(Online) ISSN 2712-0562
Review Article

Sustainable Engineering and Innovation
Vol. 7, No. 2, 2025, pp.415-424
https://doi.org/10.37868/sei.v7i2.id504

Sustainable composite materials: Applications and future

Fehim Findik[1,2,*]
[1] Metallurgy and Materials Engineering Department, Faculty of Technology, Sakarya Applied Sciences University, Sakarya, Turkey
[2] Istanbul Aydın University, Mechanical Eng Dept, Engineering Faculty, Florya Halit Aydın Campus, Istanbul, Turkey

*Corresponding author E-mail: name. findik@subu.edu.tr

Received May. 16, 2025
Revised Jul. 21, 2025
Accepted Jul. 30, 2025
Online Sep. 19, 2025

Abstract

Sustainable composite materials represent a critical step towards a more environmentally friendly future. They are an alternative to traditional composites by reducing waste. Sustainability of materials can be achieved through various studies. Composite materials will become more efficient and environmentally friendly with the various findings of researchers. They will play an important role in overcoming challenges such as resource scarcity. Sustainable composites significantly decrease environmental problems related to the production of biodegradable engineered materials. The production of sustainable composites results in less energy consumption and lower toxic gases. Sustainable composites are used in packaging, construction, automobiles, sports, and furniture equipment. In this study, sustainable composite materials are examined and criticized considering their benefits, innovations, applications and challenges, and future perspectives.

Keywords: Composite materials, Sustainability, Benefits, Innovations, Applications

1. Introduction

Composite materials have long been celebrated for their exceptional strength-to-weight ratios, durability, and versatility, making them indispensable in industries such as aerospace, automotive, construction, and consumer goods. However, the environmental impact of traditional composites—often derived from non-renewable resources like petroleum-based polymers and synthetic fibers—has become a growing concern. The manufacture, usage, and discarding of these materials contribute significantly to carbon emissions, resource depletion, and persistent waste. In response, sustainable composite materials have emerged as a transformative solution, offering the same performance benefits while aligning with global sustainability goals [1], [2], [3].

Sustainable composites are engineered materials that prioritize environmental responsibility throughout their lifecycle. They are typically composed of renewable, biodegradable, or recycled components, reducing reliance on fossil fuels and minimizing ecological harm. These constituents can be classified into three groups: fiber-reinforced, bio-based, and hybrid composites [4]. Fiber-reinforced composites combine natural fibers, for example, flax or kenaf, with recycled polymer matrices as reinforcement. Natural fibers are biodegradable and require less energy than artificial fibers, such as glass. In recycled composites, recycled plastics include industrial waste materials. For example, recycled polyethylene terephthalate (PET) can be reused to create new composite materials. Bio-based composites use bio-based resins such as corn or soy. These resins can replace traditional petroleum-based plastics and reduce the carbon footprint of the material. In this study, sustainable composite materials are examined and criticized considering their benefits, innovations, applications and challenges, and future perspectives.

2. Benefits

The advantages of sustainable composites are summarized in the following 5 points in terms of environment, recycling, performance, benefit, and efficiency [4], [5].

Sustainable composites significantly reduce the environmental burden in production. For example, natural fibers can be preferred over synthetic fibers because they require less energy to process. As is known, the use of waste materials reduces the need for virgin resources. Biodegradability is an important feature in terms of environmental pollution. Some sustainable composites, such as polylactic acid (PLA), are designed to be biodegradable. The production of sustainable composites consumes less energy, resulting in lower greenhouse gas emissions. This feature also provides energy efficiency in the composite.

Performance of composites is the other benefit owing to their high strength and low density. Sustainable composites can be personalized to meet the specific requirements of various applications. Developments in material science have enabled the progress of composites that rival the mechanical properties of traditional materials, making them appropriate for demanding applications such as automotive parts, wind turbine blades, and construction materials.

The final issue is the economic benefit of composites. The use of sustainable composites can stimulate rural economies by creating demand for natural fibers, which are often grown in developing regions. Additionally, these materials are parallel with consumer favorites for eco-friendly goods, attractive brand reputation, and marketability.

3. Innovations

The field of sustainable composites is rapidly evolving, with several promising innovations on the horizon. These are abridged as follows, including hybrid composites, 3D printing with sustainable composites, self-healing composites, as well as circular economy models [4].

In hybrid composites, combining natural fibers with artificial fibers or nanoparticles can improve mechanical properties while maintaining a reduced environmental impact. For example, adding a small percentage of carbon fibers to a natural fiber composite can significantly improve strength and stiffness.

Additive manufacturing (3D printing) techniques are being adapted to use sustainable composite materials, enabling the production of complex, lightweight structures with minimal waste. About self-healing composites, researchers are developing bio-based composites with self-healing properties, which can extend the lifespan of materials and reduce the need for replacements. Finally, companies are exploring circular economy approaches, such as designing composites for easy disassembly and recycling or using waste materials as feedstock for new composites.

4. Applications

Sustainable composites are finding applications across an extensive variety of industries, including automotive, building, wrapping, aerospace, and consumer goods. These are briefly reported in automotive, construction, packaging, aerospace, consumer goods, as well as recent applications as follows [6], [7], [8]:

In automotive applications, lightweight natural fiber composites are being utilized for interior boards, dashboards, and door coatings, reducing vehicle weight and improving fuel efficiency (Tables 1-3, Figure 1).

Composites in construction applications are another area. Sustainable composites are used in insulation, roofing, and structural components, offering durability and thermal efficiency. Packaging is also an important application area. Biodegradable composites are replacing traditional plastics in packaging, reducing waste and pollution.

Due to lightness and high strength, composites can also be used in the aerospace industry. While still in the experimental stage, sustainable composites are being explored for non-structural components to reduce the environmental impact of aircraft. About consumer goods from furniture to sporting goods, sustainable composites are being embraced for their eco-friendly appeal and performance. Recently, composites were applied in various areas including ballistics [9], [10], [11], contactors [12], brakes [13], [14], bio-composites [15], [16], as well as polymer-based composites [17], [18] and ceramic based composites [19].

Table 1. Automotive producers and request extents of natural fibers [6], [7], [8]

Company/Manufacturer	Model Applications	Automobile Parts
Audi	A2, A3, A4, A6, A8, Roadster, Coupe	Seat backs, side and back door panels, boot lining, hat rack, spare tire lining
BMW	3, 5, 7 series, BMW I series	Door panels, headliner panel, boot lining, seat backs, noise insulation panels, door trim
Citroën	CS	Interior door paneling
Chrysler	A, C, E, and S-class models	Door panels, windshield, dashboard, business table, pillar cover panel
Fiat	Punto, Brava, Marea, Alfa Romeo 146, 156	Door cladding, seat-back linings, door panels, seat bottoms, head restraints, back cushions
Ford	Mondeo CD 162, Focus, Freestar	Door panels, boot liner, sliding door inserts
Lotus	Eco Elise	Body panels, spoiler, seats, and interior carpets
Mercedes-Benz	Trucks, Mercedes A	Internal engine and roof cover, sun visor, interior insulation, bumper, wheel box
Opel	Vectra	Packing trays, panel inserts
Peugeot	406	Seat backs, parcel shelf
Renault	Clio, Twingo	Rear parcel shelf
Rover	2000	Insulation, rear storage shelf/panel
Saab	—	Door panels
Seat	—	Door panels, seat backs
Saturn	L300s	Packing trays, door panel inserts
Toyota	Brevis, Harrier, Celsior, Raum	Door panels, seat backs, spare tire cover
Vauxhall	Corsa, Astra, Vectra, Zafira	Headliner panel, interior door panels, instrument panel
Volkswagen	Golf, Passat, Bora	Door panel, seat back, boot lid finish panel, boot liner
Volvo	C70, V70	Seat padding, natural foams, cargo floor tray

Table 2. Flame retardants used in the automotive sector [6]

Automotive Components	**Polymer**	**Flame Retardants (FRs)**
Printed circuit board	Epoxy/Phenolics	Brominated FRs; Sulfonates
Housing and dashboard	HIPS/ABS/PC-ABS alloys/PP	Brominated FRs
Wire and cables	PP copolymers/EPR	Brominated FRs
Battery casing	PP	Brominated FRs
Textile for seats	Latex back-coating	Brominated and phosphorus-based additives
Seats	Flexible PUF	Phosphorus-based additives

Automotive Components	Polymer	Flame Retardants (FRs)
Connectors and under-hood parts	Polyamides	Brominated FRs
Acoustic insulation	XPE foam	Brominated and mineral-based FRs
Thermal insulation	Rigid PUF/XPE foam/Plasticized PVC	Phosphorus-based additives
Truck and boat cover	Plasticized PVC	Phosphorus-based additives
Door partition and internal panels	PP and wood polymer composites	Mineral and phosphorus-based FRs

Table 3. Natural fiber-based composite portions are utilized in cars by various producers [6], [8].

Manufacturer	Vehicle Model	Natural Fiber-Based Composite Parts
Ford	Mondeo CD 162, Focus	Door panels, B-pillar, and boot liner
Audi	A2, A3, A4, Avant, A6	Seat backs, side and back door panel, boot lining, hat track, and spare tire lining
Toyota	Brevis, Harrier, Celsior, Raum	Door panels, seat backs, and spare tire cover
Mercedes-Benz	Trucks	Internal engine cover, engine insulation, sun visor, interior insulation, bumper, wheel box, and roof cover
BMW	3, 5, and 7 series and others	Door panels, headliner panel, noise insulation panels, seat backs, molded foot, and well linings
Volkswagen	Golf, Passat, Variant, Bora, Fox, Polo	Door panels, seat backs, boot liner, and boot lid finish panel

Figure 1. Automobile mechanisms founded on polymer composites reinforced with lignocellulosic fibers [6]

5. Challenges and future perspectives

5.1. Challenges

While sustainable composites offer numerous advantages (Tables 4-5), they are not without challenges [7], [8], [20], [21], [22]. These challenges can be summarized within four issues as follows:

The first issue is the durability and performance of composite materials. Natural fibers and bio-based resins may have lower mechanical strength, thermal stability, or moisture resistance compared to their synthetic counterparts. Researchers are addressing these limitations through hybridization (combining natural and synthetic fibers) and chemical treatments to enhance fiber-matrix adhesion.

Cost and scalability are also very important challenges. The production of sustainable composites can be more expensive owing to the higher costs of bio-based resins and the limited availability of high-quality natural fibers. Scaling up production to meet industrial demand remains a significant hurdle.

In a world where the population is increasing and resources are limited, recycling and end-of-life management are of great importance. While some sustainable composites are biodegradable, others require efficient recycling methods to ensure they do not contribute to waste. Developing closed-loop recycling systems and standardized processes is critical for maximizing sustainability.

The final issues are regulatory and standardization. The lack of standardized testing methods and regulations for sustainable composites can hinder their widespread adoption. Establishing clear guidelines and certifications will be essential for building trust and ensuring consistency.

Table 4. Comparison of traditional composites vs. sustainable composites [4], [5], [6]

Property	Traditional Composites	Sustainable Composites
Raw Materials	Petroleum-based polymers, glass/carbon fibers	Natural fibers, bio-based resins, recycled materials
Environmental Impact	High carbon footprint, non-renewable	Low carbon footprint, renewable, biodegradable
Energy Consumption	High energy-intensive production	Lower energy requirements
Cost	Generally lower cost	Higher initial cost, but long-term savings
Recyclability	Difficult to recycle, often landfilled	Designed for recyclability or biodegradability
Applications	Aerospace, automotive, construction	Automotive, packaging, consumer goods, and construction

Table 5. Examples of natural fibers and their properties [2], [3], [7]

Natural Fiber	Tensile Strength (MPa)	Density (g/cm^3)	Advantages	Common Applications
Flax	345-1500	1.4-1.5	High strength, low cost, biodegradable	Automotive interiors, sports equipment
Hemp	550-900	1.48	Good mechanical properties, eco-friendly	Construction, textiles, packaging
Jute	393-800	1.3-1.45	Low cost, high availability, biodegradable	Packaging, geotextiles, furniture
Bamboo	140-800	0.6-1.1	High growth rate, renewable, lightweight	Flooring, composites, textiles
Kenaf	223-930	1.2-1.4	High tensile strength, low environmental impact	Automotive panels, insulation

5.2. Future perspectives

The field of composite materials is rapidly evolving, driven by the need for sustainability, technical progressions, and the rising demand for high-performance materials. As industries and governments worldwide prioritize environmental responsibility and resource efficiency, the future of composite materials is poised to be transformative. Below, we explore key trends, innovations, and opportunities that will shape the future of this dynamic field [6], [7], [8], [20], [21], [22].

5.2.1. Advanced sustainable composites

The shift toward sustainability will continue to dominate the development of composite materials. Future innovations will focus on enhancing the environmental performance of composites while maintaining or improving their mechanical properties. Biodegradable composites and waste-derived composites are important parts of the progress:

Scientists are investigating the possibility of obtaining new bio-based resins and matrices from sources such as agricultural waste and lignin. These materials will both reduce the dependence on fossil fuels and offer biodegradability. This will enable the progress of composites that can be recycled and reused. For example, non-recyclable thermoset composites are being redesigned to include reversible chemical bonds, allowing them to be broken down and reprocessed. Thus, the use of post-consumer waste as raw materials will accelerate. For example, the use of expensive carbon fiber waste in aviation production in new composites will reduce costs.

5.2.2. Smart and functional composites

Intelligent systems can be integrated into composite materials for issues such as energy storage, structural support, sensing, and self-healing. Self-healing composites are being developed to automatically repair damage and other cracks in the structure caused by reasons such as traffic accidents. Thanks to intelligent embedded systems in the composite, repairs are made with healing substances released from the system, and the life of the material is increased. Systems that store energy by measuring temperature, vibration, and mechanical stress may be included in future composites. Again, thanks to wearable systems, patients can be monitored remotely with embedded composites by measuring temperature and stress sensors. In addition, these intelligent composites can also be used in aviation and wearable electronics. Again, thanks to these intelligent systems in composites, catastrophic failures can be prevented by detecting possible early damage in critical systems such as wind turbines, airplanes, and bridges.

5.2.3. Nanotechnology-enhanced composites

Nanotechnology can play a significant role in improving the performance of composite materials. Here, the addition of reinforcements such as nanoclay and graphene to composites will improve strength, electrical, and thermal properties. In recent years, extensive studies have been conducted on graphene-reinforced composites, which have high mechanical properties due to increased surface areas. Due to its lightness and high strength, the addition of graphene to composites can provide great advantages in the use of these composites in the energy storage and electronics industries.

Within the nano-clay composites, nano-clays can improve barrier properties, flame resistance, and mechanical performance, making them ideal for packaging, automotive, and construction applications.

5.2.4 Additive manufacturing and customization

Additive manufacturing, or 3D printing, is revolutionizing the production of composite materials. This technology allows for the creation of complex, lightweight structures with minimal waste, enabling unprecedented levels of customization and design freedom (Figure 2). In 3D-printed composites, the development of 3D-printable composite filaments and resins will enable the production of customized parts for industries such as healthcare (e.g., prosthetics), aerospace, and automotive. For example, continuous fiber 3D printing allows for the precise placement of fibers within a polymer matrix, optimizing strength and weight. On-demand manufacturing, or additive manufacturing, will facilitate decentralized, on-demand production of composite components, reducing the need for large-scale manufacturing facilities and lowering transportation costs.

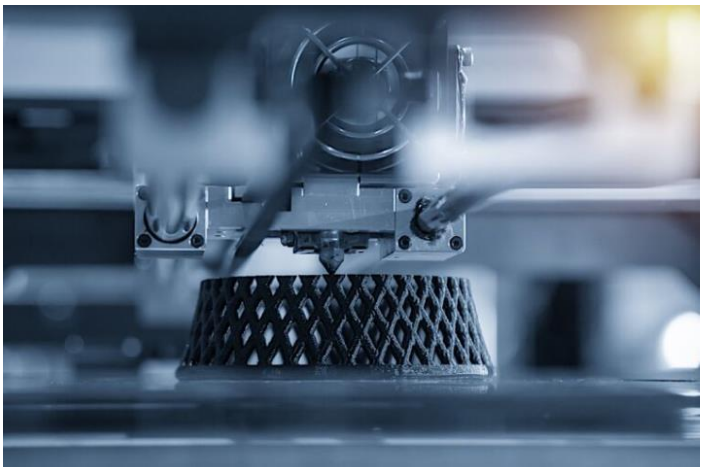

Figure 2. 3D printing of composite materials

Biodegradable constituents are transforming the creation of additive manufacturing. Recognized for their aptitude to obviously degrade, these constituents offer eco-friendly replacements to outdated polymers and alloys. This not only decreases leftovers, but also makes it even with worldwide sustainability efforts. In current eons, the additive manufacturing sector has seen an important increase in the utilization of biodegradable choices. These constituents, which are usually resulting from normal resources, break down more effortlessly in the atmosphere, serving to decrease the lasting influence of leftovers. Biodegradable constituents have several compensations in additive manufacturing, including reduced ecological impact and supply competence:

As technology advances, corporations are constantly investigating new bio-based materials to improve act and toughness while remaining biodegradable. This novelty is flagging the way for more sustainable and accountable manufacturing approaches.

An important contest with biodegradable additives is their mechanical properties. Frequently, biodegradable constituents like PLA (polylactic acid) cannot match the strength and suppleness of outdated polymers. To discuss this subject, investigators continue to develop composite materials that combine biodegradable plastics with ordinary fibers like flax or bamboo to increase strength and flexibility.

By speaking of these numerous limits through continued study and invention, the incorporation of biodegradable additives into additive manufacturing holds potential for a more sustainable and ecologically responsive upcoming.

5.2.5 Hybrid composites

Hybrid composites, which combine two or more types of fibers or matrices, will become increasingly popular. These materials offer a balance of properties that cannot be achieved with single-component composites. It is possible to think about the hybrid composites within two categories, including natural-synthetic hybrids as well as multi-functional hybrids.

In natural-synthetic hybrids, combining natural fibers with artificial fibers (e.g., glass or carbon) can enhance mechanical properties while maintaining a reduced environmental impact. For example, a flax-carbon hybrid composite could be used in automotive applications to achieve high strength and stiffness with lower weight and cost. In the future, hybrid composites could be used for many different functions such as electrical conduction, thermal insulation, and magnetic shielding.

5.2.6 Regulatory and standardization developments

Standard test methods for composites should be developed together with advanced composites. In addition, regulations regarding the production and recycling of composites should be adapted to the developed composites. In these instructions, life cycle standards should also be clearly described. In this way, environmentally friendly products will be easily distinguished by consumers. In addition, comparison of the ecological influence of composites and life cycle valuation can guide researchers in possible innovation studies and consumer decision-making.

5.2.7 Emerging applications

Composite materials, due to their superior properties, will be used more in applications such as biomedical, health, and energy in the future. It is estimated that composites will be used especially in solar panels, wind turbines, and other energy storage systems. Since composites are durable but lightweight, efficiency will increase, and longer service life can be provided.

For biomedical and healthcare applications, biocompatible composites will be used in medical implants, prosthetics, and drug delivery systems. For example, bioresorbable composites that gradually dissolve in the body could eliminate the need for secondary surgeries. For urban infrastructure claims, composites will be increasingly used in smart cities for applications such as lightweight bridges, energy-efficient buildings, and modular construction.

5.3 Market overview

The bio-composites market is undergoing important development, chiefly determined by the widespread application of bridgeable materials, for example, hemp, jute, and flax. These materials not only offer vigorous toughness but also contribute to a more maintainable and ecologically responsive upcoming. The marketplace of bio-composites, shaped by the reinforcement of natural fibers, for example, flax and hemp, has a noteworthy size due to their environmental friendliness. These composites are both environmentally friendly and have excellent durability. In addition, since these bio-composites are important alternatives to traditional composites, the development of bio-composites is supported by governments in many places. In this way, investments in this field have increased, and it is aimed to reach a larger market share. The durability performance of bio-based composites has been increased in research. Thanks to these developments, both the disadvantages, such as limited strength and low moisture resistance, have been solved, and the application areas have been expanded [10], [11].

6. Conclusions

With environmentally friendly and sustainable composite materials, waste can be reduced and energy can be saved, providing superiority over traditional composites. Research continues to further increase performance and balance costs. These composites will take a significant role in achieving the goals of a cleaner and more livable environment. As research on reinforcements and matrices continues, the efficiency of composites will increase, and they will be more environmentally friendly. Due to the potential of composites to provide both environmental friendliness and economic benefits, sustainability-related challenges will be overcome, and the future can be looked to with confidence.

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

Funding information

No funding was received from any financial organization to conduct this research.

References

[1] F. P. La Mantia and M. Morreale, “Green composites: A brief review”, Composites Part A: Applied Science and Manufacturing, vol. 42, no. 6, p. 579-588, 2011. https://doi.org/10.1016/j.compositesa.2011.01.017

[2] K. L. Pickering, M. G. A. Efendy and T. M. Le, “A review of recent developments in natural fiber composites and their mechanical performance”, Composites Part A: Applied Science and Manufacturing, vol. 83, p. 98-112, 2016. https://doi.org/10.1016/j.compositesa.2015.08.038

[3] S. V. Joshi, L. T. Drzal, A. K. Mohanty and S. Arora, “Are natural fiber composites environmentally superior to glass fiber reinforced composites?”, Composites Part A: Applied Science and Manufacturing, vol. 35, no. 3, p. 371-376, 2004. https://doi.org/10.1016/j.compositesa.2003.09.016

[4] S. Gupta, V. Chaudhary, P. Gupta (Eds.), Sustainability of Green and Eco-Friendly Composites, CRC Press, Taylor & Francis Group, 2024, London. https://doi.org/10.1201/9781003272625

[5] O. Faruk, A. K. Bledzki, H.P. Fink and M. Sain, “Bio-composites reinforced with natural fibers: 2000–2010”, Progress in Polymer Science, vol. 37, no. 11, p. 1552-1596, 2012. https://doi.org/10.1016/j.progpolymsci.2012.04.003

[6] G. Koronis, A. Silva and M. Fontul, “Green composites: A review of adequate materials for automotive applications”, Composites Part B: Engineering, vol. 44, no. 1, p. 120-127, 2013. https://doi.org/10.1016/j.compositesb.2012.07.004

[7] S. Thomas, and L. A. Pothan, Natural fiber reinforced polymer composites: From macro to nanoscale. Old City Publishing, 2009. https://doi.org/10.1504/IJMPT.2009.027839

[8] C. Baillie, R. Jayasinghe (Eds.), Green Composites, Wood head Publishing, Cambridge, 2017. https://doi.org/10.1016/B978-0-08-100783-9.00001-0

[9] N. Tarim, F. Findik, H. Uzun, “Ballistic Impact Performance of Composite Structures”, Composite Structures, V.56/1 APR 2002, pp. 13-20. https://doi.org/10.1016/S0263-8223(01)00177-5

[10] F. Findik, N. Mrad, A. Johnston, “Strain Monitoring in Composite Patched Structures”, Composite Structures, vol. 49, no.3, p. 331-338, 2000. https://doi.org/10.1016/S0263-8223(00)00065-9

[11] E. Camci, M. Caliskan, I. Tural, O. Ergu, F. Findik, “Investigation of the performance of a V-shaped inner plate array armor system against 7.62 mm caliber bullets”, International Journal of Precision Engineering and Manufacturing, vol. 25, no. 2, p. 363-381, 2024. https://doi.org/10.1007/s12541-023-00928-y

[12] F. Findik, H. Uzun, “Microstructure, hardness and electrical properties of silver-based refractory contact Structures, vol. 56, no.1, p. 13-20, 2002. https://doi.org/10.1016/S0263-8223(01)00177-5

[13] I. Mutlu, O. Eldogan, F. Findik, “Tribological properties of some phenolic composites suggested for automotive brakes”, Tribology International, vol. 39, no. 4, p. 317-325, 2006. https://doi.org/10.1016/j.triboint.2005.02.002

[14] I. Mutlu, C. Oner, F. Findik, “Boric acid effect in phenolic composites on tribological properties in brake linings”, Materials & Design, vol. 28, no. 2, p. 480-487, 2007. https://doi.org/10.1016/j.matdes.2005.09.002

[15] E. Yilmaz, B. Cakiroglu, A. Gokce, F. Findik F, “Novel hydoxyapatite/graphene oxide/collagen bioactive composite coating on Ti16Nb alloys by electrodeposition”, Materials Science and Engineering C-Materials for Biological Applications, vol. 101, p. 292-305, 2019. https://doi.org/10.1016/j.msec.2019.03.078

[16] E. Yılmaz, F. Kabatas, A. Gökçe, F. Fındık, “Production and Characterization of a Bone-Like Porous Ti/Ti-Hydroxyapatite Functionally Graded Material”, Journal of Materials Engineering and Performance, vol. 29, no. 10, p. 6455-6467, 2020. https://doi.org/10.1007/s11665-020-05165-2

[17] H. Unal, F. Findik, A. Mimaroglu, “Mechanical behavior of nylon composites containing talc and kaolin”, Journal of Applied Polymer Science, vol. 88, no. 7, p. 1694-1697, 2003. https://doi.org/10.1002/app.11927

[18] H. Yetgin, H. Ünal, A. Mimaroğlu, F. Findik, "Influence of Process Parameters on the Mechanical and Foaming Properties of PP Polymer and PP/TALC/EPDM Composites", Polymer - Plastics Technology and Engineering, vol. 52, p. 433 - 439, 2013. https://doi.org/10.1080/03602559.2012.748802

[19] N. Altinkok, I. Ozsert, F. Findik, "Dry sliding wear behavior of Al2O3/SiC particle reinforced aluminum based MMCs fabricated by stir casting method", Acta Physica Polonica A, vol. 124, no. 1, p. 11-19, 2013. http://dx.doi.org/10.12693/APhysPolA.124.11

[20] J. P. Davim (Ed.), Green Composites, De Gruyter, 2017, Berlin. https://doi.org/10.1515/9783110435788

[21] C. Alves, P. Ferrão, A. Silva, L. Reis, M. Freitas, L. Rodrigues, D. Alves, “Ecodesign of automotive components making use of natural jute fiber composites”, Journal of Cleaner Production, vol. 18, no. 4, p. 313-327, 2010. https://doi.org/10.1016/j.jclepro.2009.10.022.

[22] P. Rakesh, I. Singh (Eds.), Processing of Green Composites, Springer, 2019, Singapore. https://doi.org/10.1007/978-981-13-6019-0