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Editorial

Application of Wood Composites III

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Composite wood materials, also known as engineered wood products, are fabricated from wood veneer, particles, strands, flakes, or fibers that are bonded together with synthetic or renewable, biobased adhesive systems and designed to meet a wide range of structural and non-structural applications [1–3]. A wide variety of engineered woods are frequently used in a variety of settings [4–7]. The use of wood-based composite technology to manufacture products with high added value and conventional building materials is widely accepted on a global scale. It allows the transformation of low-quality, small-diameter timber, agricultural biomass, and other lignocellulosic raw materials into products with added value, thus ensuring the resource efficiency of the wood-based composite industry and supporting its green transition [8–13]. In addition, engineered wood products are highly cost-competitive, making them a desirable product line [14,15]. However, despite their satisfactory performance, current wood composites have certain drawbacks, such as poor fire resistance, inferior structural performance, free formaldehyde emission, and a short service life that must be overcome to expand their applications [16–22].

Five high-quality research articles on this subject have been compiled for this Special Issue. These research articles present intriguing perspectives on expanding the use of wood composites in a variety of applications, as well as improving manufacturing performance and workplace safety in the woodworking and furniture industry.

Due to the rapid growth and abundance of bamboo, it could serve as a promising alternative to wood for composite manufacturing [4,23–25]. Bamboo is known for its viability in the manufacture of a variety of engineered wood products [26]. Although bamboo is a potential alternative to wood, the inferior stiffness and small culm diameter hamper its wider utilisation. Thus, to overcome these drawbacks, adhesive-bonded laminated bamboo is often produced from thin lamellae converted from bamboo culms [27,28].

In this Special Issue, Abidin et al. [29] examined the properties of layered laminated woven bamboo mat boards made from the *Gigantochloa scortechinii* species and bonded them with a phenol formaldehyde resin. The authors investigated how selected variables, such as resin content and pressure, influenced the mechanical and physical properties of laboratory-fabricated boards. The results demonstrated that the boards had excellent mechanical and physical properties, such as high strength and stiffness, as well as satisfactory resistance to water and fungal decay. The authors claimed that layered laminated woven bamboo mat boards bonded with phenol formaldehyde resin can be fabricated from local bamboo species. These boards have great potential in a wide variety of applications, particularly in construction and building materials.

However, one of the major drawbacks of wood and wood-based composites is their high flammability [30], which has restricted their use as construction and building materials.

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Therefore, it is essential to improve the flame retardancy of wood composites so that they can be used more widely in the construction industry [31–33]. As a result, the researchers used coatings and heat treatment, which have been reported in this Special Issue. Gapercová et al. [34] investigated the effect of fungicide coatings with added flame retardant HRP against exposure to a small ignition source. Six different fungicide coatings with various chemical components were used on the wooden samples. Based on the evaluation of final mass loss and flame spread, protective coatings effectively reduced flame spread. Furthermore, the ignition time was also reduced. One fungicide coating was found to be particularly effective. Thus, it was suggested that incorporating these protective coatings into building codes and regulations can reduce the risk of fire in wooden structures.

Mitrenga et al. [35] investigated the effect of thermal treatment on the fire-technical properties of Norway spruce (Picea abies) wood. The study also investigated the effects of thermal treatment on the combustion process and fire spread rate as a function of the side of spruce wood, either radial or tangential, as well as the density of the material. Untreated and thermally treated spruce wood was tested for mass loss, ignition time, and flame spread rate. The findings revealed that thermal treatment improved the flame retardancy of spruce wood. Furthermore, the exposure side of the wood samples, as well as their density, has a significant impact on their fire-technical properties. In addition, thermal treatment improves the fire-technical properties of wood. However, an optimization study of treatment procedures should be conducted in the future.

In the wood industry, particularly among manufacturers of furniture and construction joinery, the amount of wear that cutting tools sustain over their lifetime has important implications for both technology and cost [36–38]. Wilkowski and colleagues [39] performed ion implantation as part of their research on circular saw blades and wooden door frame production. There was a determination of how long ion-implanted saw blades would last and how quickly they would wear out. These ion-implanted blades have increased hardness and decreased friction compared to the blades that do not have ions implanted in them. As a result, the lifespan of ion-implanted blades was noticeably longer than that of unimplanted blades. In addition, the cutting performance of ion-implanted blades was significantly better than that of their counterparts. According to the findings of the study, ion implantation is a feasible method to enhance the performance of circular saw blades utilised in the woodworking industry.

Injury prevention in the woodworking industry is essential and closely related to the health and safety of the workplace [40–42]. In particular, the presence of wood dust is hazardous to the health of workers, necessitating a suitable filtration system [43,44]. Dembiski et al. [45] investigated the resistance of filter bags to the flow of air within a dust collector. The edge-banding production line for wood-based furniture panels incorporated the use of a dust collector as one of its components, and, the airflow rate and the pressure drop were measured at various stages. An analysis was performed to determine how the dust concentration and particle size influenced flow resistance. Flow resistance undoubtedly increased due to the inevitable accumulation of dust on the filter bags, which resulted in a reduction in both the rate of airflow and the effectiveness of dust collection. Therefore, it is recommended that the filter bags should be regularly cleaned and replaced as needed to maintain the performance of dust collectors, which will ultimately enhance workplace safety in the woodworking industry.

Wood composites are becoming increasingly popular for a wide variety of applications because they have several benefits that set them apart from other materials. Because of these benefits, people tend to look past the challenges faced by wood composites. In addition, it is anticipated that the use of wood composites in contemporary industries will expand even further in the near future due to the high demand for environmentally friendly, cost-effective, and versatile products. To summarize, wood composites are potentially useful materials for a wide range of applications. To ensure the material's long-term viability, more in-depth research that can broaden the applications of wood composites should be encouraged.

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References

1. Grebner, D.L.; Bettinger, P.; Siry, J.; Boston, K. Forest products. In *Introduction to Forestry and Natural Resources*, 2nd ed.; Grebner, D.L., Bettinger, P., Siry, J., Boston, K., Eds.; Academic Press: Cambridge, MA, USA, 2022; pp. 101–129.
2. Antov, P.; Lee, S.H.; Lubis, M.A.R.; Kristak, L.; Réh, R. Advanced Eco-Friendly Wood-Based Composites II. *Forests* **2023**, *14*, 826. [CrossRef]
3. Teischinger, A.; Muszynski, L.; Niemz, P.; Ross, R.J.; Sandberg, D. Glossary of Wood Science and Technology Terms. In *Springer Handbook of Wood Science and Technology*, 1st ed.; Niemz, P., Teischinger, A., Sandberg, D., Eds.; Springer: Cham, Switzerland, 2023; pp. 2005–2026.
4. Barbu, M.C.; Reh, R.; Irle, M. Wood-based composites. In *Research Developments in Wood Engineering and Technology*; Aguilera, A., Davim, J.P., Eds.; IGI Global: Hershey, PA, USA, 2014; Chapter 1; pp. 1–45.
5. Pizzi, A.; Papadopoulos, A.N.; Policardi, F. Wood composites and their polymer binders. *Polymers* **2020**, *12*, 1115. [CrossRef] [PubMed]
6. Lee, S.H.; Lum, W.C.; Antov, P.; Kristak, L.; Md Tahir, P. Engineering wood products from *Eucalyptus* spp. *Adv. Mater. Sci. Eng.* **2022**, *2002*, 8000780.
7. Sandberg, D.; Gorbacheva, G.; Lichtenegger, H.; Niemz, P.; Teischinger, A. Advanced Engineered Wood-Material Concepts. In *Springer Handbook of Wood Science and Technology*; Niemz, P., Teischinger, A., Sandberg, D., Eds.; Springer Handbooks; Springer: Cham, Switzerland, 2023; pp. 1835–1888.
8. Grigorov, R.; Mihajlova, J.; Savov, V. Physical and Mechanical Properties of Combined Wood-Bases Panels with Participation of Particles from Vine Sticks in Core Layer. *Innov. Wood. Ind. Eng. Des.* **2020**, *1*, 42–52.
9. Khalaf, Y.; El Hage, P.; Mihajlova, J.; Bergeret, A.; Lacroix, P.; El Hage, R. Influence of agricultural fibers size on mechanical and insulating properties of innovative chitosan-based insulators. *Constr. Build. Mater.* **2021**, *287*, 123071. [CrossRef]
10. Pędzik, M.; Kwidzínski, Z.; Rogozínski, T. Particles from Residue Wood-Based Materials from Door Production as an Alternative Raw Material for Production of Particleboard. *Drv. Ind.* **2022**, *73*, 351–357. [CrossRef]
11. Lee, S.H.; Lum, W.C.; Geng, B.J.; Kristak, L.; Antov, P.; Pędzik, M.; Rogoziński, T.; Taghiyari, H.R.; Lubis, M.A.R.; Fatriasari, W.; et al. Particleboard from agricultural biomass and recycled wood waste: A review. *J. Mater. Res. Technol.* **2022**, *20*, 4630–4658. [CrossRef]
12. Savov, V.; Antov, P.; Zhou, Y.; Bekhta, P. Eco-Friendly Wood Composites: Design, Characterization and Applications. *Polymers* **2023**, *15*, 892. [CrossRef]
13. Koynov, D.; Valyova, M.; Parzhov, E.; Lee, S.H. Utilization of Scots Pine (*Pinus sylvestris* L.) Timber with Defects in Production of Engineered Wood Products. *Drv. Ind.* **2023**, *74*, 71–79. [CrossRef]
14. Adhikari, S.; Quesada, H.; Bond, B.; Hammett, T. Potential of Hardwood Lumber in Cross Laminated Timber in North America: A CLT Manufacturer's Perspective. *Mass Timber Constr. J.* **2020**, *3*, 1–9.
15. Heräjärvi, H.; Jouhiaho, A.; Tammiruusu, V.; Verkasalo, E. Small-diameter Scots pine and birch timber as raw materials for engineered wood products. *Int. J. For. Eng.* **2004**, *15*, 23–34. [CrossRef]
16. Papadopoulos, A.N. Advances in Wood Composites III. *Polymers* **2021**, *13*, 163. [CrossRef]
17. Martinka, J.; Mantanis, G.I.; Lykidis, C.; Antov, P.; Rantuch, P. The effect of partial substitution of polyphosphates by aluminium hydroxide and borates on the technological and fire properties of medium density fibreboard. *Wood Mater. Sci. Eng.* **2021**, *17*, 720–726. [CrossRef]
18. Reh, R.; Kristak, L.; Antov, P. Advanced Eco-Friendly Wood-Based Composites. *Materials* **2022**, *15*, 8651. [CrossRef]
19. Savov, V. Nanomaterials to Improve Properties in Wood-Based Composite Panels. In *Emerging Nanomaterials*; Taghiyari, H.R., Morrell, J.J., Husen, A., Eds.; Springer: Cham, Switzerland, 2023; pp. 135–153.
20. Kristak, L.; Antov, P.; Bekhta, P.; Lubis, M.A.R.; Iswanto, A.H.; Reh, R.; Sedliacik, J.; Savov, V.; Taghiayri, H.; Papadopoulos, A.N.; et al. Recent Progress in Ultra-Low Formaldehyde Emitting Adhesive Systems and Formaldehyde Scavengers in Wood-Based Panels: A Review. *Wood Mater. Sci. Eng.* **2023**, *18*, 763–782. [CrossRef]
21. Kumar, C.; Leggate, W. An overview of bio-adhesives for engineered wood products. *Int. J. Adhes. Adhes.* **2022**, *118*, 103187. [CrossRef]
22. Lykidis, C. Formaldehyde Emissions from Wood-Based Composites: Effects of Nanomaterials. In *Emerging Nanomaterials*; Taghiyari, H.R., Morrell, J.J., Husen, A., Eds.; Springer: Cham, Switzerland, 2023; pp. 337–360.
23. Irle, M.A.; Barbu, M.C.; Réh, R.; Bergland, L.; Rowell, R.M. Wood Composites. In *Handbook of Wood Chemistry and Wood Composites*; CRC Press: Boca Raton, FL, USA, 2012.

24. Sihag, K.; Yadav, S.M.; Lubis, M.A.R.; Poonia, P.K.; Negi, A.; Khali, D.P. Influence of needle-punching treatment and pressure on selected properties of medium density fiberboard made of bamboo (*Dendrocalamus strictus* Roxb. Nees). *Wood Mater. Sci. Eng.* **2022**, *17*, 712–719. [CrossRef]
25. Nkeuwa, W.N.; Zhang, J.; Semple, K.E.; Chen, M.; Xia, Y.; Dai, C. Bamboo-based composites: A review on fundamentals and processes of bamboo bonding. *Compos. Part B Eng.* **2022**, *235*, 109776. [CrossRef]
26. Yadav, M.; Mathur, A. Bamboo as a sustainable material in the construction industry: An overview. *Mater. Today Proc.* **2021**, *43*, 2872–2876. [CrossRef]
27. Li, H.T.; Zhang, Q.S.; Huang, D.S.; Deeks, A.J. Compressive performance of laminated bamboo. *Compos. Part B Eng.* **2013**, *54*, 319–328. [CrossRef]
28. Xing, W.; Hao, J.; Sikora, K.S. Shear performance of adhesive bonding of cross-laminated bamboo. *J. Mater. Civ. Eng.* **2019**, *31*, 04019201. [CrossRef]
29. Abidin, W.N.S.N.Z.; Al-Edrus, S.S.O.; Hua, L.S.; Ghani, M.A.A.; Bakar, B.F.A.; Ishak, R.; Hiziroglu, S. Properties of Phenol Formaldehyde-Bonded Layered Laminated Woven Bamboo Mat Boards Made from *Gigantochloa scortechinii*. *Appl. Sci.* **2022**, *13*, 47. [CrossRef]
30. Renner, J.S.; Mensah, R.A.; Jiang, L.; Xu, Q.; Das, O.; Berto, F. Fire behavior of wood-based composite materials. *Polymers* **2021**, *13*, 4352. [CrossRef] [PubMed]
31. Taib, M.N.A.M.; Antov, P.; Savov, V.; Fatriasari, W.; Madyaratri, E.W.; Wirawan, R.; Makovická Osvaldová, L.; Hua, L.S.; Ghani, M.A.A.; Al Edrus, S.S.A.O.; et al. Current progress of biopolymer-based flame retardant. *Polym. Degrad. Stabil.* **2022**, *205*, 110153. [CrossRef]
32. Lian, M.; Huang, Y.; Liu, Y.; Jiang, D.; Wu, Z.; Li, B.; Xu, Q.; Murugadoss, V.; Jiang, Q.; Huang, M.; et al. An overview of regenerable wood-based composites: Preparation and applications for flame retardancy, enhanced mechanical properties, biomimicry, and transparency energy saving. *Adv. Compos. Hybrid Mater.* **2022**, *5*, 1612–1657. [CrossRef]
33. Marková, I.; Ivaničová, M.; Osvaldová, L.M.; Harangózo, J.; Tureková, I. Ignition of Wood-Based Boards by Radiant Heat. *Forests* **2022**, *13*, 1738. [CrossRef]
34. Gašpercová, S.; Marková, I.; Vandlíčková, M.; Osvaldová, L.M.; Svetlík, J. Effect of Protective Coatings on Wooden Elements Exposed to a Small Ignition Initiator. *Appl. Sci.* **2023**, *13*, 3371. [CrossRef]
35. Mitrenga, P.; Vandlíčková, M.; Konárik, M.; Košútová, K. Impact of Heat Treatment of Spruce Wood on Its Fire-Technical Characteristics Based on Density and the Side Exposed to Fire. *Appl. Sci.* **2022**, *12*, 6452. [CrossRef]
36. Atanasov, V.; Kovatchev, G.; Todorov, T. Study of the influence of basic process parameters on the roughness of surfaces during wood milling. In Proceedings of the 10th Hardwood Conference, Sopron, Hungary, 12–14 October 2022; pp. 242–250.
37. Kminiak, R.; Němec, M.; Igaz, R.; Gejdoš, M. Advisability-Selected Parameters of Woodworking with a CNC Machine as a Tool for Adaptive Control of the Cutting Process. *Forests* **2023**, *14*, 173. [CrossRef]
38. Hortobágyi, Á.; Koleda, P.; Koleda, P.; Kminiak, R. Effect of Milling Parameters on Amplitude Spectrum of Vibrations during Milling Materials Based on Wood. *Appl. Sci.* **2023**, *13*, 5061. [CrossRef]
39. Wilkowski, J.; Barlak, M.; Kwidziński, Z.; Wilczyński, A.; Filipczuk, P.; Pędzik, M.; Drewczyński, M.; Zagórski, J.; Staszkiewicz, B.; Rogoziński, T. Influence of ion implantation on the wear and lifetime of circular saw blades in industrial production of wooden door frames. *Appl. Sci.* **2022**, *12*, 10211. [CrossRef]
40. Antov, P.; Neykov, N.; Savov, V. Effect of Occupational Safety and Health Risk Management on the Rate of Work–Related Accidents in the Bulgarian Furniture Industry. *Wood Des. Technol.* **2018**, *7*, 1–9.
41. Girma, B.; Ejeso, A.; Ashuro, Z.; Birhanie Aregu, M. Occupational Injuries and Associated Factors Among Small-Scale Woodwork Industry Workers in Hawassa, Southern Ethiopia: A Cross-Sectional Study. *Environ. Health Insights* **2022**, *16*, 11786302221080829. [CrossRef]
42. Júda, M.; Sydor, M.; Rogoziński, T.; Kučerka, M.; Pędzik, M.; Kminiak, R. Effect of Low-Thermal Treatment on the Particle Size Distribution in Wood Dust after Milling. *Polymers* **2023**, *15*, 1059. [CrossRef] [PubMed]
43. Kminiak, R.; Kučerka, M.; Kristak, L.; Reh, R.; Antov, P.; Očkajová, A.; Rogoziński, T.; Pędzik, M. Granulometric Characterization of Wood Dust Emission from CNC Machining of Natural Wood and Medium Density Fiberboard. *Forests* **2021**, *12*, 1039. [CrossRef]
44. Dembiński, C.; Potok, Z.; Kučerka, M.; Kminiak, R.; Očkajová, A.; Rogoziński, T. The Flow Resistance of the Filter Bags in the Dust Collector Operating in the Line of Wood-Based Furniture Panels Edge Banding. *Appl. Sci.* **2022**, *12*, 5580. [CrossRef]
45. Dembiński, C.; Potok, Z.; Kučerka, M.; Kminiak, R.; Očkajová, A.; Rogoziński, T. The Dust Separation Efficiency of Filter Bags Used in the Wood-Based Panels Furniture Factory. *Materials* **2022**, *15*, 3232. [CrossRef] [PubMed]