



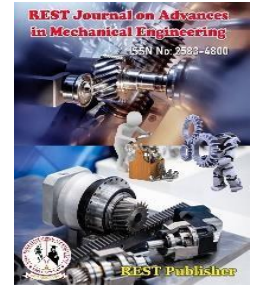
REST Journal on Advances in Mechanical Engineering
Vol: 4(1), March 2025

REST Publisher; ISSN: 2583-4800 (Online)

Website:

<https://restpublisher.com/journals/jame/>

DOI: <https://doi.org/10.46632/jame/4/1/5>



Improving Material Behaviour Analysis in Solid Mechanics Using the PROMETHEE Method

***B.Gokul, R.Maheshkumar, E.Ramnath, S.Vengatesh, R.Joseph**

Arasu Polytechnic College, Kumbakonam, Tamil Nadu, India.

*Corresponding Author Email: 24gokul7@gmail.com

Abstract: Mechanics is the scientific study of forces and motion of matter, focusing on both the behavior of materials and the fundamental principles of how matter moves under various forces. Solid mechanics, a subfield of mechanics, specifically investigates the behavior of solid materials when subjected to external forces and stresses. This field is pivotal in physics, engineering, chemistry, and biology, driving critical breakthroughs across various disciplines. For instance, in physics, solid mechanics has contributed to key advancements like the theory of relativity and quantum mechanics, while in chemistry; it helps understand molecular structures, crystal formations, and polymerization processes. In biology, biomechanics is essential to comprehending the movement and interaction of biological structures, from molecules to entire organisms.

This research contributes to advancing the field of solid mechanics by introducing new computational techniques for solving large-scale problems. By addressing issues such as computational efficiency, mesh distortion, and handling complex interfaces, it offers improvements in modeling mechanical behavior, with applications in tumor mechanics, tribology, and nonlinear solid mechanics. Alternatives: Acrylonitrile Butadiene Styrene (ABS), PLA (Polylactic Acid), PETG (Polyethylene Terephthalate Glycol), And TPU (Thermoplastic Polyurethane). Evaluation Parameters: Tensile Strength (C1), Yield Strength (C2), Compression Strength (C3), Elongation at Break (C4), Yield Strength Ratio (C5), Water Absorption Percentage (C6). The results show that Acrylonitrile Butadiene Styrene (ABS) received the highest ranking, whereas TPU (Thermoplastic Polyurethane) received the lowest ranking.

Acrylonitrile Butadiene Styrene (ABS) has the highest value for Solid mechanics according to the PROMETHEE approach.

Keywords: Solid Mechanics, Finite Element Methods, Tumor Mechanics, Tribology, Computational Techniques.

1. INTRODUCTION

Mechanics is the branch of science that focuses on the forces and movement of matter. Solid mechanics specifically deals with the forces and motion of matter in its solid state. Physicists, naturally, have a keen interest in mechanics, as many of the most significant breakthroughs in physics during the 20th century are closely tied to mechanics, including the theory of relativity, quantum mechanics, and statistical mechanics. Chemists are concerned with the mechanics of chemical reactions, the formation of molecular structures, crystal creation, the development of materials with specific properties, and polymerization of large molecules, among other topics. Biologists focus on biomechanics, which examines how structure relates to function across various levels, from biomolecules and cells to tissues, organs, and entire organisms [1]. Existing most engineers can solve their linear and nonlinear structural and solid mechanics problems using finite element techniques. issues. Finding a solution, however, may become problematic due to the computational and storage requirements when the system of finite element equations is too big. This study presents a novel method for resolving finite element equations that offers considerable benefits over conventional direct elimination methods, especially for large systems. Notably, it eliminates the need to store an array that is global. In its

most basic form, an approximation factorization technique is used to solve the system of equations the solution is obtained element-by-element by factorizing each element arrays separately [2]. The development and buildup of mechanical stresses are intrinsically linked to the growth of the tumor mass at the expense of the surrounding host tissue is known as tumor progression. Here, solid tumors are an example of a complicated mechanical system that combines fluid and solid mechanics. Both the fluid strains and the cancer's growth are significantly influenced by the stresses produced by the tumor's solid phase. Three types of solid stresses in tumors can be distinguished at the tissue level: extrinsic stresses that the host tissue applies to the tumor, stressors that cause swelling, Residual stresses [3]. Several important areas are covered by current tribology research, which applies solid mechanics: models for thermal and contact stresses on sliding surface asperities; magnetic recording head design specifications; friction and wear in bearings under dynamic loading to enhance bearing longevity; and the behavior of human-artificial joints to extend their lifespan. The combination of solid mechanics and tribology provides insights into the many types of stress and deformation, as well as surfaces' frictional reaction when moving relative to one another [4]. The foundation of the classical theory of solid mechanics is the idea that a body's mass distribution is continuous. The partial differential equations (PDEs) that underpin the mathematical framework used to describe a solid under these assumptions also presume that the deformation is sufficiently smooth for the PDEs to be applicable in either their strong or weak forms[5]. It is easier to impose necessary boundary conditions because between adjacent nodes on the edge of the convex hull, the NEM interplant is precisely linear. The study also describes an approach for employing NEM to represent non-convex bodies, like cracks, and material discontinuities. The discrete system of linear equations is derived using a conventional displacement-based Galerkin approach. It is addressed how NEM can be applied to resolve a range of solid mechanics problems, including be applied to resolve a number of solid mechanical issues, including fracture problems. This demonstrates its potential for solving other types of problems, such as crack growth, plate deformations, and large deformations [6]. The study shows that in order to preserve rotational invariance, mortar constraints need to be imposed to the configuration as well as the displacements. Dual multiplier fields provide an effective way to implement applications that use direct linear solvers and provide a straightforward way to apply mortar constraints to the reference configuration [7]. The aim of this paper is to offer a comprehensive discussion of the fundamentals of multi-rigid body dynamics and continuum mechanics, especially as they relate to finite rotations. This approach, which has often been shown to provide higher accuracy for both linear and nonlinear problems compared to standard methods that solely discretize the displacement field, provides the foundation for recent developments in hybrid or mixed field formulations [8]. The foundation of nonlinear solid mechanics is considered to be non-equilibrium thermodynamics, where internal variables are controlled by rate equations. In order to explain viscoelastic, viscoelastic, and plastic behaviors, various kinds of rate equations are examined. Additionally, the particular situation of uncoupled instantaneous elasticity is examined in the work, along with materials that exhibit combined behaviors [9]. We provide a method for assessing elastic solid domains' dynamic structural response. It is crucial to apply a single unstructured mesh using a consistent set of finite volume (FV) techniques in order to analyze dynamic fluid-structure interaction. A vertex-based, FV approach in three dimensions (3D) for dynamic solid mechanics is described in this study. The fundamental natural frequency, including the oscillation's amplitude and period, was predicted with remarkable accuracy by adding a tiny amount of viscous damping [10]. A comprehensive approach to the formulation of the completely connected implicit ALE is given. Incorporating dynamic factors, temperature, heat transmission, and fracture propagation impacts is covered in the article. Detailed matrix equations and formulas for the discretized virtual work idea are provided, along with explicit forms for the resulting finite element matrices and vectors. A method for element-level processing of the equivalent stiffness matrix and removing grid displacements is shown. Lastly, a number of applications of nonlinear solid mechanics are addressed and shown [11]. The method accommodates discontinuities within the elements across the interface in its approximation. We suggest a universal method that can handle interfaces that are properly or imperfectly bonded without requiring any code changes. We show that for linear elasticity, the interface's location in relation to the mesh has no bearing on the attainment of optimal convergence order. The linear case, contact, and fracture propagation model problems are all numerically illustrated [12]. Large deformation plasticity and other issues involving history-dependent constitutive models in solid mechanics are better suited for a Lagrangian computational framework. When tracking numerous materials or material-free surfaces, a Lagrangian description is also helpful. A completely Lagrangian mesh, on the other hand, can become warped or need extremely small time steps to operate correctly when significant deformations take place. The presence of history-dependence makes remising difficult. For these reasons, solid mechanics particle techniques are gaining popularity [13]. This state-of-the-art article focuses on analyzing new trends and recent findings from the past decade in the use of fractional calculus to dynamic problems in solid mechanics. Research on the dynamic behavior of linear and nonlinear one-DOF systems, systems with an unlimited number of degrees of freedom,

and systems with two or more degrees of freedom is included in the review. Among the topics covered are the vibrations of suspension systems, multilayered systems, plates, shells, beams, and rods. Additionally, the impact response of viscoelastic plates and rods is investigated in the article [14]. The computational approach to plastic instability in solid mechanics is reviewed in this study. The fundamental equations used in the instability analysis of strain-rate-independent and strain-rate-dependent solids include the virtual work principle, an energy balance equation, a description of the nominal traction rate, and several constitutive equations that are first described. An updated Lagrangian is used to formulate these fundamental equations method is chosen [15]. Two in-plane displacements are involved in the more complex (but perhaps more identifiable) plane strain deformation, can be viewed as supplementary to anti-plane shear, which involves only one scalar axial displacement field. Analyzing recently, there has been a lot of interest in anti-plane shear deformations in the context of various constitutive theories (both linear and nonlinear) in solid mechanics [16]. Instead of more complex or coupled systems of partial differential equations, the governing equations for these researches are a single second-order linear or quasi-linear partial differential equation, they have the potential to be relatively simpler analytically than plane problems. Consequently, the anti-plane shear issue serves as a valuable pilot problem, allowing for the examination of different facets of solid mechanics solutions within a notably simpler context [17]. The purpose of this study is to show how fundamental contact theory and simplified solid mechanics models can be used to extract information about gripping. In the development and use of tactile sensors, mechanics has frequently been neglected [18]. By The ALE approach efficiently handles mesh distortion and entanglement by fusing the benefits of both Lagrangian and Eulerian formulations. More significantly, it can reduce load fluctuations, precisely specify any contact boundary conditions, and more when the nodes on the tool-work piece's present interface are defined as Eulerian points remove the need for after every incremental step, the boundary condition is updated. Consequently, It is clear that a number of complex solid mechanics problems, particularly those involving finite strain deformation and fracture, are better solved using the ALE approach [19]. We thoroughly explore classical topics such as plasticity under finite deformations, thin structures, material interfaces, elasticity, and incompressibility. We describe the numerical approaches employed and provide comprehensive benchmark settings to support this. The results are assessed using meticulously designed quantities of interest that enable comparisons across different models, discretizations, and implementations. Additionally, we demonstrate the computational robustness through mesh refinement studies [20].

2. MATERIALS AND METHODS

Alternatives:

Acrylonitrile Butadiene Styrene (ABS): A tough, impact-resistant thermoplastic polymer utilized in applications requiring strength and durability, such as automotive parts, toys (e.g., LEGO bricks), and electronics casings. It is renowned for having great strength, stiffness, and good performance in high-impact situations.

PLA (Polylactic Acid): A biodegradable, environmentally friendly thermoplastic made from maize or sugarcane starch, two renewable resources. PLA's simplicity of processing makes it a common option for high tensile strength 3D printing, though it is more brittle and less resistant to heat compared to other plastics.

PETG (Polyethylene terephthalate Glycol): A thermoplastic polymer with good chemical resistance and impact resistance. PETG is widely used in 3D printing, packaging, and medical applications because it combines the strength of PET with better adaptability and clarity.

TPU (Thermoplastic Polyurethane): A highly flexible, elastic, and abrasion-resistant thermoplastic, TPU is often used for items that need to be flexible and long-lasting, such as belts, gaskets, phone cases, wheels. It is valued for its high tear resistance and good stretch ability.

Evaluation Parameters:

Tensile Strength (C1): The maximum strain a material can withstand when subjected to pulling or stretching forces before breaking. Higher tensile strength indicates a material can resist higher tension forces before rupturing.

Yield Strength (C2): how much amount of stress a material can bear before irreparably deforming. It represents the point when a substance changes from elastic deformation, which returns it to its previous shape, to plastic deformation, which is permanent change in shape).

Compression Strength (C3): The ability of a material to withstand compressive (squashing or pushing) forces without crushing or deforming. Materials with high compression strength are ideal for applications where the material will be under high loads or pressure.

Elongation at Break (C4): The ability of a material to stretch before breaking, expressed as a percentage increase in length. Higher elongation indicates the material is more flexible and can deform more before failure.

Yield Strength Ratio (C5): The proportion between the tensile and yield strengths, indicating how well a material maintains its strength before permanent deformation. A higher ratio suggests the material can handle more stress before permanently changing shape, which is useful for applications requiring high durability.

Water Absorption Percentage (C6): The percentage of water a material absorbs when exposed to moisture, which can affect its dimensional stability and mechanical properties. Higher water absorption can lead to swelling, softening, or deterioration of the material, making it less suitable for wet environments.

3. PROMETHEE METHOD

The PROMETHEE technique is successfully used in various banking, industrial site planning, human resource management, water resources, investments, tourism, chemistry, healthcare, ethics, mechanics, and management, among other industries. Its strong mathematical foundations and ease of use in real-world applications are the reasons for its effectiveness. [21] Various fields have been explored, such as chemistry, administration of businesses and finances, production and assembly, transportation and logistics, energy management, society and hydrology and water management. The previous section had papers from various areas including medicine, agriculture, education, design, government and sports. To prevent duplication, even if an academic work relates to two different areas, applicant papers were assigned to the most appropriate topic in subsequent review. The selection of the most appropriate topic was given major attention. [22] To select the best model, the PROMETHEE approach is used for criterion weights, which are established the Analytical Hierarchy Process (AHP) is involved. This strategy is illustrated in the paper by using state-of-the-art techniques and a priority ranking mechanism to determine which of six laptop models is the best each with unique specifications. [23] The complexity of the problem and, in particular, proximity is two factors that contribute to instability. It can be concluded that the contribution of PROMETHEE lies in its stability and that in the future it will be useful to increasingly use "soft" priority functions such as Gaussian. [24] The PROMETHEE method (Ranking of Enrichment Evaluation) stands out for its simplicity in design and implementation, making it an easy-to-use and efficient approach for multi-criteria decision-making, especially when compared to other multivariate analysis techniques. As a foundation for this approach, it is particularly helpful in situations where a small number of options need to be evaluated and ranked. [25] Even when only a subset of frontier portfolios are used in the search for the ideal portfolio, there could still be a considerable number of portfolios to evaluate to compare. Although some optimization models must be solved in both ways, the total effort required is less than studying each portfolio individually or performing a full PROMETHEE analysis on the complete collection of frontier portfolios. PROMETHEE rankings were conducted simultaneously for frontier portfolios and all possible portfolios. [26] This assumption is often broken in many decision-making situations because the criteria often interact with each other, creating some degree of synergy or redundancy. For example, since high-speed automobiles generally have better acceleration, the criteria of maximum speed and acceleration may be redundant when evaluating sports cars. Although both factors are important for a buyer's desired sports car, their combined weight is less important than the sum of their individual weights. On the other hand, an automobile that is both fast and reasonably priced is more valuable, so factors such as price and high speed may work together. [27] The AHP technique offers a unique advantage by breaking down the decision-making process into a structure with a hierarchy of components and criteria. This permits a more thorough analysis of the problem, emphasizing the importance of each criterion. In contrast, PROMETHEE does not have this hierarchical structure, making it challenging for decision-makers to effectively understand and interpret the results when dealing with a significant number of criteria (above seven). [28] The PROMETHEE family, also known as the Priority Ranking Method for Enrichment Assessment, is designed to assess criteria in a structured and quantitative manner. It is based on three basic ideas: generating results that allow for partial and complete rankings; maximizing dominance relationships between alternatives for each criterion; and optimizing the preference structure by mixing different priority functions. [29] Uniform evaluation scales and priority functions are commonly used to evaluate the criteria in these types of investigations. But establishing separate priority functions for different criteria has a major impact on how accurate the decision-making process is. The PROMETHEE approach, in contrast to traditional ranking techniques, allows for the definition of unique priority functions for each criterion. The PROMETHEE approach, chosen for its simplicity and ability to represent how the human mind integrates and processes information when faced with multiple, often conflicting, decision-making dimensions, is used to answer the equipment selection problem in this work. [30].

4. ANALYSIS AND DISSECTION

TABLE 1. Solid Mechanic

	Solid Mechanic					
	Tensile Strength (C1)	Yield Strength (C2)	Compression Strength (C3)	Elongation at Break (C4)	Yield Strength Ratio (C5)	Water Absorption Percentage (C6)
Acrylonitrile Butadiene Styrene (ABS)	1360	1750	8.5	2.18	90.5	0.145
PLA (Polylactic Acid)	1670	1550	6.5	3.35	94.3	0.268
PETG (Polyethylene Terephthalate Glycol)	1660	1250	7.5	4.76	88.6	0.395
TPU (Thermoplastic Polyurethane)	1570	1150	3.5	3.18	96.4	0.972
Max	1670	1750	8.5	4.76	96.4	0.972
Min	1360	1150	3.5	2.18	88.6	0.145
max-Min	310	600	5	2.58	7.8	0.827

The data in Table 1 Solid Mechanic provides a comparative analysis of different thermoplastic materials based on their mechanical properties, including tensile strength, yield strength, compression strength, elongation at break, yield strength ratio, and water absorption percentage. Among the materials analyzed, PLA (Polylactic Acid) exhibits the highest tensile strength (1670 MPa), while ABS (Acrylonitrile Butadiene Styrene) shows the highest yield strength (1750 MPa), indicating superior structural resistance before deformation. ABS also has the best compression strength (8.5 MPa), making it ideal for load-bearing applications. In terms of elongation at break, which measures flexibility, PETG (4.76%) outperforms the others, showing the highest ability to stretch before breaking. Conversely, ABS (2.18%) has the lowest elongation, indicating brittleness under tensile stress. TPU (Thermoplastic Polyurethane) has the highest yield strength ratio (96.4), meaning it maintains its strength well under stress. Water absorption is a crucial factor in determining material stability in humid environments. TPU has the highest water absorption (0.972%), making it less suitable for moisture-prone applications, while ABS (0.145%) absorbs the least, ensuring dimensional stability.

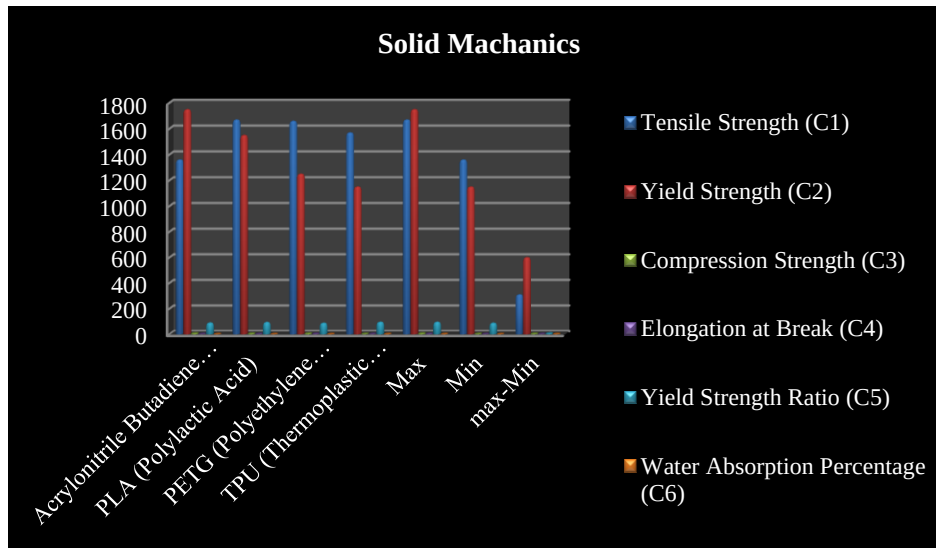


FIGURE 1. Solid Mechanics

Figure 1's data illustrates the mechanical properties of different thermoplastics. PLA has the highest tensile strength (1670 MPa), making it the strongest under tension, while ABS has the highest yield strength (1750 MPa) and compression strength (8.5 MPa), indicating its superior load-bearing capability. PETG exhibits the highest elongation at break (4.76%), meaning it is the most flexible. TPU has the highest yield strength ratio (96.4%) but also the highest

water absorption (0.972%), making it less suitable for humid environments. This comparison helps determine the best material based on application needs.

TABLE 2. Normalized Matrix

	Normalized Matrix					
	Tensile Strength (C1)	Yield Strength (C2)	Compression Strength (C3)	Elongation at Break (C4)	Yield Strength Ratio (C5)	Water Absorption Percentage (C6)
Acrylonitrile Butadiene Styrene (ABS)	0	1	1	0	0.24359	0
PLA (Polylactic Acid)	1	0.666667	0.6	0.453488	0.730769	0.14873
PETG (Polyethylene Terephthalate Glycol)	0.967742	0.166667	0.8	1	0	0.302297
TPU (Thermoplastic Polyurethane)	0.677419	0	0	0.387597	1	1

The normalized matrix in Table 2 provides a comparative analysis of the mechanical properties of different thermoplastics by scaling their values between 0 (minimum) and 1 (maximum). This helps in understanding relative performance across different criteria. ABS (Acrylonitrile Butadiene Styrene) achieves the highest yield strength (1.00) and compression strength (1.00), making it the strongest under stress and compression. However, its tensile strength (0.00) and elongation at break (0.00) indicate that it is less flexible. It also has the lowest water absorption (0.00), making it highly stable in humid conditions. PLA (Polylactic Acid) exhibits the highest tensile strength (1.00) and a moderately high yield strength ratio (0.7308), meaning it maintains strength well under stress. However, its compression strength (0.60) and elongation at break (0.4535) suggest that it is not the most flexible material. PETG (Polyethylene Terephthalate Glycol) scores highest in elongation at break (1.00), meaning it has the best flexibility and stretching ability before breaking. However, its yield strength (0.1667) and yield strength ratio (0.00) indicate lower structural stability under prolonged stress. TPU (Thermoplastic Polyurethane) has the best yield strength ratio (1.00) and water absorption (1.00), making it highly elastic but prone to moisture absorption. It has the lowest compression strength (0.00), showing reduced resistance to compressive forces.

TABLE 3. Pair wise Comparison

	Pair wise Comparison					
	Tensile Strength (C1)	Yield Strength (C2)	Compression Strength (C3)	Elongation at Break (C4)	Yield Strength Ratio (C5)	Water Absorption Percentage (C6)
D12	-1	0.333333	0.4	-0.45349	-0.48718	-0.14873
D13	-0.96774	0.833333	0.2	-1	0.24359	-0.3023
D14	-0.67742	1	1	-0.3876	-0.75641	-1
D21	1	-0.33333	-0.4	0.453488	0.487179	0.14873
D23	0.032258	0.5	-0.2	-0.54651	0.730769	-0.15357
D24	0.322581	0.666667	0.6	0.065891	-0.26923	-0.85127
D31	0.967742	-0.83333	-0.2	1	-0.24359	0.302297
D32	-0.03226	-0.5	0.2	0.546512	-0.73077	0.153567
D34	0.290323	0.166667	0.8	0.612403	-1	-0.6977
D41	0.677419	-1	-1	0.387597	0.75641	1
D42	-0.32258	-0.66667	-0.6	-0.06589	0.269231	0.85127
D43	-0.29032	-0.16667	-0.8	-0.6124	1	0.697703

Table 3 provides a pairwise comparison of different materials (labeled D12, D13, D14, etc.) based on six mechanical properties. Positive values indicate that the material in the first column outperforms the one in the second column, while negative values suggest the reverse. This comparison highlights the strengths and weaknesses of materials in specific categories, such as tensile strength, yield strength, compression strength, and elongation at break, yield strength ratio, and water absorption. For example, in the tensile strength comparison between D12 and D13, D12 is significantly inferior with a value of -1, showing a large difference in performance. However, D13 excels in yield strength (0.8333), indicating that it can better withstand stress before permanent deformation. D14 performs the best in compression strength (1) and yield strength (1), suggesting it is the most robust material under compressive forces and high stress, although it is less flexible and more prone to lower elongation at break. D31 excels in elongation at break (1), which indicates it is highly flexible, but its performance in other categories like compression strength is weaker. On the other hand, D42 and D43 consistently show weaker performances in key properties, indicating they may not be the most suitable materials for applications requiring high tensile or compressive strength.

TABLE 4. Preference Value

	Preference Value						
	0.2336	0.1652	0.3355	0.1021	0.0424	0.1212	
D12	0	0.055067	0.1342	0	0	0	0.189267
D13	0	0.137667	0.0671	0	0.010328	0	0.215095
D14	0	0.1652	0.3355	0	0	0	2
D21	0.2336	0	0	0.046301	0.020656	0.018026	0.318584
D23	0.007535	0.0826	0	0	0.030985	0	0.12112
D24	0.075355	0.110133	0.2013	0.006728	0	0	0.393516
D31	0.226065	0	0	0.1021	0	0.036638	0.364803
D32	0	0	0.0671	0.055799	0	0.018612	0.141511
D34	0.067819	0.027533	0.2684	0.062526	0	0	0.426279
D41	0.158245	0	0	0.039574	0.032072	0.1212	0.351091
D42	0	0	0	0	0.011415	0.103174	0.114589
D43	0	0	0	0	0.0424	0.084562	0.126962

Table 4 shows the preference values assigned to different materials (D12, D13, D14, etc.) based on multiple criteria, such as tensile strength, yield strength, compression strength, and other mechanical properties. Each material is evaluated by the assigned preference value, where higher values indicate better performance or suitability for a specific application. D14 stands out with the highest total preference value (2), indicating that it is the most preferred material overall based on its mechanical properties. This suggests that D14 excels in the criteria considered, making it an ideal choice in scenarios that prioritize these properties. D24 also ranks high with a preference value of 0.3935, reflecting good performance, particularly in compression strength and elongation at break, though it is outperformed by D14 overall. D12 and D13 have preference values of 0.1893 and 0.2151, respectively, indicating they perform well in certain areas, such as yield strength, but are less preferred compared to materials like D14 or D24. D41 and D34 also score favorably with 0.3511 and 0.4263, respectively, showing good balance across the criteria, especially in compression strength and water absorption. D42 and D43 are at the lower end of the spectrum, with preference values of 0.1146 and 0.12696, suggesting that they are less favorable in terms of overall material performance.

TABLE 5. Positive flow, Negative Flow, Net flow

	positive flow	Negative Flow	Net flow
Acrylonitrile Butadiene Styrene (ABS)	0.801454	0.344826	-0.80145
PLA (Polylactic Acid)	0.27774	0.148456	-0.27774
PETG (Polyethylene Terephthalate Glycol)	0.310864	0.154392	-0.31086
TPU (Thermoplastic Polyurethane)	0.197547	0.939932	-0.19755

Table 5 shows the positive flow, negative flow, and net flow for four materials—ABS (Acrylonitrile Butadiene Styrene), PLA (Polylactic Acid), PETG (Polyethylene Terephthalate Glycol), and TPU (Thermoplastic Polyurethane). These values indicate the relative advantages and disadvantages of each material based on specific criteria, helping assess their overall suitability. ABS has the highest positive flow (0.801454) and the highest negative flow (-0.80145), suggesting that it has significant strengths in certain areas, but also considerable drawbacks. Its net flow is negative (-0.80145), indicating that despite its positive attributes; the material's disadvantages outweigh its strengths. PLA shows

a smaller positive flow (0.27774) and negative flow (-0.27774), resulting in a net flow of 0. This indicates a balance between strengths and weaknesses, suggesting PLA is more neutral in performance. PETG has a similar trend with a positive flow (0.310864) and a negative flow (-0.31086), leading to a net flow of 0. This shows that it also has balanced strengths and weaknesses, though slightly more favorably than PLA. TPU has the highest negative flow (0.939932) but a positive flow (0.197547), resulting in a net flow of -0.19755. This suggests that TPU's strengths are outweighed by its significant disadvantages, making it less favorable compared to the other materials.

TABLE 6. Rank

	Rank
Acrylonitrile Butadiene Styrene (ABS)	1
PLA (Polylactic Acid)	3
PETG (Polyethylene Terephthalate Glycol)	2
TPU (Thermoplastic Polyurethane)	4

Table 6 provides a ranking of four materials—ABS (Acrylonitrile Butadiene Styrene), PLA (Polylactic Acid), PETG (Polyethylene Terephthalate Glycol), and TPU (Thermoplastic Polyurethane)—based on their overall performance according to various criteria. The rank is assigned from 1 to 4, with 1 indicating the best-performing material and 4 indicating the least favorable. ABS is ranked 1, indicating that it outperforms the other materials in the set of evaluated criteria. This ranking suggests that ABS is the most versatile or strongest choice, likely due to its superior yield strength, compression strength, and overall durability. PETG is ranked 2, showing that it performs well, especially in flexibility and elongation at break, but it doesn't surpass ABS in other critical areas. PETG may be preferred when flexibility and clarity are prioritized over rigidity or strength. PLA is ranked 3, indicating that while it has strengths like high tensile strength; it lags behind ABS and PETG due to its lower compression strength and somewhat limited flexibility. However, PLA remains a good option for environmentally conscious applications. TPU is ranked 4, reflecting that it has significant water absorption and flexibility drawbacks. While it excels in elasticity, it is less preferred compared to the other materials in terms of overall balance.

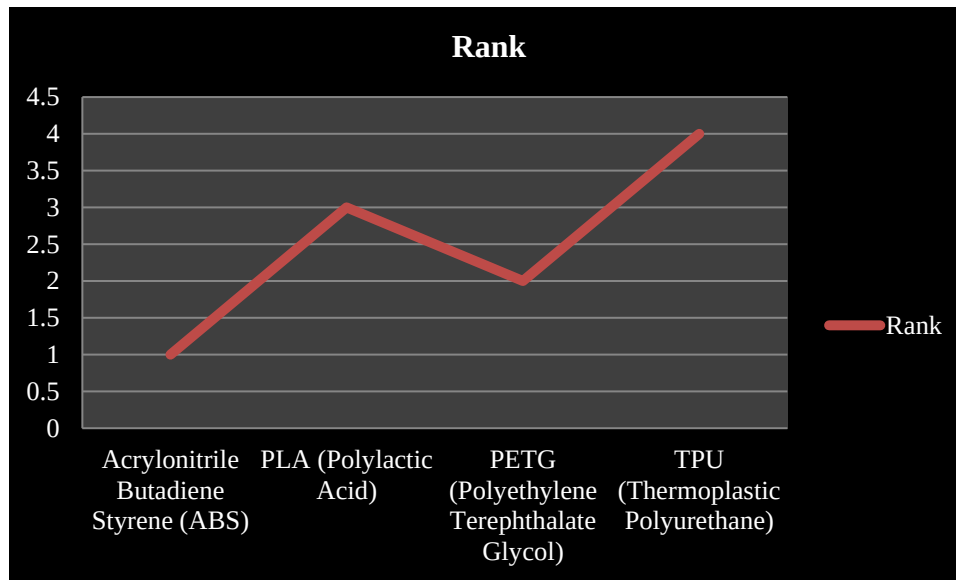


FIGURE 2. Rank

Figure 2 ranks four materials ABS (Acrylonitrile Butadiene Styrene), PLA (Polylactic Acid), PETG (Polyethylene Terephthalate Glycol), and TPU (Thermoplastic Polyurethane) based on their overall performance. ABS is ranked 1, showing it as the best-performing material due to its strength and durability. PETG is ranked 2, offering a good balance of flexibility and strength. PLA follows at 3, indicating it is slightly less versatile due to lower compression strength and elongation. TPU is ranked 4, reflecting its higher water absorption and flexibility limitations, making it the least favored overall.

5. CONCLUSION

Solid mechanics, a fundamental branch of physics and engineering, deals with the forces and motion of matter in its solid state. As a crucial field, solid mechanics underpins advancements in various domains such as physics, chemistry, biology, and engineering. The development of theories and models in solid mechanics has been instrumental in understanding phenomena like material deformation, fracture mechanics, and the behavior of structures under stress. In physics, solid mechanics has informed key theories, such as quantum mechanics and relativity, contributing to the development of the modern scientific worldview. In the realm of chemistry, solid mechanics aids in the understanding of molecular and atomic structures, particularly in processes like crystallization and polymerization. For biologists, biomechanics offers insights into how the structure and function of living organisms are interrelated, helping to better understand biological systems, from cellular behavior to tissue dynamics. Recent advancements in solid mechanics, such as the application of finite element methods (FEM), have allowed engineers to address complex structural problems. However, challenges arise when dealing with exceptionally large finite element systems, requiring innovative solutions like approximate factorization techniques. These methods significantly reduce computational costs and eliminate the need for large-scale storage, enabling more practical solutions for complex engineering problems. Additionally, the study of tumor mechanics has revealed the critical role that mechanical stresses play in cancer progression, opening avenues for medical research focused on developing therapies that target the mechanical environment of tumors. Tribology, the study of friction, wear, and lubrication, is another area where solid mechanics plays a crucial role. Research in tribology is applied to improve the performance and longevity of components such as bearings, artificial joints, and other mechanical systems subjected to dynamic loads. The integration of solid mechanics with tribology has led to better understanding of surface interactions and wear, ultimately improving the reliability of mechanical systems.

REFERENCE

- [1] Fung, Yuan-cheng, Pin Tong, and Xiaohong Chen. Classical and computational solid mechanics. 2001.
- [2] Hughes, Thomas JR, Itzhak Levit, and James Winget. "An element-by-element solution algorithm for problems of structural and solid mechanics." *Computer Methods in Applied Mechanics and Engineering* 36, no. 2 (1983): 241-254.
- [3] Stylianopoulos, Triantafyllos. "The solid mechanics of cancer and strategies for improved therapy." *Journal of biomechanical engineering* 139, no. 2 (2017): 021004.
- [4] Tichy, John A., and Donna M. Meyer. "Review of solid mechanics in tribology." *International Journal of Solids and Structures* 37, no. 1-2 (2000): 391-400.
- [5] Silling, Stewart A., and Richard B. Lehoucq. "Peridynamic theory of solid mechanics." *Advances in applied mechanics* 44 (2010): 73-168.
- [6] Sukumar, Natarajan, Brian Moran, and Ted Belytschko. "The natural element method in solid mechanics." *International journal for numerical methods in engineering* 43, no. 5 (1998): 839-887.
- [7] Puso, Michael A. "A 3D mortar method for solid mechanics." *International Journal for Numerical Methods in Engineering* 59, no. 3 (2004): 315-336.
- [8] Atluri, S. N., and A. N. T. O. N. I. O. Cazzani. "Rotations in computational solid mechanics." *Archives of Computational Methods in Engineering* 2 (1995): 49-138.
- [9] Lubliner, Jacob. "On the thermodynamic foundations of non-linear solid mechanics." *International Journal of Non-Linear Mechanics* 7, no. 3 (1972): 237-254.
- [10] Slone, A. K., C. Bailey, and M. Cross. "Dynamic solid mechanics using finite volume methods." *Applied mathematical modelling* 27, no. 2 (2003): 69-87.
- [11] Gadala, Mohamed S. "Recent trends in ALE formulation and its applications in solid mechanics." *Computer methods in applied mechanics and engineering* 193, no. 39-41 (2004): 4247-4275.
- [12] Hansbo, Anita, and Peter Hansbo. "A finite element method for the simulation of strong and weak discontinuities in solid mechanics." *Computer methods in applied mechanics and engineering* 193, no. 33-35 (2004): 3523-3540.
- [13] Sulsky, Deborah, Shi-Jian Zhou, and Howard L. Schreyer. "Application of a particle-in-cell method to solid mechanics." *Computer physics communications* 87, no. 1-2 (1995): 236-252.
- [14] Rossikhin, Yuriy A., and Marina V. Shitikova. "Application of fractional calculus for dynamic problems of solid mechanics: novel trends and recent results." (2010): 010801.
- [15] Tomita, Yoshihiro. "Simulations of plastic instabilities in solid mechanics." (1994): 171-205.

- [16] Gadala, Mohamed S., and J. Wang. "ALE formulation and its application in solid mechanics." *Computer Methods in Applied Mechanics and Engineering* 167, no. 1-2 (1998): 33-55.
- [17] Horgan, Cornelius O. "Anti-plane shear deformations in linear and nonlinear solid mechanics." *SIAM review* 37, no. 1 (1995): 53-81.
- [18] Fearing, Ronald S., and John M. Hollerbach. "Basic solid mechanics for tactile sensing." *The International journal of robotics research* 4, no. 3 (1985): 40-54.
- [19] Wang, J., and Mohamed S. Gadala. "Formulation and survey of ALE method in nonlinear solid mechanics." *Finite Elements in Analysis and Design* 24, no. 4 (1997): 253-269.
- [20] Schröder, Jörg, Thomas Wick, Stefanie Reese, Peter Wriggers, Ralf Müller, Stefan Kollmannsberger, Markus Kästner et al. "A selection of benchmark problems in solid mechanics and applied mathematics." *Archives of Computational Methods in Engineering* 28 (2021): 713-751.
- [21] Brans, Jean-Pierre, and Yves De Smet. "PROMETHEE methods." *Multiple criteria decision analysis: state of the art surveys* (2016): 187-219.
- [22] Behzadian, Majid, Reza Baradaran Kazemzadeh, Amir Albadvi, and Mohammad Aghdasi. "PROMETHEE: A comprehensive literature review on methodologies and applications." *European journal of Operational research* 200, no. 1 (2010): 198-215.
- [23] Goswami, Shankha Shubhra. "Outranking methods: Promethee i and promethee ii." *Foundations of Management* 12, no. 1 (2020): 93-110.
- [24] Brans, Jean-Pierre, Ph Vincke, and Bertrand Mareschal. "How to select and how to rank projects: The PROMETHEE method." *European journal of operational research* 24, no. 2 (1986): 228-238.
- [25] Albadvi, Amir, S. Kamal Chaharsooghi, and Akbar Esfahanipour. "Decision making in stock trading: An application of PROMETHEE." *European journal of operational research* 177, no. 2 (2007): 673-683.
- [26] Vetschera, Rudolf, and Adiel Teixeira De Almeida. "A PROMETHEE-based approach to portfolio selection problems." *Computers & Operations Research* 39, no. 5 (2012): 1010-1020.
- [27] Corrente, Salvatore, José Rui Figueira, and Salvatore Greco. "The smaa-promethee method." *European Journal of Operational Research* 239, no. 2 (2014): 514-522.
- [28] Macharis, Cathy, Johan Springael, Klaas De Brucker, and Alain Verbeke. "PROMETHEE and AHP: The design of operational synergies in multicriteria Analysis. Strengthening PROMETHEE with ideas of AHP." *European journal of operational research* 153, no. 2 (2004): 307-317.
- [29] Oubahman, Laila, and Szabolcs Duleba. "Review of PROMETHEE method in transportation." *Production Engineering Archives* 27, no. 1 (2021): 69-74.
- [30] Dağdeviren, Metin. "Decision making in equipment selection: an integrated approach with AHP and PROMETHEE." *Journal of intelligent manufacturing* 19 (2008): 397-406.