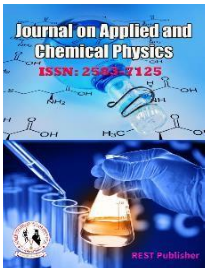
Journal on Applied and Chemical Physics

Vol: 4(3), September 2025

REST Publisher; ISSN: 2583-7125

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

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



Case Study Comparative Analysis of Brake Disc Materials Using the WASPAS Method

Poonkodi Sathiyamoorthy, Ramya Sharma, M. Ramachandran, Sathiyaraj Chinnasamy

REST Labs, Kaveripattinam, Krishnagiri, Tamil Nadu, India

*Corresponding Author Email: poonkodisri205@gmail.com

Abstract: *Selecting materials for vehicle brake discs is a critical engineering decision that directly impacts vehicle safety, braking performance, durability, and cost. Brake discs must efficiently convert kinetic energy into thermal energy while withstanding high temperatures, friction, and mechanical stresses during braking. Key factors influencing material selection include mechanical strength, stiffness, thermal conductivity, wear resistance, friction characteristics, manufacturability, and economic feasibility. Traditionally, cast iron – particularly gray cast iron – has been the most widely used brake disc material due to its excellent heat dissipation, high wear resistance, stable friction behavior, and cost-effectiveness. However, increasing demands for lightweight vehicles, improved fuel efficiency, and enhanced braking performance have driven research into advanced materials such as titanium alloys, aluminum matrix composites (AMCs), metal matrix composites (MMCs), and carbon or ceramic-based composites. These materials offer advantages such as reduced weight, superior thermal stability, and improved fade resistance, although they often involve higher manufacturing costs and production complexity. In this study, the material selection process is carried out using the WASPAS (Weighted Aggregated Sum Product Assessment) method, a multi-criteria decision-making approach that combines weighted sum and weighted product models. Key performance parameters considered include compressive strength, friction properties, specific heat, specific gravity, and wear rate. The materials evaluated include gray cast iron (GCI), Ti-6Al-4V alloy, and composite-based alternatives. The results indicate that gray cast iron achieves the highest overall ranking due to its balanced thermo-mechanical properties and cost-effectiveness, while the Ti-6Al-4V alloy ranks lowest based on the selected criteria. Brake disc material selection is a multi-dimensional optimization problem that requires careful evaluation of performance, safety, and economic factors. While advanced materials hold promise for high-performance applications, gray cast iron remains the most suitable choice for conventional automotive braking systems due to its reliability, affordability, and proven performance.*

Keywords: *Brake pad, Brake friction, Periwinkle shell, wear rate, scratch hardness, bonding strength, Disc Brake Rotor, Temperature analysis, Weight Reduction, Transient Analysis.*

1. INTRODUCTION

Disc brake noise automobile a continuum in the field problem. Customers annoying brake noise, a problem with the braking system it is also considered indicative. In most situations, this type of noise is braking small in system performance or have no effect. However, it is quality and satisfaction appraisals and warranty costs significant impact on causes that is why it's the car industry management solutions looking for disc brake noise to investigate and reduce a substantial amount of work have gone in these works most are issue breaking done in systems, its designs are ultimate were made (trichus et al et al., 2002). In these circumstances, noise reduction techniques the only way is to use it. Consequently, the add-on noise reduction treatments to reduce braking noise have become a popular method. However, this treatment a frequent repeat of the application considered as an approach, of a massive matrix in which effects on a framework are investigated experimentally. In most situations, for brake noise concerns appropriate noise reduction to find the solution, passive brake dynamometer re used in practice. However, this technique is expensive high and time consuming, because of the emollient properties (loss factor and shear etc. Modulus) and of the brake system (shoe and lining, rotor and caliper) for resonant response interaction between in contrast, the current testing techniques and using procedures, brake noise problem effective noise reduction control changes creating can be accomplished easily. In terms of noise production dynamic braking system from installing features phase, in which the audible and source of noise emissions determining the mechanism (papinnemi et al., 2002). Once these features are recognized, test procedures and material tamping expertise using specific brake to reduce the noise problem suitable mitigation material can be identified. This is a sample of how to study analytical methods and expertise in mitigating material how to use describes. Approach a on a specific brake system used, too results will be displayed. This technique in august 2004 a new approved supported by paper. Of which b. Silva freer, he is a technical teacher. Used in braking system humidifier of choice dynamometer with object tests. It was the sound of brakes based on frequency of occurrence classified into several categories. Low frequency noise, low frequency screeching and high frequency noise is brake there are three broad categories of noise (dunlap et al., 1999). Low frequency disc brake noise is 100 to 1000 in the frequency range of hz a common problem that occurs. Screaming and moaning sounds noise concerns in this area are common occurrences. This kind of problem the method of creation in rotor and lining materials friction is the stimulus, which provides energy to the system. This power brake assembly and suspension and chassis through connections with components the vibration is transmitted as a reaction. For some types of braking systems, a low frequency noise although a significant issue, noise noise is very common and it's an unpleasant problem (dunlap et al., 1999). A noise is 1000 hz or a higher frequency a noise with content is, it's too much of a system for high amplitude mechanical vibrations occurs when subjected to how does this phenomenon occur? Two to explain that there are ideas. The first is called "stick-slip". Is called squeal, this according to the hypothesis, by two factors of the induced braking system self-excited vibration: constant the coefficient of friction is sliding friction is greater than the coefficient; coefficient of sliding friction f and relative sliding speed the relationship between however, the only frictional couple pair (rotor and pads) in different brake systems when used, of squeal why the trend is different this theory cannot explain (chung et al., 2001). Therefore, the second is called "sprague-slip". The theory was developed. Braking self-excited vibration of the system and brake excessive vibrations of the geometrical parameters of the system that is caused by wrong choice it indicates. Coefficient of friction when increasing, two geometries fixed system methods are closer in frequency. Both these methods are same frequency and match mode when combining patterns, they become unstable. In pad-rotor contact variable friction forces braking system vibration and for both theories of noise cause. This variable is friction energy in the system of forces introducing squealing during the event, this is done by the computer to dissipate part of the energy can't, resulting in vibration there is a large amount of amplitude. Lightweighting: lightweighting is a vehicle being popular in design coming up is an essential consideration. Of automobiles in the future in design and development this concept continues to be significant will be in vehicle design total of light target vehicle weight loss, therefore increasing fuel efficiency, from automobiles the discharge discharge reduction and protection of the vehicle and improving driving performance. Also, the aluminum matrix for brake discs such as composite use of lightweight materials faster acceleration, longer braking distance abatement, abatement of noise (monkey and noise), high wear resistance and static friction will give regeneration braking is the totality of an ev about 25-30 kg in weight adds, this is the beginning improve vehicle traction. Lighter brake discs ev driving by using performance is improved, this is the spring of the brake system reduces mass. Brake producers driving performance lightweight disk to upgrade the conclusion is that they will look for things. Improved disc corrosion resistance: friction in electric vehicles brake system is limited itching due to use due to brake failure a major problem in the future will change. Friction of brake discs erosion of surfaces, widespread and severe. Gci stands for vehicle brake disc used in applications conventional material. As a disk object its use is mostly because of its favorable qualities was unfortunately, gci limited to water erosion it has resistance a key to brake discs the problem is because they are constantly water, moisture and for road salt [13]. Will emerge. In traditional vehicles, on the friction surfaces of the gci disk corrosion product formed often cleaning is done. Electric friction brakes in vehicles since it is rarely used, oxide on the friction surfaces of the disc layer formation is long term it is allowed to accumulate corrosion induced friction leading to instability, also direct brake system it can even lead to failure. Low corrosion of gci the resistor is called a break judder may cause unpleasant condition, it's in evs of the future may spread more. It is corrosion surface to combat using therapeutic techniques conventional gci brake discs manufacturers to replace pushing manufacturers of brake pads erosion from friction surfaces material is easily removable to incorporate highly abrasive compounds can change the composition of their pads. The challenge is the aluminum matrix more on composite material an alternative to developmental research the brake disc can accelerate materially. Disc brake noise reduction: disc brake noise present vehicles around the world affect manufacturers among the most important concerns is one. Brake noise protection braking, though not dangerous less impact on performance although caused, its existence vehicle quality for buyers that has problems provides feedback. Further, buyers in the braking system the noise coming from a as a sign of wrong position consider and its as a result the quality of the cars losing faith. Unfortunately, due to this problem many car manufacturers return automobiles in addition to receiving, brake and from vehicle manufacturers expensive warranty requests have also been received. Evs in the automobile market totally dominant in future years, braking the noise issue is a major concern will be because internal combustion mechanical automobiles unlike the engine noise brake reduces noise, evs a lot it runs quietly coming from the braking system noise is more noticeable in evs indicates that there will be very loud noise to meet the limits, brake producers of the old model to change or specifications a new item that matches to search. Maximum operating temperature – in traditional automobiles, brake discs are brake applications for high thermal stress during are subjected, of which as a result the system heats up and 7000c on the friction surfaces of the disc the higher the temperature increases. The introduction of evs could change the story, because evs are regenerative great braking mechanism dependent on, ie the vehicle friction brakes are rare are used. Brake discs the maximum that is usually subjected to working temperature in the future reduced, especially hybrid and for electric vehicles. This breakthrough is the future brake possible for disk upgrade aluminum matrix as material to use the mixture let's open the path. Theory of disc brakes: frederick william in 1902 invented the first disc brake. Early and original concept two discs rub against each other created friction, which slow down the automobile also used to stop. Disc brakes are usually disc/rotor assembly and brake caliper the assembly consists of the latter is by hydraulic pistons as, they are for a rotating disk press the brake pads against, thus the pads on the rotating disk/rotor a clamping force is held create this clamping the force is the frictional force, friction, heat generation and operation to create energy transfer leads to in this regard, disks are often this keep in mind the important variables are constructed with heat generation and dissipation, as well as the power exerted.

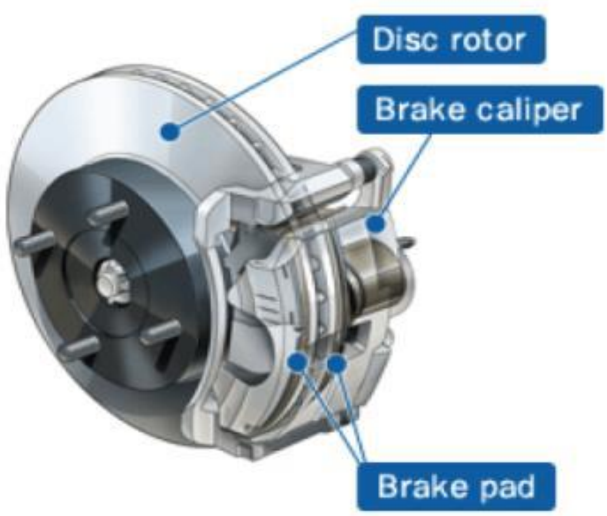


FIGURE 1. A typical arrangement of a disc brake and its components.

Types of Brake Disc Rotors:

FIGURE 2. Vented and non-vented (Solid) disc brake rotor

Disc brakes are ventilated or non-aerated (solid) are classified as dual vented brake discs made up of metal discs, they are large with ribs provide area. Figure 2 ventilation and non-ventilated brake discs depicts. Brake disc whether airy or although non-ventilated, based on its geometry in the following categories can be classified together.

2. MATERIALS AND METHODS

WASPAS (Weighted Aggregated Sum Product Assessment)

In the WASPAS method, two for optimality a composite scale based on criteria searched for. The first criterion of optimality, viz the weighted average success criterion is the WSM method like it is a famous and well the adopted MCDM approach is several several based on decision criteria used to evaluate alternatives. Weighted aggregate product assessment (WASPAS) the methodology consists of eight manufacturing decision-making problems as a useful MCDM tool when solving are investigated, cutting fluid, electroplating system, forging stage, arc welding process, industrial robot, grinding stage, materials machinability. All exams considered difficulties and disabilities accurately this method has sorting capability. WASPAS effect of λ parameter on ranking performance the method is also investigated. The WASPAS method is a technique, it changed into progressed by using which this method in many decision problems and contexts used and extended. Bagosius et al. (2013) based on the WASPAS method a multi-criterion incorporated selection-making procedure select the best version construction net page for deep water port. Advanced an MCDM technique on a reconstructed vernacular constructing the use of AHP address the issue of daylighting and traditional continuity. Hashemkhani solfani et al. (2013) swara hierarchical weight estimation ratio analysis and WASPAS methods using multiple to solve the shopping mall location problem criterion developed approach to decision making. Javadskas et al. (2013a) waspas and moora multi-objective based on ratio analysis validates the robustness of optimization methods. Javadskas et al. (2013b) some public and commercial to evaluate facades of buildings WASPAS method was used. Weighted discussed in recent years' total product assessment (WASPAS) and ambiguous extensions. The new MCDM will determine the utility approach is weighted total product evaluation (WASPAS) is called. In WASPAS 2012 recommended for the first time and it is strong in deterministic approaches to new MCDM application is one. This approach is a weighted one product version (WPM) and weighted sum model (WSM) is zavadskas, turskis, proposed and the argued combination. The accuracy of this approach stronger than wpm and WSM. WASPAS formal, ordered fuzzy using numbers (OFNS), which is proposed by zadeh an extension of ambiguity set approach. The concept of OFNS is introduced. Ambiguous as opposed to numbers, arithmetic in this model functions functions of real numbers as such, they a unique case of OFNS. WASPAS approach through zavadskas, turskis, antucheviciene was created. WASPAS method accuracy is a weighted amount rather than used method or weighted ones recommended product model that it is favorable. Current literature, to consider OFNS in ambiguous WASPAS mode failed and one of the methods mentioned above the concept lacks unifying research. Weighted aggregate product assessment (WASPAS) systematic, downside risks to the project used to assess outcomes. Change compared to independent methods of ranking this method is efficient and highly accurate. Waspas methodology in new multi-index decision making techniques one, it is accepted in many areas is used. In this research, road in iran we identify the risks of the construction project we evaluated, the results of which, access to baroque pits infeasible/irrelevant, during the project life cycle loss of key manpower, inexperienced support hiring contractors among the identified risks are the most important risks. Weighted aggregate product assessment (WASPAS), time usage choice of attendance software including the problem is integrated. Critic approach is a goal for figuring out scale weights methodology, which include depth of version and choice-making a contradiction within the structure of the hassle is protected. It belongs to the elegance of conversation methods and alternatives information at the standards to be assessed primarily based totally on WASPAS the method is weighted sum version (WSM) and of weighted product model (WPM). Mixing, and it's full of alternatives used to rank. Kritik and WASPAS a new based on combination of methods applicability decision making approach of this article to the literature the main contribution is proof. Healthcare outsourcing for 15 different strategies has been developed. QSPM tool and several standards decision making device WASPAS method integrating an integrated approach to evaluate the strategic options used recommended. Top five best ranking strategic options are QSPM and WASPAS be mindful of using approaches want also, a strong, math-based as the WASPAS method was used, the result was accurate can also be considered reliable. One based on the WASPAS approach the new method was developed with HFS. Experts and various information to calculate scale weights actions are proposed. Changes to the WASPAS technique, HF-operators and scalar weight estimation procedure is carried out. For the inexperienced dealer selection problem, the generated method is executed. With HFSS WASPAS method for estimating MCDM problems and an integrated based on information activities. WASPAS the technique is very realistic and the rating is correct strongly attracts the idea of WASPAS approach weighted sum model (WSM) and weighted product model (WPM) uses advantages. WSM and wpm in addition, the rating accuracy of WASPAS options will increase. At that factor, WASPAS is a highest quality mixture calculates the parameter, that is distinctive later may be given. Many of the WASPAS systems were successful despite the applications (mardani et al., 2017), most published works rank ignores the concept of precision, and WSM and composition parameter of wpm on temporal basis is determined. Waipoua et al. (2014) priority areas for implementation of solar energy projects. Current research examines the effectiveness of TSPS intuitive fuzzy weighted aggregate for comparison uses product assessment (if-WASPAS) technique. The proposed method IFSS operators based on more scaled weights a new method of calculating scale weights to calculate, to arrive at more reasonable weights objectivity derived from similarity measure method results with weights expressed by experts we aggregate the subjective weights. Objective new unity for IFSS to calculate weights actions are developed and proposed a variety of harmony activities are elegant demonstrates characteristics.

Alternative parameters:

Gray cast iron (gci): gray cast iron (gci) is at its best widely known engineering material used castability, wear resistance, and damping properties. It is a type of cast iron that contains graphite flakes dispersed throughout its matrix, giving it a distinct gray appearance. Gci is composed primarily of iron and carbon; carbon content is generally 2.5% to 4.0%. Silicon, manganese and phosphorus other composite elements like added in smaller quantities to enhance specific properties.

Ti-alloy (ti-6al-4v): ti-6al-4v alloy is a an α-β titanium alloy, the more strength it has, the less density and good erosion express resistance. It is commonly used titanium metal one of the compounds.

Tmc: tmcft, (tmc ft), (tmc), (tmc), is thousand million cubic ft (1,000,000,000 = 109 = 1 billion) is short for , which is usually reservoir in india or of water in river flow used to indicate size.

Amc 1: amc 1 refers to the first amc (advanced motor controller) model developed by a particular manufacturer or organization. Without further context, it's challenging to provide specific details about amc 1 since there are various applications and industries that use motor controllers, each with their own specifications and features.

Amc 2: amc 2 would refer to the second iteration or version of an advanced motor controller (amc) developed by a specific manufacturer or organization. Similar to amc 1, the exact details and features of amc 2 would depend on the specific manufacturer and industry application.

Evaluation Parameters:

Properties Material: Properties of materials refer to the characteristics and behaviours exhibited by different substances when subjected to various conditions. These properties determine how materials interact with their environment and are essential for understanding their applications and limitations.

Compressive: Compressive strength is the capacity of an object A mechanical property of measurement resist compressive forces or loads without undergoing permanent deformation or failure. It is an important parameter in structural engineering and materials science.

Friction: Friction is related between two surfaces Relative motion in or opposite the direction of motion A key. It occurs when two objects slide or try to slide past each other. Friction is caused by the interlocking of irregularities or microscopic roughness on the surfaces of the objects in contact.

Specific Heat: Specific heat, specific Also called heat capacity, It is a unit of matter temperature of the mass One degree Celsius (or Kelvin) to raise of heat energy required A physics measure of quantity is characteristic. It is called "C". denoted by the symbol and one degree Celsius (J/kg·°C) or (J/g·°C) a Unit mass is energy expressed in units.

Specific Gravity: Specific gravity is Density of a substance of a reference object Compared to density The measure is, usually water. It is a dimensionless quantity and how much is an object Thick or light compared to water gives an indication that

Wear rate: Wear rate refers to the rate at which material is removed from a surface due to mechanical contact or friction with another surface. It is a measure of how quickly a material wears down or deteriorates over time.

3. ANALYSIS AND DISCUSSION

TABLE 1. Automotive Brake Disc Material Selection

Properties Material	Compressive Strength (MPa)	Friction coefficient(μ)	Specific heat, Cp (KJ/Kg. K)	Specific gravity (Mg/m^{3})	Wear rate (x10^{-6}mm^{3} /N/m)
Gray cast iron (GCI)	1293	0.41	0.46	7.2	2.36
Ti-alloy (Ti-6Al-4V)	1070	0.34	0.58	4.42	246.3
TMC	1300	0.31	0.51	4.68	8.19
AMC 1	406	0.35	0.98	2.7	3.25
AMC 2	761	0.44	0.92	2.8	2.91

Table 1 shows Table 1 presents properties of different materials used for automotive brake discs. Gray cast iron (GCI): GCI has a compressive strength of 1293 MPa, a friction coefficient of 0.41, a specific heat (Cp) of 0.46 KJ/Kg.K, a specific gravity of 7.2 Mg/m^3, and a wear rate of 2.36 x 10^-6 mm^3/N/m. Ti-alloy (Ti-6Al-4V): Ti-alloy has a compressive strength of 1070 MPa, a friction coefficient of 0.34, a specific heat (Cp) of 0.58 KJ/Kg.K, a specific gravity of 4.42 Mg/m^3, and a wear rate of 246.3 x 10^-6 mm^3/N/m. TMC: TMC has a compressive strength of 1300 MPa, a friction coefficient of 0.31, a specific heat (Cp) of 0.51 KJ/Kg.K, a specific gravity of 4.68 Mg/m^3, and a wear rate of 8.19 x 10^-6 mm^3/N/m. AMC 1: AMC 1 has a compressive strength of 406 MPa, a friction coefficient of 0.35, a specific heat (Cp) of 0.98 KJ/Kg.K, a specific gravity of 2.7 Mg/m^3, and a wear rate of 3.25 x 10^-6 mm^3/N/m. AMC 2: AMC 2 has a compressive strength of 761 MPa, a friction coefficient of 0.44, a specific heat (Cp) of 0.92 KJ/Kg.K, a specific gravity of 2.8 Mg/m^3, and a wear rate of 2.91 x 10^-6 mm^3/N/m. These properties provide information about the mechanical and thermal characteristics of each material. They can be used for material selection in automotive brake disc applications, considering factors such as strength, friction performance, thermal behavior, and wear resistance.

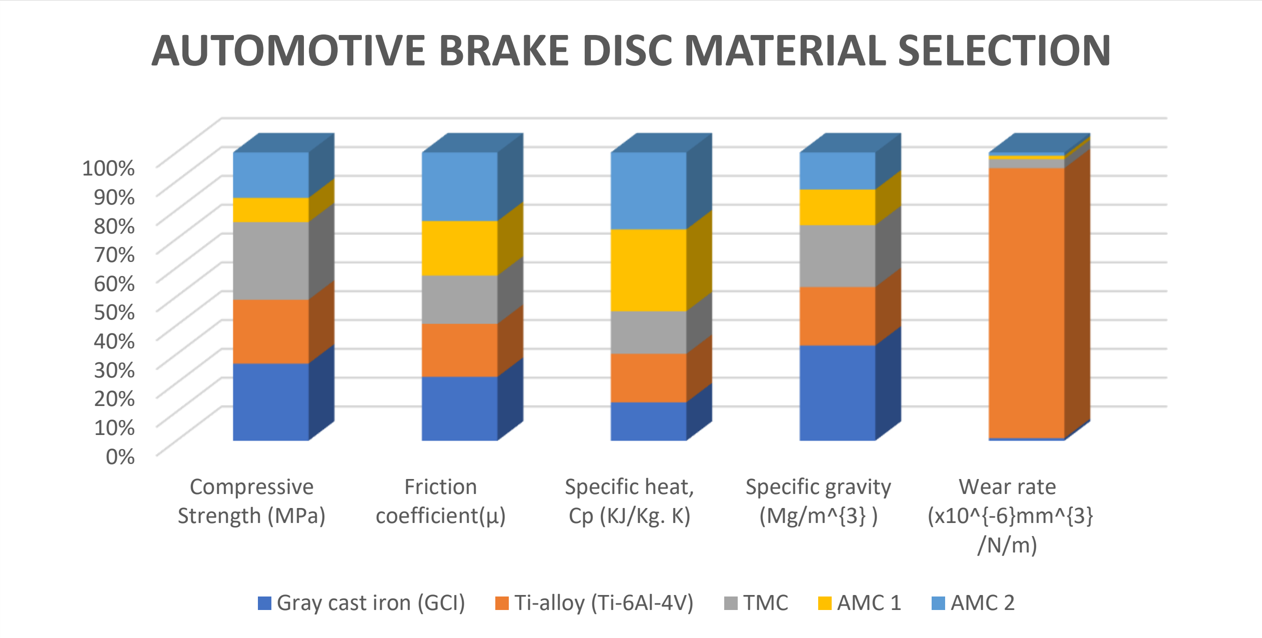


FIGURE 3. Automotive Brake Disc Material Selection

Figure 3. shows the Automotive Brake Disc Material Selection the Compressive Strength (MPa) it is seen that TMC is showing the highest value for AMC 1 is showing the lowest value. Friction coefficient(µ) it is seen that AMC 2 is showing the highest value for TMC is showing the lowest value. Specific heat, Cp (KJ/Kg. K) it is seen that AMC 1 is showing the highest value for Gray cast iron (GCI) is showing the lowest value. Specific gravity (Mg/m^{3}) it is seen that Gray cast iron (GCI) is showing the highest value for AMC 1 is showing the lowest value. Wear rate (x10^{-6}mm^{3} /N/m) it is seen that Ti-alloy (Ti-6Al-4V) is showing the highest value for Gray cast iron (GCI) is showing the lowest value.

TABLE 2. Normalized Data

Performance value					
Gray cast iron (GCI)	1.00000	1.00000	1.00000	1.00000	1.00000
Ti-alloy (Ti-6Al-4V)	0.82753	0.82927	1.26087	0.61389	0.00958
TMC	1.00541	0.75610	1.10870	0.65000	0.28816
AMC 1	0.31400	0.85366	2.13043	0.37500	0.72615
AMC 2	0.58855	1.07317	2.00000	0.38889	0.81100

Table 2 shows The table you provided presents normalized performance values for different materials: Gray cast iron (GCI), Ti-alloy (Ti-6Al-4V), TMC, AMC 1, and AMC 2. The values are normalized relative to the highest value in each column, with the highest value assigned a normalized value of 1. Gray cast iron (GCI): This material has the highest performance value in all five categories, and therefore, it has a normalized value of 1. This means that GCI serves as the baseline for comparison in this table. Ti-alloy (Ti-6Al-4V): In the first category, Ti-alloy has a normalized value of 0.82753 relative to GCI. In the second category, it has a slightly higher normalized value of 0.82927. In the third category, Ti-alloy has a normalized value of 1.26087, indicating a higher performance than GCI. In the fourth category, its normalized value is 0.61389, and in the fifth category, it has the lowest normalized value of 0.00958. TMC: This material has a slightly higher performance value than GCI in the first category, with a normalized value of 1.00541. In the second category, its normalized value is 0.75610. In the third category, TMC has a normalized value of 1.10870. In the fourth category, it has a normalized value of 0.65000, and in the fifth category, its normalized value is 0.28816. AMC 1: In the first category, AMC 1 has a normalized value of 0.31400 compared to GCI. In the second category, its normalized value is 0.85366. In the third category, AMC 1 has the highest performance value with a normalized value of 2.13043. In the fourth category, it has a normalized value of 0.37500, and in the fifth category, its normalized value is 0.72615. AMC 2: This material has a higher performance value than GCI in the first category, with a normalized value of 0.58855. In the second category, its normalized value is 1.07317. In the third category, AMC 2 has a normalized value of 2.00000. In the fourth category, it has a slightly higher normalized value of 0.38889 compared to AMC 1. In the fifth category, its normalized value is 0.81100. Overall, this table provides a comparison of the performance values for different materials across five categories. The normalized values allow for relative assessments of performance, indicating which materials perform better or worse compared to each other in each category.

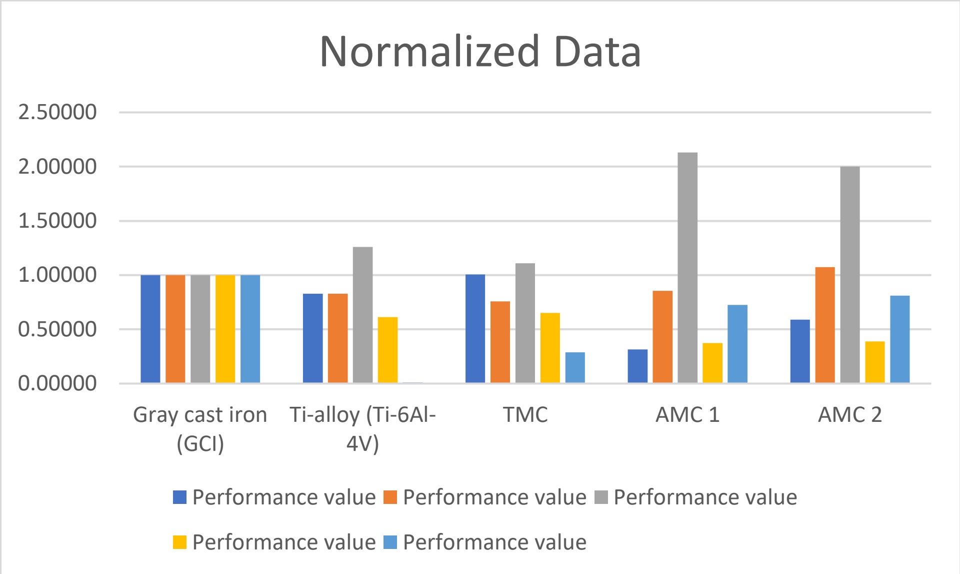


FIGURE 4. Normalized Data

Figure 4 shows Alternative parameters: Gray cast iron (GCI), Ti-alloy (Ti6Ai-4V), TMC, AMC1, AMC2 and Evaluation parameters: Compressive, Friction, Specific Heat, Specific Gravity, Wear rate.

TABLE 3. Weight

Weight				
0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2

Table 3 Weight shows the informational set for the weight all same value 0.2.

TABLE 4. Weighted Normalised Decision Matrix (WSM)

Weighted normalized decision matrix					
Gray cast iron (GCI)	0.19892	0.00006	0.00111	0.24661	0.24661
Ti-alloy (Ti-6Al-4V)	0.16462	0.00005	0.00009	0.00068	0.00236
TMC	0.20000	0.00005	0.00008	0.00072	0.07106
AMC 1	0.06246	0.00005	0.00015	0.00042	0.17908
AMC 2	0.11708	0.00007	0.00014	0.00043	0.20000

Table 4 shows the which is the Weighted Normalized Decision Matrix (WSM), presents the weighted and normalized values for each material across different criteria. Gray cast iron (GCI): GCI has the highest weighted normalized value in the first criterion with 0.19892. In the second criterion, its value is the lowest with 0.00006. Similarly, it has the lowest values in the third and fourth criteria with 0.00111 and 0.24661, respectively. In the fifth criterion, GCI has the highest value again with 0.24661. Ti-alloy (Ti-6Al-4V): Ti-alloy has relatively lower values across all criteria compared to GCI. Its highest value is in the first criterion with 0.16462, while its lowest values are in the second, third, and fourth criteria with 0.00005, 0.00009, and 0.00068, respectively. In the fifth criterion, Ti-alloy has a slightly higher value of 0.00236. TMC: TMC has similarly low values in the second, third, and fourth criteria compared to Ti-alloy. Its highest value is in the first criterion with 0.20000, and its value in the fifth criterion is relatively higher with 0.07106. AMC 1: AMC 1 has the lowest values across all criteria compared to the other materials. Its highest value is in the first criterion with 0.06246, and its highest value among the other criteria is in the fifth criterion with 0.17908. AMC 2: AMC 2 has values slightly higher than AMC 1 in all criteria except the fourth criterion. Its highest value is in the first criterion with 0.11708, and its value in the fifth criterion is the same as GCI with 0.20000. Overall, the weighted normalized decision matrix provides a quantitative assessment of the materials' performance across different criteria, taking into account the weights assigned to each criterion. The values in the matrix reflect the relative performance of each material within each criterion.

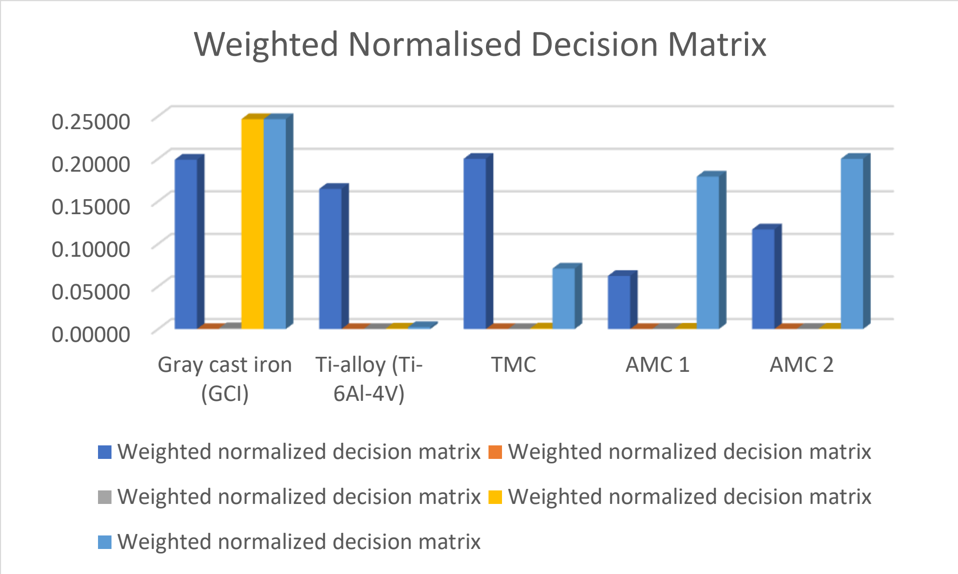


FIGURE 5. Weighted Normalized Decision Matrix

Figure 5 shows Alternative parameters: Gray cast iron (GCI), Ti-alloy (Ti6Ai-4V), TMC, AMC1, AMC2 and Evaluation parameters: Compressive, Friction, Specific Heat, Specific Gravity, Wear rate.

TABLE 6. Preference Score (WSM, WPM) & WASPAS Coefficient & Rank

	Preference Score (wpm)	Preference Score (wsm)	WASPAS Coefficient	RANK
Gray cast iron (GCI)	0.693314	1	1	1
Ti-alloy (Ti-6Al-4V)	0.1678	0.347806	0.347806	5
TMC	0.271908	0.691282	0.691282	3
AMC 1	0.242158	0.689204	0.689204	4
AMC 2	0.317717	0.83189	0.83189	2

Table 6 presents the preference scores based on the Weighted Product Model (WPM) and the Weighted Sum Model (WSM), as well as the WASPAS coefficient and the rank for each material. Gray cast iron (GCI): GCI has the highest preference score in both WPM and WSM with values of 0.693314 and 1, respectively. It also has the highest WASPAS coefficient and is ranked first. Ti-alloy (Ti-6Al-4V): Ti-alloy has the lowest preference scores among all materials in both WPM and WSM, with values of 0.1678 and 0.347806, respectively. Its WASPAS coefficient and rank are also the lowest, indicating it is ranked fifth. TMC: TMC has higher preference scores compared to Ti-alloy and AMC 1 in both WPM and WSM, with values of 0.271908 and 0.691282, respectively. Its WASPAS coefficient and rank are higher, indicating it is ranked third. AMC 1: AMC 1 has preference scores similar to TMC, with values of 0.242158 in WPM and 0.689204 in WSM. Its WASPAS coefficient and rank are also similar, and it is ranked fourth. AMC 2: AMC 2 has higher preference scores compared to TMC and AMC 1 in both WPM and WSM, with values of 0.317717 and 0.83189, respectively. Its WASPAS coefficient and rank are higher, indicating it is ranked second. Overall, GCI has the highest preference scores and is ranked first, while Ti-alloy has the lowest preference scores and is ranked fifth. TMC, AMC 1, and AMC 2 fall in between, with AMC 2 having the highest preference scores among the three and being ranked second.

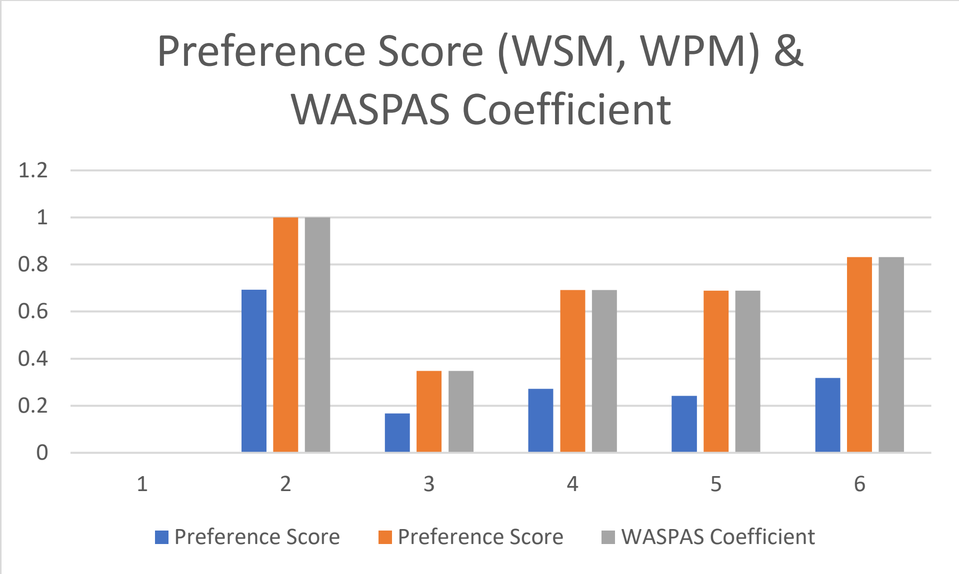


FIGURE 6. Preference Score (WSM, WPM) & WASPAS Coefficient

Figure 6 displays the preference scores based on the Weighted Sum Model (WSM) and the Weighted Product Model (WPM), as well as the WASPAS coefficient for each material. The values are as follows: Gray cast iron (GCI): The preference score for GCI is 0.693314 in WPM and 1 in WSM. Its WASPAS coefficient is 1. Ti-alloy (Ti-6Al-4V): Ti-alloy has a preference score of 0.1678 in WPM and 0.347806 in WSM. Its WASPAS coefficient is 0.347806. TMC: TMC has a preference score of 0.271908 in WPM and 0.691282 in WSM. Its WASPAS coefficient is 0.691282. AMC 1: AMC 1 has a preference score of 0.242158 in WPM and 0.689204 in WSM. Its WASPAS coefficient is 0.689204. AMC 2: AMC 2 has a preference score of 0.317717 in WPM and 0.83189 in WSM. Its WASPAS coefficient is 0.83189. The preference scores reflect the relative performance of each material based on the models used. GCI has the highest preference scores in both WPM and WSM, indicating that it performs the best according to these models. Ti-alloy has the lowest preference scores. The WASPAS coefficient provides an overall measure of preference, with higher coefficients indicating a stronger preference for a particular material.

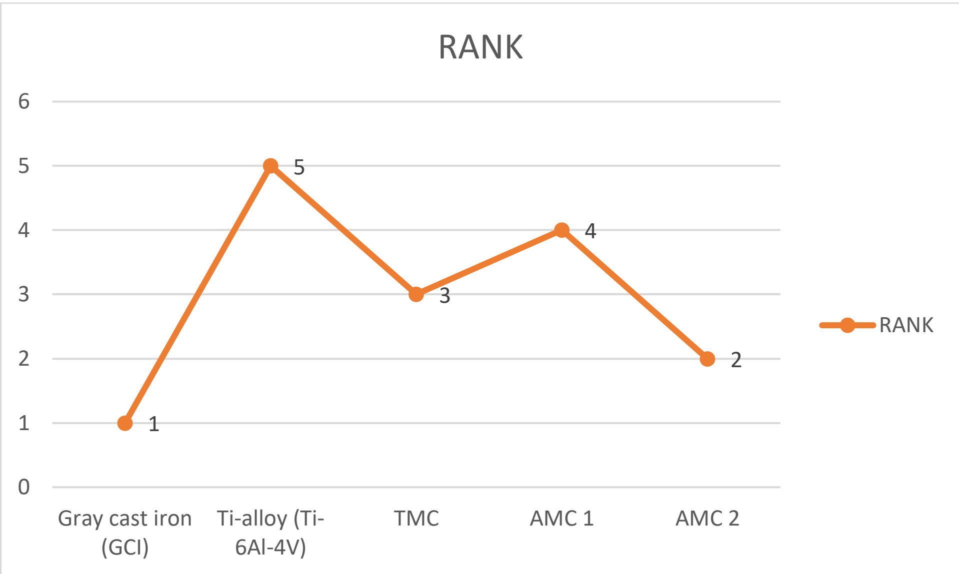


FIGURE 7. Rank

Figure 7 shows the ranks assigned to each material based on their performance. Gray cast iron (GCI) is ranked 1. Ti-alloy (Ti-6Al-4V) is ranked 5. TMC is ranked 3. AMC 1 is ranked 4. AMC 2 is ranked 2. The ranks provide an ordering of the materials based on their performance, with GCI being ranked the highest and Ti-alloy being ranked the lowest. TMC is ranked in the middle, while AMC 1 and AMC 2 fall between TMC and GCI in terms of performance ranking.

4. CONCLUSION

In conclusion, weighted aggregate Product Assessment (WASPAS) Application of the method for automotive brake disc material selection provides a systematic and effective approach to decision-making. The WASPAS method allows for the consideration of multiple criteria, such as thermal conductivity, mechanical strength, wear resistance, and cost, by assigning appropriate of their relative importance Basically for every criterion weights. This is weighty the approach is very objective assessment and Comparison of different brake ensures disc materials. By utilizing the WASPAS method, automotive manufacturers and engineers can make informed decisions regarding the selection of brake disc materials. They can analyse and rank various materials based on their performance characteristics, taking into account specific requirements and priorities. For example, a high-performance sports car may prioritize heat dissipation and mechanical strength, while a commuter vehicle may prioritize cost-effectiveness and durability. The WASPAS method brings transparency and clarity to the material selection process, providing a structured framework for decision-making. It enables stakeholders to consider a wide range of factors and weigh them accordingly, leading to well-informed choices. By leveraging the WASPAS method, automotive brake systems can be optimized to deliver the desired balance between performance, safety, and cost-effectiveness. However, it is important to note that the effectiveness of the WASPAS method relies on the accuracy of the criteria weights assigned by experts. The selection process should involve knowledgeable professionals who have a deep understanding of the specific requirements and trade-offs involved in brake disc material selection. In conclusion, the WASPAS method offers a valuable tool for automotive brake disc material selection, aiding in the optimization of braking performance and ensuring the safety and durability of vehicles on the road.

REFERENCES

[1]. Awe, Samuel A. "Developing material requirements for automotive brake disc." Mod. Concepts Mater. Sci 2 (2019): 1-4.

[2]. Maleque[1], M. A., S. Dyuti, and M. M. Rahman. "Material selection method in design of automotive brake disc." In Proceedings of the world congress on engineering, vol. 3. 2010.

[3]. Rudramoorthy, S., V. MOHANAVEL, S. Karthikeyan, and T. Sathish. "Investigation on structural and Thermal analysis of disc brake with Aluminium Metal Matrix Composite." Int. J. Mech. Prod. Eng. Res. Devel. (IJMPERD) 8 (2018): 431-440.

[4]. Gurubasannavar, S. D. "A Predictive and Scalable Framework for B2b Commerce Platforms Using Micro Services, Micro Frontends." And Machine Learning Models. International Journal of Artificial intelligence and Machine Learning 1, no. 3 (2023): 1-9.

[5]. Abebe, Lemi, Ramesh Babu Nallamothu, K. H. S. Subrahmanyam, Seshu Kishan Nallamothu, and Anantha Kamal Nallamothu. "Thermal analysis of disc brake made of different materials." system 3 (2016)

[6]. Mulani, Shoaib Munir, Ashwani Kumar, Haris Naiyer E. Azam Shaikh, Ashish Saurabh, Pravin Kumar Singh, and Piyush Chandra Verma. "A review on recent development and challenges in automotive brake pad-disc system." Materials Today: Proceedings 56 (2022): 447-454.

[7]. Chan, D. S. E. A., and G. W. Stachowiak. "Review of automotive brake friction materials." Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering 218, no. 9 (2004): 953-966.

[8]. Barton, D. C. "Modelling of materials for automotive braking." International materials reviews 49, no. 6 (2004): 379-385.

[9]. Ramesh, Gopisetty, Narendra B. Mustare, and K. Uday3 C. Pramod Kumar. "Development of e-stick for blind persons using IoT." I-Manager's Journal on Embedded Systems 10, no. 2 (2022).

[10]. Gurubasannavar, S. D. "Evaluating Enterprise Data Accuracy Using Batch Migration Algorithm Analysis." International Journal of Computer Science and Data Engineering 1, no. 2 (2024): 1-6.

[11]. Barros, Liu Y., Jean Carlos Poletto, Patric D. Neis, Ney F. Ferreira, and Carlos HS Pereira. "Influence of copper on automotive brake performance." Wear 426 (2019): 741-749.

[12]. Seelam, Anil Babu, Nabil Ahmed Zakir Hussain, and Sachidananda Hassan Krishanmurthy. "Design and analysis of disc brake system in high-speed vehicles." International Journal for Simulation and Multidisciplinary Design Optimization 12 (2021): 19.

[13]. Mathad, Manoj, Anirudh Kohli, Mahesh Hombalmath, Basavaraj Kakol, Arun Y. Patil, B. B. Kotturshettar, H. K. Suresh, and Vishal Patil. "Non-Linear structural and thermal analysis of automotive brake disc." Materials Today: Proceedings 59 (2022): 1221-1224.

[14]. Mustare, Narendra, and V. Sreelathareddy. "Development of automatic identification and classification system for malaria parasite in thin blood smears based on morphological techniques." In 2017 IEEE International Conference on Power, Control, Signals and Instrumentation Engineering (ICPCSI), pp. 3006-3011. IEEE, 2017.

[15]. Bashar, Dan-Asabe, Peter B. Madakson, and Joseph Manji. "Material selection and production of a cold-worked composite brake pad." World Journal of Engineering and Pure & Applied Sciences 2, no. 3 (2012): 92.

[16]. Karakoc, Kerem, Edward J. Park, and Afzal Suleman. "Design considerations for an automotive magnetorheological brake." Mechatronics 18, no. 8 (2008): 434-447.
[17]. Chavan, Chetan Babasaheb, Anurag Shankar More, and Nikhil Nishikant Patil. "Static structural and thermal analysis of brake disc with different cut patterns." Journal of applied research and technology 16, no. 1 (2018): 41-52.
[18]. Huang, Scott Xiaodi, and Kip Paxton. "A macrocomposite Al brake rotor for reduced weight and improved performance." Jom 50, no. 8 (1998): 26.
[19]. Ramesh, Gopisetty, Narendra B. Mustare, and K. Uday3 C. Pramod Kumar. "Development of e-stick for blind persons using IoT." I-Manager's Journal on Embedded Systems 10, no. 2 (2022).
[20]. Aka, V. P. K. "Improving the Performance of Artificial Intelligence and Robotics Systems Through Comprehensive Sensor-Based Data Analysis and Predictive Model." International Journal of Artificial intelligence and Machine Learning 1, no. 3 (2023): 1-7.
[21]. Sunku, Raghavendra. "AI-Powered Data Warehouse: Revolutionizing Cloud Storage Performance through Machine Learning Optimization." International Journal of Artificial intelligence and Machine Learning 1, no. 3 (2023): 278.
[22]. Wu, Jiayi, Yan Zhao, Chinmay Chakraborty, Sandeep Kumar Thota, Jingmin Xin, and Keping Yu. "Cell-Level Free Cervical Lesion Detection in Cytology Images Via Weakly Supervised Self-Correction." IEEE Journal of Biomedical and Health Informatics (2025).
[23]. Pateriya, Janvijay, Raj Kumar Yadav, Vikas Mukhraiya, and Pankaj Singh. "Brake disc analysis with the help of Ansys software." International Journal of Mechanical Engineering and Technology 6, no. 11 (2015): 114-122.
[24]. Emovon, Ikuobase, and Okpako Stephen Oghenenyerovwho. "Application of MCDM method in material selection for optimal design: A review." Results in Materials 7 (2020): 100115.
[25]. Sivaprakasam, Palani, Esayas Abebe, Robert Čep, and Muniyandy Elangovan. "Thermo-Mechanical Behavior of Aluminum Matrix Nano-Composite Automobile Disc Brake Rotor Using Finite Element Method." Materials 15, no. 17 (2022): 6072.
[26]. Bhanderi, Jaydeep, Jitendra Mehta, and Kinjal Rank. "A Parametric Study of Simple Footing and Piled Raft." INTERNATIONAL JOURNAL OF ENGINEERING DEVELOPMENT AND RESEARCH 3, no. 4 (2015): 820-826.
[27]. Aka, V. P. K. "Strategic Framework for SAP S/4HANA Transformation Planning: Support Vector Regression Analysis of Migration Parameters and Implementation Paths." International Journal of Computer Science and Data Engineering 1, no. 2 (2024): 1-7.
[28]. Dandasi, V. V. "Credit Intelligence Reimagined: Leveraging Predictive Algorithms for Smarter Commercial Lending Decisions." International Journal of Computer Science and Data Engineering 2, no. 3 (2025): 1-7.
[29]. Sunku, Raghavendra. "AI-Powered Forecasting and Insights in Big Data Environments." Journal of Business Intelligence and Data Analytics 1, no. 2 (2024): 254.
[30]. Thota, Sandeep Kumar, Kumari Gubbala, Ashok Polavarapu, Vikram Narayandas, Hari Suresh Babu Gummadi, Narendra Chennupati, Sreedhar Babu Seshagani, Shivakrishna Deepak Veeravalli, and Manisha Guduri. "Adversarial Training with Attention-Guided DCGAN for Robust Lung Segmentation in Medical Imaging." In 2025 IEEE Region 10 Symposium (TENSYMP), pp. 1-6. IEEE, 2025.
[31]. Diana George, R. Navya, Vinitha V, "Next-Gen Air Quality Index Forecasting with Hybrid Machine Learning Models and Cloud Synergy", International Journal of Engineering Trends and Technology, 73(8), 2025, 129-136.
[32]. Singh, Tej, Amit Aherwar, Lalit Ranakoti, Prabhakar Bhandari, Vedant Singh, and László Lendvai. "Performance Optimization of Lignocellulosic Fiber-Reinforced Brake Friction Composite Materials Using an Integrated CRITIC-CODAS-Based Decision-Making Approach." Sustainability 15, no. 11 (2023): 8880.
[33]. Keshavarz-Ghorabaee, Mehdi, Maghsoud Amiri, Edmundas Kazimieras Zavadskas, Zenonas Turskis, and Jurgita Antucheviciene. "Determination of objective weights using a new method based on the removal effects of criteria (MEREC)." Symmetry 13, no. 4 (2021): 525.
[34]. Dandasi, V. V. "Healthcare Data Warehouse Implementation with Machine Learning Regression Analysis: A Comparative Study of Random Forest, AdaBoost, and XGBoost for Regulatory Compliance Prediction." Journal of Artificial intelligence and Machine Learning 2, no. 2 (2024): 1-7.
[35]. KINJAL RANK, "Comparative Study on Effect of Expansive Soil Properties While Using Stabilizer as Lime Fly ashAnd Cement Dust Manufacturing Waste", Journal of Emerging Technologies and Innovative Research", 3(6), 2019.
[36]. Surya Hadi Saputra, Rahmad, Budhi Hascaryo Iskandar, Vita Rumanti Kurniawati, Desrial Desrial, and Ari Purbayanto. "Material Selection of Collapsible Pot Hauler and Finite Element Analysis Simulation Applied to the Selected Material." Advances in Science and Technology. Research Journal 17, no. 2 (2023).
[37]. Steinberg, S., M. Dicke, L. E. M. Vet, and R. Wanningen. "Response of the braconid parasitoid Cotesia (= Apanteles) glomerata to volatile infochemicals: effects of bioassay set-up, parasitoid age and experience and barometric flux." Entomologia experimentalis et applicata 63, no. 2 (1992): 163-175.
[38]. Ganji, Dileep Kumar, and Rajyalakshmi Gajjela. "Selection of elemental composition of a Nickel-based super alloy through neural networks and multi-criteria decision making." Australian Journal of Mechanical Engineering (2021): 1-13.
[39]. Sunku, Raghavendra. "Enterprise Sales Compensation Optimization: A Machine Learning Framework for Accurate Payout Forecasting." International International Journal of Robotics and Machine Learning Technologies 1, no. 2 (2025): 240.

[40]. Samuel, K. K. M. "Artificial Intelligence in Big Data Visualization: Advancing Dashboard Technology." International Journal of Computer Science and Data Engineering 1, no. 2 (2024): 1-6.
[41]. Abhinav, E. Meher, Sai Naveen Kavuri, Thota Sandeep Kumar, Maragani Thirupathi, M. Chandra Mohan, and A. Suresh Reddy. "Analysis of molecular single-electron transistors using silicene, graphene and germanene." In Proceedings of the Second International Conference on Computer and Communication Technologies: IC3T 2015, Volume 1, pp. 77-84. New Delhi: Springer India, 2015.
[42]. Vidhya Prasanth, M Ramachandran, Ramya sharma, Chinnasami Sivaji, Solving the Conveyor Selection Problems in a Manufacturing Industry with the Grey Relational Analysis (GRA) Technique" Aeronautical and Aerospace Engineering, 1(4), December 2023, 32-38.
[43]. Reid, Chris R., Tanya Latty, Audrey Dussutour, and Madeleine Beekman. "Slime mold uses an externalized spatial “memory” to navigate in complex environments." Proceedings of the National Academy of Sciences 109, no. 43 (2012): 17490-17494.
[44]. Rains, Glen. "Behavioral Monitoring of Microplitis croceipes, a Parasitoid Wasp, for Detecting Target Odorants Using a Computer Vision..."
[45]. Chandrasekar Raja, Ramya sharma, M. Ramachandran, Vidhya Prasanth, "A Review on Selecting material suitable for a statically loaded thermal conductor using the TOPSIS Method", Journal on Applied and Chemical Physics, 3(4), December 2024, 1-12.
[46]. Aka, Venkata Pavan Kumar, and Kiran Kumar Mandula Samuel. "Adoption of SAP FSCM–Enhancing Collections and Dispute Processes in Spain, Portugal, and UK Operations." International Journal of Information Technology and Management Information Systems (IJITMIS) 15, no. 2 (2024): 148-161.
[47]. George, Diana, and Sam G. Benjamin. "Survey Paper on Different Types of Prediction Algorithm for Air Quality Index and Comparative Study on Types of Algorithms Used." INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS 9, no. 6 (2021): b557-b562.
[48]. Wan, Bin, Emilie Goguet, Marc Ravallec, Olivier Pierre, Séverine Lemauf, Anne-Nathalie Volkoff, Jean-Luc Gatti, and Marylène Poirié. "Venom atypical extracellular vesicles as interspecies vehicles of virulence factors involved in host specificity: the case of a Drosophila parasitoid wasp." Frontiers in immunology 10 (2019): 1688.

