various components. Therefore, to achieve the required outcome with minimal cost involvement and specialized applicability, the designers must identify and choose appropriate materials with certain capabilities [10]. A common "multi-criteria decision-making (MCDM)" difficulty is choosing the best material when there are numerous, typically contradictory criteria present. The optimum alternative for a specific input must therefore be chosen using a methodical and appropriate method to material picking [11]. In this study, the "COPRAS (COmplex PRoportional ASsessment) technique" is used to address some typical issues with material choice. "The complex proportional assessment (COPRAS)" technique, which employs a stepwise ranking and evaluation procedure of the available options in terms of relevance and usefulness degree, was first developed by "Zavadskas et al". Numerous issues in building, property maintenance, economics, etc. were addressed using this methodology [12]. While having a few small drawbacks, "COPRAS MCDM" has a lot of strong good traits that more than make up for them. The capacity of "COPRAS" to treat advantageous and non-beneficial factors individually is the primary and most important benefit [13]. According to COPRAS, a collection of criteria that effectively specifies the possibilities, as well as the weights and amounts of the criterion, determines the significance and utility level of the versions under investigation. The COPRAS strategy is an essential MCDM technique and a useful decision-making tool, as shown by these guiding principles [14]. With a single evaluation approach that takes into account the effects of both the cost and advantage type factors, COPRAS rates options. The fact that COPRAS considers the "utility degree of options", which denotes a percentage and indicates the amount to which one solution is greater or inferior to the other different options used for evaluation, sets it apart from other MCDM techniques [15]. Additionally, according to recent studies, judgements embedded with COPRAS are more accurate and less biased than outcomes with "TOPSIS and WSM", and COPRAS is more stable than WSM in the involvement of data changes. Additionally, COPRAS has a lot of benefits over other MCDM tools like "PROMETHEE, DEA, VIKOR, AHP, and ELECTRE", including a highly straightforward and visible MCDM method that takes a lot less computing effort and a high likelihood of pictorial understanding [16,17].

**Step 1:** The decision array X, which displays how various options perform concerning certain criteria, is created.

$$x_{ij} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & x\cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (1)$$

**Step 2:** Weights for the criteria are expressed as

$$w_j = [w_1 \ \cdots \ w_n], \quad (2)$$

$$\sum_{j=1}^{n} (w_1 \ \cdots \ w_n) = 1$$

the sum of the weight distributed among the evaluation parameters must be one.

**Step 3:** The matrix $x_{ij}$'s normalized values are computed as

$$n_{ij} = \frac{x_{ij}}{\sum_{j=1}^{n} x_{ij}} \quad (3)$$

**Step 4:** Weighted normalized matrix $N_{ij}$ is calculated by the following formula

$$N_{ij} = w_j \times n_{ij} \quad (4)$$

**Step 5:** sum of benefit criteria and the sum of cost criteria are calculated by following equations 5 and 6 respectively.

$$B_i = \sum_{j=1}^{k} N_{ij} \quad (5)$$

$$C_i = \sum_{j=k+1}^{m} N_{ij} \quad (6)$$

**Step 6:** “Relative significance Qi of each alternative” is determined using equations 5 and 6.

$$Q_i = B_i + \frac{min\,(C_i) \times \sum_{i=1}^{n} C_i}{C_i \times \sum_{i=1}^{n} (\frac{min\,(C_i)}{C_i})} \quad (7)$$

**Step 7:** Next $U_i$ is calculated.

$$U_i = \frac{Q_i}{max\,(Q_i)} \times 100\% \quad (8)$$

In this paper " Al2024-T6, Al5052-O, SS301-FH, SS310-3AH, Inconel718 and 70Cu-30Zn" are further materials chosen for the cryogenic storage tank. "Toughness Index, Elastic Modulus, Yield Strength, Specific Heat, Thermal Conductivity, and Density" are the material properties used as evaluation criteria.

"The toughness index" was defined by "ACI Committee 544" as "the ratio between the energy needed to deflect a fibre concrete beam (used in the modulus of rupture test) by a specified amount and the energy needed to move the fibre beam to the site of first crack". This definition, which is unaffected by the units used, assigns a

numerical number to toughness [18]. When a force is given to an item or substance, its propensity to deform “elastically (i.e., non-permanently)” when deformed is mathematically described by the "elastic modulus (modulus of elasticity)". " The slope of an object's stress-strain curve in the elastic deformation zone" is called the “elastic modulus”. The elastic modulus gauges a material's susceptibility to elastic, or "springy," deformation [19]. "Yield strength" is a “measure of the greatest stress that a material can withstand without deforming plastically”. It is a practical estimate of the elastic threshold and is "the stress at which a material exhibits a particular permanent deformation". Yield strength is crucial for designing structural elements in engineering [20]. "The quantity of heat needed to raise a substance's temperature by one degree Celsius in one gramme", also known as “specific heat”. Typically, “calories or joules per gramme per degree Celsius” are used as the “units of specific heat”. Determining the operating temperatures and amount of heat necessary can benefit from the capacity to discriminate between two composite materials using "specific heat" [21]. "Thermal conductivity", which is commonly denoted by the letters "$k, \lambda, or\ \kappa$" is "the intrinsic ability of a substance to transport or conduct heat." It is one of the three methods of heat transfer, the other two being convection and radiation. Heat-transfer procedures can be measured using appropriate rate formulas. [22]. One of any material's most essential physical characteristics is its density. " Mass per unit volume" is the definition of density for a material. It is described as a "ratio of material mass to volume". "P" stands for it. The SI system uses the unit KG/m3. Since most designs are constrained by either size or weight, density is crucial in many equations [23].

## 3. Analysis and Discussion

**TABLE 1.** Performance rating matrix

| Materials | Yield Strength | Elastic Modulus | Toughness Index | Density | Specific Heat | Thermal Conductivity |
|---|---|---|---|---|---|---|
| **Al2024-T6** | 420 | 74.2 | 75.5 | 2.8 | 0.16 | 0.37 |
| **Al5052-O** | 91 | 70 | 95 | 2.68 | 0.16 | 0.33 |
| **SS301-FH** | 1365 | 189 | 770 | 7.9 | 0.08 | 0.04 |
| **SS310-3AH** | 1120 | 210 | 187 | 7.9 | 0.08 | 0.03 |
| **Inconel718** | 1190 | 217 | 239 | 8.51 | 0.07 | 0.31 |
| **70Cu-30Zn** | 200 | 112 | 273 | 8.53 | 0.06 | 0.29 |

Table 1 shows the value of dataset Performance ratings of materials used in the cryogenic storage tank. In this paper " Al2024-T6, Al5052-O, SS301-FH, SS310-3AH, Inconel718 and 70Cu-30Zn" are further materials chosen for the cryogenic storage tank. "Toughness Index, Elastic Modulus, Yield Strength, Specific Heat, Thermal Conductivity, and Density" are the material properties used as evaluation criteria.

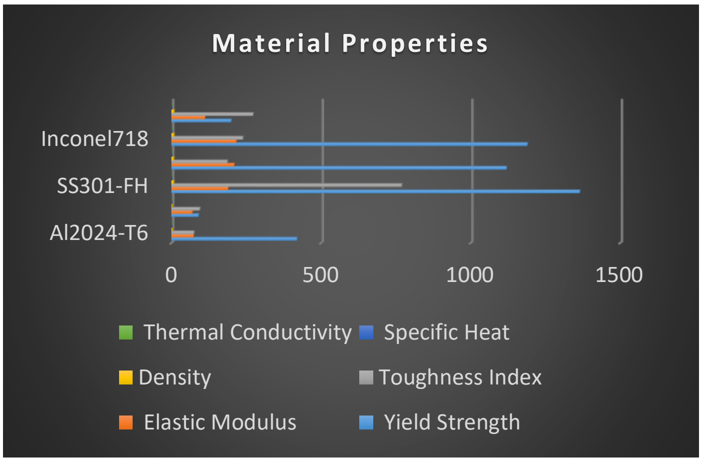


**FIGURE 1.** Performance ratings

The performance ratings of the materials used are represented graphically in this figure 1. In this paper " Al2024-T6, Al5052-O, SS301-FH, SS310-3AH, Inconel718 and 70Cu-30Zn" are further materials chosen for the cryogenic storage tank. "Toughness Index, Elastic Modulus, Yield Strength, Specific Heat, Thermal Conductivity, and Density" are the material properties used as evaluation criteria.

Table 2 Shows the normalized matrix of Performance Ratings of Materials Used in the cryogenic storage tank is displayed in Table 2 above. Equation 3 was used to create this matrix.

**TABLE 2.** Normalized matrix

| | | | | | |
|---|---|---|---|---|---|
| 0.0958 | 0.0851 | 0.0461 | 0.0731 | 0.2623 | 0.2701 |
| 0.0207 | 0.0803 | 0.0579 | 0.0699 | 0.2623 | 0.2409 |
| 0.3112 | 0.2167 | 0.4697 | 0.2062 | 0.1311 | 0.0292 |
| 0.2554 | 0.2408 | 0.1141 | 0.2062 | 0.1311 | 0.0219 |
| 0.2713 | 0.2488 | 0.1458 | 0.2221 | 0.1148 | 0.2263 |
| 0.0456 | 0.1284 | 0.1665 | 0.2226 | 0.0984 | 0.2117 |

**TABLE 3.** Weight Distribution

| | | | | | |
|---|---|---|---|---|---|
| 0.1667 | 0.1667 | 0.1667 | 0.1667 | 0.1667 | 0.1667 |
| 0.1667 | 0.1667 | 0.1667 | 0.1667 | 0.1667 | 0.1667 |
| 0.1667 | 0.1667 | 0.1667 | 0.1667 | 0.1667 | 0.1667 |
| 0.1667 | 0.1667 | 0.1667 | 0.1667 | 0.1667 | 0.1667 |
| 0.1667 | 0.1667 | 0.1667 | 0.1667 | 0.1667 | 0.1667 |
| 0.1667 | 0.1667 | 0.1667 | 0.1667 | 0.1667 | 0.1667 |

The preferred weight for the evaluation parameters is shown in Table 3. In this case, weight is equally distributed among evaluation criteria and the sum of weight distributed is one.

**TABLE 4.** Weighted normalized decision matrix

| | | | | | |
|---|---|---|---|---|---|
| 0.01596 | 0.01418 | 0.00768 | 0.01218 | 0.04372 | 0.04501 |
| 0.00346 | 0.01338 | 0.00966 | 0.01166 | 0.04372 | 0.04015 |
| 0.05187 | 0.03612 | 0.07828 | 0.03436 | 0.02186 | 0.00487 |
| 0.04256 | 0.04013 | 0.01901 | 0.03436 | 0.02186 | 0.00365 |
| 0.04522 | 0.04147 | 0.02430 | 0.03701 | 0.01913 | 0.03771 |
| 0.00760 | 0.02140 | 0.02775 | 0.03710 | 0.01639 | 0.03528 |

The Performance Ratings of Materials Used in the cryogenic storage tank are shown in Table 4 as a normalized matrix. Equation 4 was used to calculate this matrix, which was produced by multiplying tables 2 and 3.

**TABLE** 5. the sum of benefit criteria and the sum of cost criterion

| Materials | Bi | Ci |
|---|---|---|
| **Al2024-T6** | 0.03781 | 0.10091 |
| **Al5052-O** | 0.02649 | 0.09552 |
| **SS301-FH** | 0.16626 | 0.06108 |
| **SS310-3AH** | 0.10170 | 0.05987 |
| **Inconel718** | 0.11098 | 0.09385 |
| **70Cu-30Zn** | 0.05675 | 0.08877 |

Table 5 displays the total cost and total benefit criteria that were determined using equations 5 and 6. "Al2024-T6, Al5052-O, SS301-FH, SS310-3AH, Inconel718 and 70Cu-30Zn" are further materials chosen for the cryogenic storage tank.

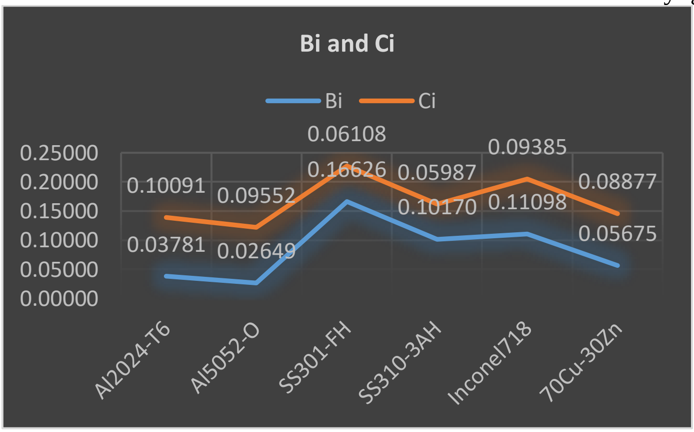


**FIGURE 2.** Bi and Ci

Equations 5 and 6 were used to calculate the total beneficial criteria and total cost criterion shown in Figure 2. "Al2024-T6, Al5052-O, SS301-FH, SS310-3AH, Inconel718 and 70Cu-30Zn" are further materials chosen for the cryogenic storage tank.

**TABLE 6.** Relative significance and Utility degree

| Materials | Qi | Ui |
|---|---|---|
| **Al2024-T6** | 0.10355 | 37.6753 |
| **Al5052-O** | 0.09594 | 34.9052 |
| **SS301-FH** | 0.27486 | 100.0000 |
| **SS310-3AH** | 0.21250 | 77.3134 |
| **Inconel718** | 0.18166 | 66.0933 |
| **70Cu-30Zn** | 0.13148 | 47.8352 |

Using equations 7 and 8, Table 6 displays the relative relevance and utility degree. Here utility degree value for Al2024-T6 is 37.6753, Al5052-O is 34.9052, SS301-FH is 100, SS310-3AH is 77.3134, Inconel718 is 66.0933 and 70Cu-30Zn is 47.8352.

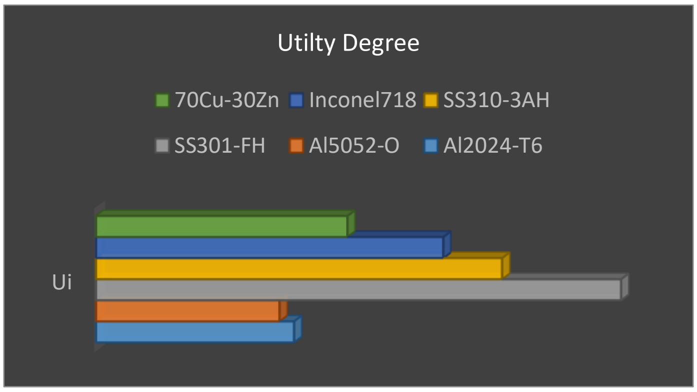


**FIGURE 3.** Utility Degree

Figure 3 shows the illustration of the Relative significance and Utility degree calculated by using equations 7 and 8. Here utility degree value for Al2024-T6 is 37.6753, Al5052-O is 34.9052, SS301-FH is 100, SS310-3AH is 77.3134, Inconel718 is 66.0933 and 70Cu-30Zn is 47.8352.

**TABLE 7.** Rank

| Materials | Rank |
|---|---|
| **Al2024-T6** | 5 |
| **Al5052-O** | 6 |
| **SS301-FH** | 1 |
| **SS310-3AH** | 2 |
| **Inconel718** | 3 |
| **70Cu-30Zn** | 4 |

Table 7 shows the rank of alternatives Al2024-T6, Al5052-O, SS301-FH, SS310-3AH, Inconel718 and 70Cu-30Zn using utility degree values in table 6. Here rank of alternatives using the COPRAS method for Al2024-T6 is fifth, Al5052-O is sixth, SS301-FH is first, SS310-3AH is second, Inconel718 is third and 70Cu-30Zn is fourth.

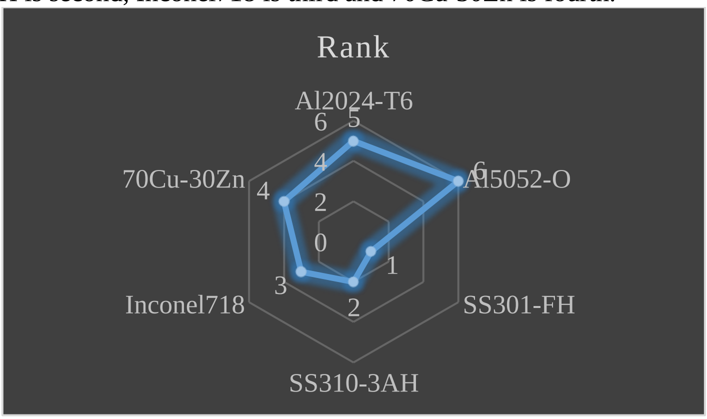


**FIGURE 4.** Rank

Figure 4 illustrates the ranking of Ui from Table 6. Here rank of alternatives using the COPRAS method for Al2024-T6 is fifth, Al5052-O is sixth, SS301-FH is first, SS310-3AH is second, Inconel718 is third and 70Cu-30Zn is fourth. The best material for the cryogenic tank is 301 Full Hard Tempered Stainless Steel followed by Stainless Steel 310.

## 4. Conclusion

Materials have a well-established function in industrial innovation and improvement. There are numerous materials with various qualities on the market right now. Before deciding on the best material for a specific object, the design engineer must give it some thought. Any error in material selection could lead to issues during manufacturing and integration. The design professional must choose the best material from a broad range of components with varied "mechanical, physical, and chemical properties" to satisfy various design parameters. The design engineer must also take into account a variety of material selection requirements before drawing a final determination.; otherwise, the product could fail before it should while in use. The choice to choose a resource for a particular product is an element of a complex choice dilemma because it involves several competing factors and a limited number of potential options. In this study, the "COPRAS (COmplex PRoportional ASsessment) technique" is used to address some typical issues with material choice. Here rank of alternatives using the COPRAS method for Al2024-T6 is fifth, Al5052-O is sixth, SS301-FH is first, SS310-3AH is second, Inconel718 is third and 70Cu-30Zn is fourth. The outcome demonstrates that "301 Full Hard Tempered Stainless Steel" and "Stainless Steel 310" are the best materials for cryogenic tanks.

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