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Motor Vehicles & Motors 2024

ECOLOGY - VEHICLE AND ROAD SAFETY - EFFICIENCY

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PREDGOVOR

U oktobru se na Fakultetu inženjerskih nauka Univerziteta u Kragujevcu tradicionalno održava skup istraživača i naučnika koji se bave proučavanjem motornih vozila, motora i drumskog saobraćaja. Od 1979. do 2004. godine održano je trinaest bienalnih MVM simpozijuma koji su 2006. prerasli u Međunarodni kongres MVM. Od tada je održano devet MVM kongresa, a oktobra 2024. godine Fakultet inženjerskih nauka je organizovao deseti međunarodni kongres MVM od 10. do 11. oktobra 2024. godine.

Na deseti kongres Motorna vozila i motori, MVM2024 dostavljen je veliki broj naučnih radova iz Srbije i inostranstva. Kongres tradicionalno podržavaju Ministarstvo za nauku, tehnološki razvoj i inovacije Republike Srbije, Univerzitet u Kragujevcu, Fakultet inženjerskih nauka i međunarodni časopis „Mobility and Vehicle Mechanics“.

Tema Kongresa MVM 2024 bila je „Ekologija – Bezbednost vozila i na putevima – Efikasnost“. Tokom ovog istraživačkog putovanja, učesnici su puno naučili kroz rad na različitim sekcijama, koje su pokrivale širok spektar tema u vezi sa inženjerstvom u automobilskoj industriji, od fundamentalnih istraživanja do industrijskih primena, naglašavaju interakciju između vozača, vozila i životne sredine i stimulišući naučnu interakcije i saradnju.

Međunarodni naučni odbor u saradnji sa organizacionim odborom izradio je podsticajan naučni program. Program je ponudio preko 54 prezentacije radova, uključujući predavanja po pozivu i radove u sekcijama. Prezentacije na ovom kongresu obuhvatile su aktuelna istraživanja u oblasti motornih vozila i motora sprovedena u 12 zemalja iz celog sveta.

Zadovoljstvo nam je bilo što su nam uvodničari bili profesor Emrulah Hakan Kaleli (sa Tehničkog univerziteta Yıldız, Turska), profesor Ralph Putz (sa Univerziteta Landshut UAS, Nemačka) i profesori Nenad Miljić i Slobodan Popović (sa Univerziteta u Beogradu, Srbija). Izazovi i rešenja u korišćenju vodonika kao goriva za motore sa unutrašnjim sagorevanjem, korišćenje aditiva nanoborne kiseline dodatog u motorno ulje, kao i evropska politika o budućoj mobilnosti na putevima su bile teme uvodnih predavanja.

Sigurni smo da je ovaj program pokrenuo živu diskusiju i podstakao istraživače na nova dostignuća.

10. Kongres MVM 2024. finansijski je podržalo Ministarstvo za nauku, tehnološki razvoj i inovacije Republike Srbije.

Zahvaljujemo se iskusnim i mladim istraživačima koji su prisustvovali i prezentovali svoju stručnost i inovativne ideje na našem kongresu.

Posebnu zahvalnost dugujemo članovima međunarodnog naučnog odbora i svim recenzentima za njihov značajan doprinos visokom nivou kongresa.

Naučni i organizacioni komitet Kongresa MVM2024

FOREWARD

In October, the Faculty of Engineering University of Kragujevac traditionally holds gatherings of researchers and academics who study motor vehicles, engines and road traffic. From 1979 to 2004, thirteen, biennal MVM Symposiums have been held and they grew into an International Congress MVM in 2006. Since then, ninth MVM Congresses have been held, and in October 2024, the Faculty of Engineering organized the tenth International Congress MVM from 10th to 11th October 2024.

A large number of scientific papers from the Serbia and abroad were submitted to the tenth Congress “MVM2024”. Congress is traditionally supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, University of Kragujevac, Faculty of Engineering and the International Journal “Mobility and Vehicle Mechanics”.

The theme of the Congress MVM 2024 was "Ecology - Vehicle and Road Safety - Efficiency". Along this journey we learned from the various sessions, which broadly cover a wide range of topics related to automotive engineering from fundamental research to industrial applications, highlight the interaction between the driver, vehicle and environment and stimulate scientific interactions and collaborations.

The International Scientific Committee in collaboration with the Organising Committee built up a stimulating scientific program. The program offered over 54 presentations, including key-note speakers and paper sessions. The presentations to this conference covered current research in motor vehicle and motors conducted in 12 countries from all over the world.

We were pleased to have professor Emrullah Hakan Kaleli (from Yıldız Technical University, Türkiye), professor Ralph Pütz (from Landshut University UAS, Germany) and professors Nenad Miljić and Slobodan Popović (from University of Belgrade, Serbia) as the keynote speakers, addressing Challenges and solutions in using hydrogen as a fuel for internal combustion engines, using nanoboric acid (nBA) additive added in engine oil, as well as European policy on future road mobility.

We are sure this program will trigger lively discussion and will project researchers to new developments.

The 10th Congress MVM 2024 was financially supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia.

We would like to thank experienced and young researchers, for attending and bringing their expertise and innovative ideas to our conference.

Special thanks are due to the International Scientific Board Members and all reviewers for their significant contribution in the high level of the conference.

Scientific and Organizational committee of Congress MVM2024

CONTENT

INTRODUCTORY LECTURES

SECTION A
Power Train Technology

SECTION B
Vehicle Design and Manufacturing

SECTION C
Vehicle Dynamics and Intelligent Control Systems

SECTION D
Driver/Vehicle Interface, Information and Assistance Systems

SECTION E
Transport Challenges in Emerging Economies

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Motor Vehicles & Motors

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CHARACTERISTICS AND APPLICATION OF POLYMER COMPOSITES IN THE AUTOMOTIVE INDUSTRY

ABSTRACT: Composite materials are increasingly pervading various fields of modern engineering, primarily due to their exceptional characteristics in terms of light weight, excellent strength-to-weight ratio, corrosion resistance and high resistance to temperature changes. As a result of the above, engineers recognized the importance and benefits of using composites in various aggregates, assemblies and parts of vehicles, starting from the simplest ones to the most complex and crucial ones on each individual vehicle. Due to the increasing use of electric and hybrid vehicles, compared to conventional vehicles, composite materials are used in various assemblies of these vehicles, starting from energy and power units, in the form of batteries, electric motors and generators, and through body and chassis elements to rubber parts, plastic and glass, which are subject to wear and aging and which are periodically changed, according to the exploitation and time resources of electric and hybrid vehicles. The expectations of the majority of researchers are that there will be further expansion in the matter of the application of composite materials for an even larger assortment of vehicle components, but also the development and improvement of the current characteristics of composite materials.

KEY WORDS: polymer composite, hybrid vehicle, electric vehicle, nanoparticles.

INTRODUCTION

Composite materials are increasingly used, especially in modern transport systems, but also in advanced industries and areas of life, work and human life that are closely related to environmental protection. The use of composite materials in the automotive, aviation, marine and wind energy industries is particularly pronounced [1].The key advantages of composites compared to classical materials that have been widely used so far are reflected in low weight, high durability, high strength, excellent strength-to-weight ratio, corrosion resistance and low thermal expansion [2].

Composite materials retain their special properties compared to metal alloys, thus providing even lighter and more durable constructions [3]. Composite materials are divided into five basic categories: polymer matrix composites, metal matrix composites, ceramic metal composites, carbon-carbon composites and hybrid composites [4].

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The first composite materials were applied to vehicles after the Second World War, already in 1947, first in the United States of America [5,6]. A significant contribution was also made by Japanese vehicle constructors as early as 1974 in order to reduce the weight of the vehicle, which aimed to reduce fuel consumption. Initially, composite materials are the most widely used for making vehicle bodies [7].The engineers of the British vehicle manufacturer Rolls Royce experimented with thermoset polymers reinforced with glass fibers for the production of turbine engine components, but these experiments did not lead to major successes [8]. In the period from the 1960s and 1990s, various manufacturers of vehicles and their components, as well as many institutes, development centres and research laboratories developed various materials that are recognized as composite materials. A special achievement in the field of development of composite materials took place in 1990, when a carbon vehicle with a large proportion of composite materials was presented for the first time, the main element of which was carbon, and it was presented by the Formula 1 racing team, McLaren, i.e. its design bureau [9].

POLYMER COMPOSITES, TERM AND CHARACTERISTICS

The term composite means a material obtained by the composition of two or more materials, which results in a third material with unique and improved characteristics compared to the basic materials [10]. At the same time, the basic materials are not soluble in each other. One material is called the matrix phase and the other the reinforcement phase. Most often, the strengthening phase is applied in the form of particles, fibres and flakes, the material flow of the matrix phase is mostly continuous fibers with pronounced plastic deformations [11]. Composite materials have found their application in the most modern engineering methods of obtaining materials, making structures and the most innovative branches of industry and economy, primarily because of their exceptional properties [12]. Composites show special capabilities for applications in the automotive industry for various vehicle components, and improvements over traditional materials are reflected in several key properties.

Strength to weight ratio

The strength-to-weight ratio of a material is shown through its specific strength. Composite materials show an exceptional strength-to-weight ratio, and this property is the main advantage of composites over other classic materials.

For example, although carbon composite fibres are stronger and stiffer per unit weight than both steel and aluminium, these fibres are only 25% of the weight of steel and 70% of the weight of aluminium [13]. Multi-layer composite laminates absorb more energy than conventional single-layer steel, allowing automotive engineers to reduce vehicle weight by up to 60%, while increasing crash safety [14]. For example, it is possible to make a composite material that will not bend in one direction where the metal usually has to be thicker to achieve the desired level of strength, which adds weight. The superior feature of composite materials is that they can be robust, without being heavy at the same time [15].

Durability, stability and resistance to damage

Unlike composites, metals are subject to fatigue. In any weather and atmospheric conditions, i.e. whether it is hot or cold, wet or dry, composites can retain their shape and most of their characteristics, without the appearance of corrosion with excellent dimensional stability. From the mentioned facts, it follows that composite materials are extremely suitable for various constructions, in different conditions of the external environment and with significant temperature and other oscillations [16].

Impact resistance

A particularly important feature of the composite is its resistance to impacts, such as high-speed projectiles or explosions. For the above reasons, composite materials are used in the military industry, for the production of clothing, panels and other barriers, military vehicles, helmets and various types of armour for the protection of personnel and equipment [17].

Thermal conductivity

In addition to the above, composite materials show low thermal and electrical conductivity, which makes them excellent insulators for components that require insulation [18]. On the other hand, if there is a need for thermally conductive elements, thermally conductive materials can be incorporated into the composite part, so that this property is not lost when constructing composite parts [19]. For example, polyimide composites have exceptional thermal conductivity, while being less heavy than metals [20].

APPLICATION OF POLYMER COMPOSITES IN MODERN VEHICLES

The application of composite materials in the automotive industry is increasingly intensive. These composites for modern vehicle applications are made of long carbon, glass and silver threads woven into metal reinforcing matrices [21]. The high performance composites market for automotive applications is estimated to achieve growth during the projected period of 2021 to 2028. Statistical analyses reveal that the growth of the application of composite materials to a value of about 13.8 billion USD by 2028 can be expected with an average annual growth rate of the application of these materials of 6.10%, which is shown in Figure 1 [22].

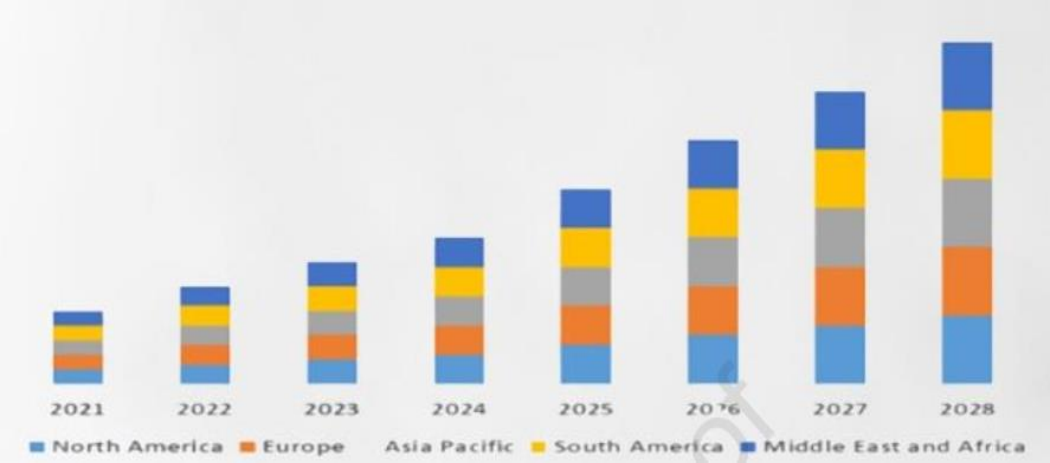

Figure 1 Global composite materials application market analysis expected till 2028 [22]

The most common application of the mentioned composite materials is for the following vehicle components: brakes, shock absorbers, hood, chassis, leaf springs, bumpers, doors, sunroof, engine mounts, fenders and other parts [23].

Brake pads

Brake pads are one of the key elements of a vehicle's braking system. Materials used for brake pads should exhibit consistent and reliable friction and low levels of wear under appropriate load, speed and temperature [24].

Considering their high coefficient of friction and reduced wear, both at room temperature and at higher temperatures up to about 250°C, phenolic composites are often used in automotive brake pads [25]. Polymer composites are commonly used as brake linings. Traditional steel or iron brake pads are heavier than composite brake pads, with composite pads proving to be easier to install and remove [26]. Figure 2 shows the structure of the composite material used to make brake pads on vehicles [27].

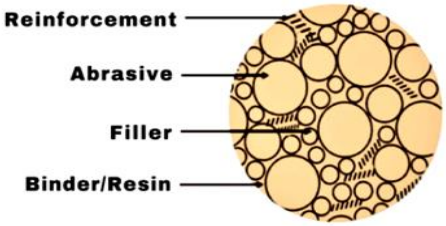

Figure 2 The structure of the composite material of the brake pads [27]

Hood

The hood is a prime example of the application of composites, which, among other things, has a steel coating. The requirements for these materials are primarily that they can be recycled, that they have good impact resistance, low weight and high stiffness [28]. Composite hoods can provide superior impact resistance, increasing the safety of vehicle occupants in the event of an accident. Composite materials allow greater design freedom, allowing vehicle manufacturers to produce hoods with complex curved surfaces and shapes [29]. The materials used to make vehicle hoods must be highly recyclable, have good impact resistance, low weight and high stiffness [28].

Chassis

Due to the pronounced lightness, high strength-to-weight ratio, as well as corrosion resistance, composite materials are increasingly used in the automotive industry [30]. Syntactic foam as a special material is used in modern vehicles to strengthen the rigidity of the thin sheet sandwich construction of the chassis. High performance materials, which are very expensive, use kevlar honeycomb core materials [31].The use of composites in the vehicle chassis contributes to the overall weight reduction of the vehicle, improving the handling and handling of the vehicle, while reducing fuel consumption [32]. Composite materials, among other things, have improved damping characteristics, which reduce the transmission of noise and vibrations through the chassis [33].

APPLICATION OF POLYMER COMPOSITES IN HYBRID AND AN ELECTRIC VEHICLES

Due to high fuel prices and increasing environmental degradation, the demand for the use of electric vehicles is increasing. Electric vehicles serve as an alternative to diesel, gasoline and other fossil fuels, which are currently predominantly powered by lithium-ion batteries that offer hybrid charging capabilities. It can be stated that the components of electric vehicles are made of composite materials, significantly lighter compared to conventional materials, which increases the efficiency of the vehicle, reduces energy consumption and reduces environmental pollution [34].

Regarding the production of hybrid and electric vehicles, composite materials have been widely used, primarily in the production of the bodies of these types of vehicles, because the mentioned materials have characteristics that enable the relatively easy and cheap production of these vehicle parts [35].

Polymer composites that are composed of inorganic nanoparticles such as calcium carbonate [36] and carbon nanotubes (CNT) [37], provide a wide range of performance for various purposes in mechanical reinforcement, thermal conductivity and noise and vibration reduction of hybrid and electric vehicles [38].

In recent years, intensive research has been carried out in order to understand the characteristics of various metals and non-metals for their application in the fields of nanoelectronics, nanophotonics, optoelectronics and other fields aimed at energy storage. The applications of different materials in electrochemical energy storage, i.e. in devices such as lithium, sodium-ion batteries and super capacitors, are particularly interesting [39].

In electric vehicles (Figure 3), the asymmetric supercapacitor device, which, among other things, consists of nickel cobalt oxide reduced by graphite oxide ($NiCO_2O_4$–rGO), as a composite material, shows better stability during a multi-stage discharge cycle [40]. Lightweight structures are necessary to achieve greater efficiency in all types of transport. Creating more free space under the hood is imperative, because it provides more space for housing energy storage elements, but also for housing advanced electric vehicle equipment and various goods for transportation [39].

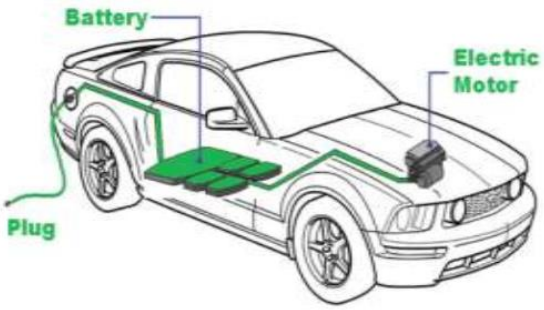

Figure 3 Electric vehicle battery placement [39]

A large number of electrical conductors are used in vehicles for different purposes, for energy transmission, but also for collecting and transmitting various information from sensors to control units. In some hybrid and electric vehicles, the conductors for the transmission of information are completely replaced by composite materials in the form of carbon-reinforced fibres with insulation, they are used as communication devices with accompanying equipment [39].

Electrical equipment in the car, external signals and the increasing number of electric and hybrid cars are some sources of electromagnetic interference. Composite shielding materials can improve overall vehicle performance by reducing electromagnetic interference. Carbon-based composite polymers, such as polyaniline, polypyrrole, are a good example of electromagnetic shielding [41].The high-voltage systems of electric cars cause the production of electromagnetic fields. For the protection and maintenance of electronic equipment of electric vehicles and external

communication systems, composite shielding successfully helps control and limit electromagnetic interference. The reliability, safety and performance of next-generation electric vehicles are likely to depend heavily on composite electromagnetic shielding in vehicles [42].

CONCLUSION

With the increasing demand for composite materials in the automotive sector today, their use is expected to expand successfully in the future. The development of composite materials for use in electric vehicles has fundamentally changed the automotive industry, providing a host of benefits that improve sustainability, efficiency and performance.

Various composite applications are included, e.g. chassis, brake pads, hood, bumpers, fenders, engine mounts, body interior and exterior, tires, etc. to achieve light construction, high strength, good fatigue resistance, toughness, resistance to damage, stiffness, thermal insulation, resistance to wear and other improved properties within optimal production and exploitation costs. Special opportunities are provided by the further development of composite materials that can be used for specific components of electric vehicles, such as batteries, electric power units, elements for the protection of energy and information conductors and electronic blocks, as well as equipment for charging vehicles and assistance in the exploitation and maintenance of electric vehicles and hybrid vehicles.

LITERATURE

[1] Krauklis, A. E., Karl, C. W., Gagani, A. I., & Jørgensen, J. K. Composite material recycling technology—state-of-the-art and sustainable development for the 2020s. Journal of Composites Science, 5(1), 2021, pp. 28.
[2] Ravishankar, B., Nayak, S. K., & Kader, M. A. Hybrid composites for automotive applications–A review. Journal of Reinforced Plastics and Composites, 38(18), 2019, pp. 835-845.
[3] Abramovich, H. Introduction to composite materials. In Stability and vibrations of thin walled composite structures, Woodhead Publishing, 2017, pp. 1-47.
[4] Gebrehiwet, L., Abate, E., Negussie, Y., Teklehaymanot, T., & Abeselom, E. Application of composite materials in aerospace & automotive industry. International Journal of Advances in Engineering and Management (IJAEM), 5(3), 2023, pp. 697-723.
[5] Johnson, T. History of composites. The evolution of lightweight composite materials. ThoughtCo, 2018.
[6] Singh, S., Uddin, M., & Prakash, C. Introduction, history, and origin of composite materials. In Fabrication and Machining of Advanced Materials and Composites.CRC Press, 2022, pp. 1-18.
[7] Khan, F., Hossain, N., Mim, J. J., Rahman, S. M., Iqbal, M. J., Billah, M., & Chowdhury, M. A. Advances of composite materials in automobile applications–A review. Journal of Engineering Researc, 2024.
[8] Harris, B. A perspective view of composite materials development. Materials & Design, 12(5), 1991, pp. 259-272.
[9] Seydibeyoğlu, M. Ö., Doğru, A., Kandemir, M. B., & Aksoy, Ö. Lightweight composite materials in transport structures. In Lightweight Polymer Composite Structures.CRC Press, 2020, pp. 103-130.
[10] Gupta, G., Kumar, A., Tyagi, R., & Kumar, S.. Application and future of composite materials: A review, International Journal of Innovative Research in Science, Engineering and Technology, 5(5), 2016, pp. 6907-6911.
[11] Fan, J., & Njuguna, J. An introduction to lightweight composite materials and their use in transport structures, In Lightweight Composite Structures in Transport Woodhead Publishing, 2016, pp. 3-34.
[12] Lotfi, A., Li, H., Dao, D. V., & Prusty, G. Natural fiber–reinforced composites: A review on material, manufacturing, and machinability. Journal of Thermoplastic Composite Materials, 34(2), 2021, pp. 238-284.
[13] Amran,Y.M.,Alyousef,R.,Rashid,R.S.,Alabduljabbar,H.,Hung,C. Properties and applications of FRP in strengthening RC structures: A review, Structures 16, 2018, pp. 208–238.
[14] Arya,A.,Ahamad,A.,Kumar,P.,Chandra,A. A review on lignin basednanocomposites: fabrication, characterization and application, Mater. Today.Proc. 78, 2023, A10–A15.
[15] Nagavally, R.R. Composite materials - history, types, fabricationtechniques, advantages, and applications, International Journal of CurrentResearch. (n.d.), 2016.
[16] Rubino, F., Nisticò, A., Tucci, F., & Carlone, P. Marine application of fiber reinforced composites: a review. Journal of Marine Science and Engineering, 8(1), 2020, pp. 26.
[17] Mahir, F. I., Keya, K. N., Sarker, B., Nahiun, K. M., & Khan, R. A. A brief review on natural fiber used as a replacement of synthetic fiber in polymer composites. Materials Engineering Research, 1(2), 2019, pp. 86-97.
[18] Blackwell,J. A. Transient-Flow method for determination of thermal constants of insulating materials in bulk Part I—theory, J. Appl. Phys. 25 (2), 1954, pp. 137–144.
[19] N. Burger, A. Laachachi, B. Mortazavi, M. Ferriol, M.P. Lutz, V. Toniazzo,D. Ruch, Alignments and network of graphite fillers to improve thermalconductivity of epoxy-based composites, Int. J. Heat. Mass Transf. 89, 2015, pp. 505–513.

[20] D. Liaw, K. Wang, Y. Huang, K. Lee, J. Lai, C. Ha, Advanced polyimide materials:Syntheses, physical properties and applications, Prog. Polym. Sci. 37 (7), 2012, pp.907–974.
[21] Elmarakbi, A. Advanced composite materials for automotive applications: Structural integrity and crashworthiness. John Wiley & Sons, 2013.
[22] Global High Performance Composites Market – Industry Trends and Forecast to 2028; https://www.databridgemarketresearch.com/reports/global-high-performance-compositesmarket; Accessed on July 2022.
[23] Walters, B. D., & Stegemann, J. P. Strategies for directing the structure and function of three-dimensional collagen biomaterials across length scales. Acta biomaterialia, 10(4), 2014, pp. 1488-1501.
[24] Crăciun, A. L., Pinca-Bretotean, C., Birtok-Băneasă, C., & Josan, A. Composites materials for friction and braking application. In IOP Conference Series: Materials Science and Engineering, IOP Publishing, 200 (1), 2017,pp. 10-11.
[25] Praveenkumar, B., Gnanaraj S.D., Case Studies on the Applications of PhenolicResin-Based Composite Materials for Developing Eco-Friendly Brake Pads, J. Inst.Eng. (India) Ser. D. 101 (2), 2020, pp. 327–334.
[26] Rajak, D.K., Pagar, D.D., Behera, A., Menezes, P.L., Role of composite materials inthe automotive sector: Potential applications. In Energy, Environment, andSustainability, Springer Nature, 2021, pp. 193–217.
[27] Khan, F., Hossain, N., Mim, J. J., Rahman, S. M., Iqbal, M. J., Billah, M., & Chowdhury, M. A. Advances of composite materials in automobile applications–A review. Journal of Engineering Research, 2024.
[28] Yuliang,X., He,Y., Zhang,F., Liu,Y., Leng,J. A Review of Shape Memory Polymersand Composites: Mechanisms, Materials, and Applications, Adv. Mater. 33 (6), 2020.
[29] T. Ngo, Introduction to composite materials, In Intech Open eBooks, 2020.
[30] J. Hirsch, Recent development in aluminium for automotive applications, Trans.Nonferrous Met. Soc. China. 24 (7), 2014, pp. 1995–2002.
[31] G.S. Cole, A.M. Sherman, Lightweight materials for automotive applications,Mater. Charact. 35 (1), 1995, pp. 3–9.
[32] S. Das, Life cycle assessment of carbon fibre-reinforced polymer composites. Int.J. Life Cycle Assess. 16 (3), 2011,pp. 268–282.
[33] M. Rao, Recent applications of viscoelastic damping for noise control inautomobiles and commercial airplanes, J. Sound Vib. 262 (3), 2003, pp. 457–474.
[34] Wazeer, A., Das, A., Abeykoon, C., Sinha, A., & Karmakar, A. Composites for electric vehicles and automotive sector: A review. Green Energy and Intelligent Transportation. 2(1), 100043, 2023, pp. 4-5.
[35] Ward, C., Hazra, K., & Potter, K. Development of the manufacture of complex composite panels. International Journal of Materials and Product Technology. 42(3-4), 2011, pp. 131-155.
[36] Alvarez, V., & Paulis, M. Effect of acrylic binder type and calcium carbonatefiller amount on the properties of paint-like blends. Progress in Organic Coatings. 112, 2017, pp. 210-218.
[37] Gou, J., Liang, Z., Zhang, C., & Wang, B. Computational analysis of effect ofsingle-walled carbon nanotube rope on molecular interaction and load transfer ofnanocomposites. Composites Part B: Engineering, 36(6-7), 2005, pp.524-533.
[38] Schadler, L. S. Polymer-based and polymer-filled nanocomposites.Nanocomposite science and technology, 2003, pp.77-153.
[39] Rajak, D. K,Pagar, D. D., Kumar, R.and Pruncu C.I.Recent progress of reinforcement materials:A comprehensive overview of compositematerials‖, Review, Journal of materialresearch and technology, 8(6),2019, pp. 6354–6374.
[40] Fang, K. Encapsulation process technology. In. Encapsulation technologies for electronic applications. 2nd ed. William Andrew, 2019, pp. 123–81.
[41] Kumar, R., Sahoo, S., Joanni, E., Singh, R.K., Tan, W.K., Kar, K.K., Matsuda, A., Recentprogress on carbon-based composite materials for microwave electromagneticinterference shielding, Carbon 177, 2021, pp. 304–331.
[42] Gupta,P., Toksha,B., Patel,B., Rushiya,Y., Das,P., Rahaman,M. Recentdevelopments and research avenues for polymers in electric vehicles, Chem. Rec., 2022.