Editorial Corner

Applications of Hybrid Composites in Railway

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Hybrid composite materials are turning into an emerging alternative for traditional materials that are currently being extensively used in railways for satisfying specific demands, such as a high strength to weight ratio, fatigue resistance, vibration control, resistance towards corrosion, etc. Lightweighting in the rail industry by using these composite materials will lead to achieve higher speeds, improve comfort of the passengers through the novel and modular rail cars, reduce manufacturing cost through a combination of intelligent deployment of composite materials, increase efficiency via faster accelerations, and reduce braking distances and most importantly reduce the carbon emission by lowering energy consumptions. These benefits have urged the research community to explore the applicability of different composite materials for the rail industry. The potential choices for composite materials include substitute incorporates; interior and exterior shells, passenger amenities, restroom interiors, exterior attachments, loco pilot cabinets, doors, ceiling, etc. [1]–[20].

Recently, several studies have suggested that Fiber Reinforced Polymer (FRP) materials possess light-weight, high strength, high stiffness value and are more durable in nature. The prefabricated large-scale parts of high-speed trains are majorly molded from FRP. The fibers utilized can be made of glass or carbon, and at times, paper or wood fibers can be utilized in biodegradable composites. The polymer matrix in modern composite materials is usually polyester thermosetting plastic, epoxy, or vinyl ester.

The main advantages of using FRP composites in rail infrastructure arise from the material's high strength-to-weight and stiffness-to-weight ratios, compared to conventional construction materials such as steel and reinforced concrete, resulting in lightweight structures. The FRP materials also exhibit excellent weather and corrosion resistance, making them suitable for durable structures with less maintenance. However, drawbacks, such as the formation of material voids, creep deformation, limited information on long-term performance, behavior at elevated temperatures, the effect of impact, and fatigue loading are some of the major areas that are being explored by researchers to overcome the challenges in the use of FRP materials [21]–[30].

In the most recent investigations on the development of railcar bodies by using CFRP composites, the question of implementing an integral or a differential design played a decisive role in the early conceptual phase. Alternatively, the constitutive approach for the design of CFRP railcar body has given many advantages, such as reduction in the cost by the elimination of joints and enhanced level of lightweight design. On the other hand, the disadvantages, such as the difficult adherence to dimensional accuracy for large CFRP components (lengths > 20 m) due to hygrothermomechanically and chemically induced shrinkage effects, the limited possibility of cost-efficient and ergonomic pre-assembly of submodules, and the limited repair options in the event of damage issues are being confronted while using the FRP materials. In contrast, a multi-part differential design approach of the CFRP railcar body offers the simple replacement of individual components in the event of damage, the efficient pre-assembly of submodules, and the possibility of targeted tolerance compensation via joints. Furthermore, the differential design technique makes it easier to construct different variants of a single train type that meets the special needs of different operators, such as dimensions and design [31]–[40].

The development of hybrid composite-based specific applications for railways by overcoming the above-mentioned challenges has turned into an intriguing topic in the railway industry. The researchers are devoting their persistent efforts to come up with innovative ideas for brining in the superior substitute of existing traditional materials with hybrid composites applications in railway [41]–[44]. In summary, the specific advantages of using hybrid composites in the railway industry are as follws.

- Sustainability improvements: reduced carbon dioxide (CO_2) emissions per passenger per km.
- Operational benefits: lower energy costs, faster acceleration, increased payload.
- Reduced lifecycle costs: fast installation, lower maintenance, reduced renewal frequency.
- Enhanced functionality: new design concepts, multifunctional components, customized solutions, smart structures.

References

[1] M. Jawaid and S. Siengchin, "Hybrid composites: A versatile materials for future," *Applied Science and Engineering Progress*, vol. 12, no. 4, p. 223, 2019, doi: 10.14416/j.asep.2019.09.002.

[2] A. Sharma, Y. Munde, and V. Kushvaha, "Representative volume element based micromechanical modelling of rod shaped glass filled epoxy composites," *SN Applied Sciences*, vol. 3, no. 2, pp. 1–10, 2021.

[3] P. Kongkaoroptham, M. Boonpensin, T. Siripongsakul, and P. Promdirek, "Corrosion behaviour of AISI409 stainless steel with al slurry coating in molten salt," *Applied Science and Engineering Progress*, vol. 15, no. 1, 2022, Art. no. 3523, doi: 10.14416/j.asep.2021.02.002.

[4] S. M. Senthil and M. B. Kumar, "Effect of tool rotational speed and traverse speed on friction stir welding of 3D-printed polylactic acid material," *Applied Science and Engineering Progress*, vol. 15, no. 1, 2022, Art. no. 5403, doi: 10.14416/j.asep.2021.09.002.

[5] T. G. Y. Gowda, A. Vinod, P. Madhu, V. Kushvaha, S. M. Rangappa, and S. Siengchin, "A new study on flax-basalt-carbon fiber reinforced epoxy/bioepoxy hybrid composites," *Polymer Composites*, vol. 42, no. 4, pp. 1891–1900, 2021.

[6] S. Walzer, M. Liewald, N. Simon, J. Gibmeier, H. Erdle, and T. Böhlke, "Improvement of sheet metal properties by inducing residual stresses into sheet metal components by embossing and reforming," *Applied Science and Engineering Progress*, vol. 15, no. 1, 2022, Art. no. 5414, doi: 10.14416/j.asep.2021.09.006.

[7] S. Mahesh, M. Chandrasekar, R. Asokan, Y. C. Mouli, K. Sridhar, V. V. K. Vamsi, M. D. Varma, and P. S. Venkatanarayanan, "Influence of incident energy on sisal/epoxy composite subjected to low velocity impact and damage characterization using ultrasonic C-scan," *Applied Science and Engineering Progress*, vol. 15, no. 1, 2022, Art. no. 5220, doi: 10.14416/j.asep.2021.07.005.

[8] S. M. Rangappa, S. Siengchin, and H. N. Dhakal, "Green-composites: Ecofriendly and sustainability," *Applied Science and Engineering Progress*, vol. 13, no. 3, pp. 183–184, 2020, doi: 10.14416/j.asep.2020.06.001.

[9] M. Ramesh, L. Rajeshkumar, C. Deepa, M. T. Selvan, V. Kushvaha, and M. Asrofi, "Impact of silane treatment on characterization of ipomoea staphylina plant fiber reinforced epoxy composites," *Journal of Natural Fibers*, pp. 1–12, 2021, doi: 10.1080/15440478.2021.1902896.

[10] M. Puttegowda, H. Pulikkalparambil, and S. M. Rangappa, "Trends and developments in natural fiber composites," *Applied Science and Engineering Progress*, vol. 14, no. 4, pp. 543–552, 2021, doi: 10.14416/j.asep.2021.06.006.

[11] I. O. Oladele, T. F. Omotosho, G. S. Ogunwande, and F. A. Owa, "A review on the philosophies for the advancement of polymer-based composites: Past, present and future perspective," *Applied Science and Engineering Progress*, vol. 14, no. 4, pp. 553–579, 2021, doi: 10.14416/j.asep.2021.08.003.

[12] M. N. F. Norrrahim, R. A. Ilyas, N. M. Nurazzi, M. S. A. Rani, M. S. N. Atikah, and S. S. Shazleen, "Chemical pretreatment of lignocellulosic biomass for the production of bioproducts: An overview," *Applied Science and Engineering Progress*, vol. 14, no. 4, pp. 588–605, 2021, doi: 10.14416/j.asep.2021.07.004.

[13] V. Kushvaha, S. A. Kumar, P. Madhushri, and

A. Sharma, “Artificial neural network technique to predict dynamic fracture of particulate composite,” *Journal of Composite Materials*, vol. 54, no. 22, pp. 3099–3108, 2020.

[14] A. Dhandapani, S. Krishnasamy, T. Ungtrakul, S. M. K. Thiagamani, R. Nagarajan, C. Muthukumar, and G. Chinnachamy, “Desirability of tribo-performance of natural based thermoset and thermoplastic composites: A concise review,” *Applied Science and Engineering Progress*, vol. 14, no. 4, pp. 606–613, 2021, doi: 10.14416/j.asep.2021.07.001.

[15] B. D. S. Deeraj, K. Joseph, J. S. Jayan, and A. Saritha, “Dynamic mechanical performance of natural fiber reinforced composites: A brief review,” *Applied Science and Engineering Progress*, vol. 14, no. 4, pp. 614–623, 2021, doi: 10.14416/j.asep.2021.06.003.

[16] K. Setswalo, N. Molaletsa, O. P. Oladijo, E. T. Akinlabi, S. M. Rangappa, and S. Siengchin, “The influence of fiber processing and alkaline treatment on the properties of natural fiber-reinforced composites: A review,” *Applied Science and Engineering Progress*, vol. 14, no. 4, pp. 632–650, 2021, doi: 10.14416/j.asep.2021.08.005.

[17] B. R. Isanaka, M. A. Akbar, B. P. Mishra, and V. Kushvaha, “Free vibration analysis of thin plates: Bare versus stiffened,” *Engineering Research Express*, vol. 2, no. 1, 2020, Art. no. 015014.

[18] S. Chuayprakong, J. Chuchat, T. Poruksa, and M. Soccio, “Feasibility of using natural rubber (NR) latex foam as a soft robotic finger: Role of foaming agent in morphology and dynamic properties of NR latex foam,” *Applied Science and Engineering Progress*, vol. 14, no. 1, pp. 80–88, 2021, doi: 10.14416/j.asep.2020.12.004.

[19] M. Hemath, S. M. Rangappa, V. Kushvaha, H. N. Dhakal, and S. Siengchin, “A comprehensive review on mechanical, electromagnetic radiation shielding, and thermal conductivity of fibers/inorganic fillers reinforced hybrid polymer composites,” *Polymer Composites*, vol. 41, no. 10, pp. 3940–3965, 2020.

[20] A. Dogru, A. Sozen, G. Neser, and M. O. Seydibeyoglu, “Effects of aging and infill pattern on mechanical properties of hemp reinforced PLA composite produced by fused filament fabrication (FFF),” *Applied Science and Engineering Progress*, vol. 14, no. 4, pp. 651–660, 2021, doi: 10.14416/j.asep.2021.08.007.

[21] V. Dogra, C. Kishore, A. Verma, A. K. Rana, and A. Gaur, “Fabrication and experimental testing of hybrid composite material having biodegradable bagasse fiber in a modified epoxy resin: Evaluation of mechanical and morphological behavior,” *Applied Science and Engineering Progress*, vol. 14, no. 4, pp. 661–667, 2021, doi: 10.14416/j.asep.2021.06.002.

[22] A. Vinod, T. Y. Gowda, R. Vijay, S. M. Rangappa, M. K. Gupta, M. Jamil, and S. Siengchin, “Novel muntingia calabura bark fiber reinforced green-epoxy composite: A sustainable and green material for cleaner production,” *Journal of Cleaner Production*, vol. 294, 2021, Art. no. 126337.

[23] A. C. Özcan, K. Y. Şanlıtürk, G. Genc, and H. Körük, “Investigation of the sound absorption and transmission loss performances of green homogenous and hybrid luffa and jute fiber samples,” *Applied Science and Engineering Progress*, vol. 14, no. 4, pp. 668–679, 2021, doi: 10.14416/j.asep.2021.04.005.

[24] N. A. Nasimudeen, S. Karounamourthy, J. Selvarathinam, S. M. K. Thiagamani, H. Pulikkalparambil, S. Krishnasamy, and C. Muthukumar, “Mechanical, absorption and swelling properties of vinyl ester based natural fibre hybrid composites,” *Applied Science and Engineering Progress*, vol. 14, no. 4, pp. 680–688, 2021, doi: 10.14416/j.asep.2021.08.006.

[25] P. K. Saha, “Aluminum extrusion research opportunity for future development,” *Applied Science and Engineering Progress*, vol. 12, no. 1, pp. 1–2, 2019, doi : 10.14416/j.ijast.2019.01.008.

[26] M. E. Hoque, A. M. Rayhan, and S. I. Shaily, “Natural fiber-based green composites: Processing, properties and biomedical applications,” *Applied Science and Engineering Progress*, vol. 14, no. 4, pp. 689–718, 2021, doi: 10.14416/j.asep.2021.09.005.

[27] C. Santos, T. Santos, M. Aquino, and R. F. L. Zillio, “Statistical study of the influence of fiber content, fiber length and critical length in the mechanical behavior of polymeric composites reinforced with Carica Papaya Fibers (CPFs),” *Applied Science and Engineering Progress*, vol. 14, no. 4, pp. 719–726, 2021, doi: 10.14416/j.asep.2021.07.002.

[28] T. P. Sathishkumar, P. Navaneethakrishnan, and P. Maheskumar, "Thermal stability and tribological behaviors of tri-fillers reinforced epoxy hybrid composites," *Applied Science and Engineering Progress*, vol. 14, no. 4, pp. 727–737, 2021, doi: 10.14416/j.asep.2021.08.002.

[29] A. Sharma, V. C. Khan, G. Balaganesan, and V. Kushvaha, "Performance of nano-filler reinforced composite overwrap system to repair damaged pipelines subjected to quasi-static and impact loading," *Journal of Failure Analysis and Prevention*, vol. 20, no. 6, pp. 2017–2028, 2020.

[30] K. N. Bharath, P. Madhu, T. Y. Gowda, S. M. R. Rangappa, V. Kushvaha, and S. Siengchin, "Alkaline effect on characterization of discarded waste of *Moringa oleifera* fiber as a potential eco-friendly reinforcement for biocomposites," *Journal of Polymers and the Environment*, vol. 28, no. 11, pp. 2823–2836, 2020.

[31] A. Kengpol and C. Chanchittakarn, "The influence of vertical centrifugal casting on nickel aluminum bronze alloy for using in the Royal Thai Navy," *Applied Science and Engineering Progress*, vol. 14, no. 3, pp. 503–510, 10.14416/j.asep.2020.04.005.

[32] A. Sharma, S. A. Kumar, and V. Kushvaha, "Effect of aspect ratio on dynamic fracture toughness of particulate polymer composite using artificial neural network," *Engineering Fracture Mechanics*, vol. 228, 2020, Art. no.106907.

[33] P. E. Dim and M. Termtanun, "Treated clay mineral as adsorbent for the removal of heavy metals from aqueous solution," *Applied Science and Engineering Progress*, vol. 14, no. 3, pp. 511–524, 2021, doi: 10.14416/j.asep.2021.04.002.

[34] A. Sharma, P. Madhushri, V. Kushvaha, and A. Kumar, "Prediction of the fracture toughness of silicafilled epoxy composites using K-nearest neighbor (KNN) method," in *2020 International Conference on Computational Performance Evaluation (ComPE)*, Jul. 2020, pp. 194–198.

[35] A. Sharma and V. Kushvaha, "Predictive modelling of fracture behaviour in silica-filled polymer composite subjected to impact with varying loading rates using artificial neural network," *Engineering Fracture Mechanics*, vol. 239, 2020, Art. no.107328.

[36] V. Kushvaha, S. A Kumar, and P. Madhushri, "Dynamic fracture toughness index: A new integrated methodology for mode-I fracture behaviour of polymer composite under impact loading," *Materials Research Express*, vol. 6, no. 11, 2019, Art. no.115342.

[37] V. Kushvaha and H. Tippur, "Effect of filler shape, volume fraction and loading rate on dynamic fracture behavior of glass-filled epoxy," *Composites Part B: Engineering*, vol. 64, pp. 126–137, 2014.

[38] V. Kushvaha, A. Branch, and H. Tippur, "Effect of loading rate on dynamic fracture behavior of glass and carbon fiber modified epoxy," in *Dynamic Behavior of Materials, Volume 1*. Cham: Springer, 2014, pp. 169–176.

[39] V. Kushvaha and H. Tippur, "Effect of filler particle shape on dynamic fracture behavior of glass-filled epoxy," in *Dynamic Behavior of Materials, Volume 1.* New York: Springer, 2013, pp. 513–522.

[40] Z. Liu, J. Wang, V. Kushvaha, S. Poyraz, H. Tippur, S. Park, M. Kim, Y. Liu, J. Bar, H. Chen, and X. Zhang, "Poptube approach for ultrafast carbon nanotube growth," *Chemical Communications*, vol. 47, no. 35, pp. 9912–9914, 2011.

[41] P. Potejana and N. Seemuang, "Fabrication of metallic nano pillar arrays on substrate by sputter coating and direct imprinting processes," *Applied Science and Engineering Progress*, vol. 14, no. 1, pp. 72–79, 2021, doi: 10.14416/j.asep.2019.09.001.

[42] A. Sharma, T. Mukhopadhyay, S. M. Rangappa, S. Siengchin, and V. Kushvaha, "Advances in computational intelligence of polymer composite materials: Machine learning assisted modeling, analysis and design," *Archives of Computational Methods in Engineering*, 2022, doi: 10.1007/s11831-021-09700-9.

[43] K. Jayappa, V. Kumar, and G. G. Purushotham, "Effect of reinforcements on mechanical properties of nickel alloy hybrid metal matrix composites processed by sand mold technique," *Applied Science and Engineering Progress*, vol. 14, no. 1, pp. 44–51, 2021, doi: 10.14416/j.asep.2020.11.001.

[44] C. Tavichaiyuth, Y. Aue-u-Lan, and T. Hart-Rawung, "Evaluation of forging die defect by considering plastic deformation and abrasive wear in a hot forged axle shaft," *Applied Science and Engineering Progress*, vol. 14, no. 1, pp. 60–71, 2021, doi: 10.14416/j.asep.2020.12.005.

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