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The Role of Sustainable Green Composites in the Aviation Sector

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Keywords: Green composite, Sustainability, Recyclability, Aviation sector

Abstract

In recent times, significant progress has been made in the use of materials derived from renewable sources due to reasons such as global warming, environmental pollution, and the likelihood of depletion of petroleum. Particularly in high-tech industries such as aviation and aerospace, the need for new and innovative materials is steadily increasing. As a result of the traditional materials proving to be inadequate, the use of alternative materials has become inevitable. In this context, green composites offer advantages such as low density, biodegradability, easy accessibility, cost-effectiveness, good thermal and sound insulation, recyclability, environmental friendliness, biocompatibility, and renewability compared to glass, carbon, and other synthetic fiber-reinforced composites. The use of green composites in the aviation industry can contribute to achieving goals such as fuel efficiency, recyclability, and reduction of carbon footprint. In conclusion, green composites represent the next generation of sustainable lightweight and strong composite materials. They are considered a viable alternative to the composites currently used in the aviation sector. However, further research and development efforts are needed for their widespread commercial use. This study aims to provide a general assessment of the present and future of sustainable green composites in the aviation industry, offering a fundamental resource on this subject.

1. Introduction

In recent years, global warming, environmental pollution, and the depletion of petroleum resources have made the use of renewable sources imperative. The production of green composites from natural materials has led to a significant reduction in carbon footprint and greenhouse gas emissions throughout their lifecycle, from production to end of use. Green composites, due to their sustainability, biodegradability, high specific strength, and high specific elastic modulus, present a compelling alternative to traditional composites used in construction, aerospace, automotive, sports, packaging, and similar fields. Especially in high-tech industries like aerospace and space, there is a growing need for new and innovative materials. Green composite materials, which are constantly evolving and changing, offer many advantages such as reducing costs and enhancing product efficiency and quality. The use of green composites produced from natural resources in the aviation sector brings about cost reduction, lightweight construction, and fuel savings. However, alongside these benefits, various factors such as human health, environmental impacts, and supply constraints can influence engineering processes. Therefore, engineers continue to develop new designs, methods, and materials to adapt to these constraining factors. Particularly in this process, the use of green composites significantly reduces CO_2 emissions by decreasing fuel consumption in vehicles. Due to their environmentally friendly, cost-effective, and easily manufacturable, green composites can be considered as an alternative option for ensuring sustainability in the aviation industry. As a result of their developed features, green composites are envisioned to be preferred popular products in the aviation, defense, and automotive sectors [1–4].

2. Green Composite Materials in the Aviation Industry

The increasing occurrence of environmental disasters and global warming is pushing governments to take a role in promoting the use of green, eco-friendly materials. Therefore, the development and industrial utilization of biodegradable composite materials, known as green composites, are within the scope of interest for both researchers and industrial organizations. These fibers offer significant advantages such as low greenhouse gas emissions, low toxic gas emissions, low acquisition costs, and reduced dependence on petroleum. Green composites, due to their self-renewability, sustainability, low density, and high specific strengths, are being used as alternatives to petroleum-derived materials in many parts of the aviation sector. Natural plant-based fibers are typically used as reinforcement elements within polymer matrices in the production of durable composite materials. Animal-derived fibers, mainly composed of protein, have lower strengths compared to mineral and plant-derived reinforcement elements. Although synthetic fibers and petroleum-derived polymers have found widespread use in engineering applications, they pose significant environmental hazards. Composites produced from non-renewable sources generate large amounts of waste at the end of their lifespan and require a long time to completely degrade. In recent years, efforts to replace synthetic materials with natural ones have increased to reduce costs, CO_2 emissions, and petroleum dependence [5–7].

Increasing environmental issues and the simultaneous need for versatile polymer-based materials have heightened interest in composites produced with natural-organic matrix materials (materials derived from renewable sources and biologically degradable). Green composites are typically preferred not only for interior but also for structural components in aircraft as lightweight and durable biocomposites. Green composites are a subclass of composite materials where both the reinforcement element and the polymer come from natural or recycled sources. The proportions of materials used in the Boeing 787 aircraft are shown in Figure 1. The usage rate of composite materials is significantly higher than that of all other materials. With the use of green composites, it may be possible to make the aviation sector more fuel-efficient and environmentally friendly, thus paving the way for the adoption of new-generation sustainable composite materials [8,9].

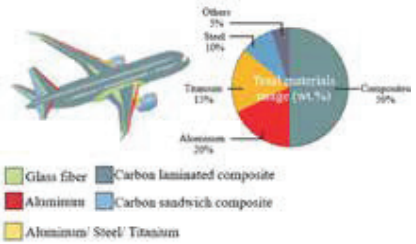

Figure 1. Distribution of materials that make up the Boeing-787 aircraft [3].

3. Recycling and Waste Management

Faced with the threats posed by global warming and climate change, transitioning to low-carbon economies has become a necessity. In this context, the concept of "carbon footprint," which expresses the total amount of greenhouse gases emitted into the atmosphere by human activities in terms of carbon dioxide equivalent, has emerged to mitigate greenhouse gas emissions and compensate for environmental damage [10]. Green composites are preferred over petroleum-derived polymers due to their environmental impact, low greenhouse gas emissions, biodegradability, lack of health risks, and absence of waste problems. Poly(lactic acid) (PLA), derived from renewable sources, is a thermoplastic biopolymer commonly used as an alternative to petroleum-derived polymers. Thermoplastic composites play an important role in the aviation sector due to their recyclability [11]. In the aviation industry, a significant amount of waste is generated annually. Therefore, the use of recyclable thermoplastic composites offers a solution to the composite waste problem. Thermoplastic composites can be reshaped and recycled through various processes. These features represent an important step in sustainability, aiming to reduce environmental impacts by minimizing barriers to recycling in the aviation industry. Due to the significant role of thermoplastic composites in the aviation industry, numerous projects and research initiatives are currently underway. One of these is the Clean Sky-ECOTECH project, which aims to clean up the aviation sector by recycling composite materials and producing fewer greenhouse gas emissions [12]. Figure 2 shows a graph comparing the carbon footprint of virgin and recycled thermoplastic materials.

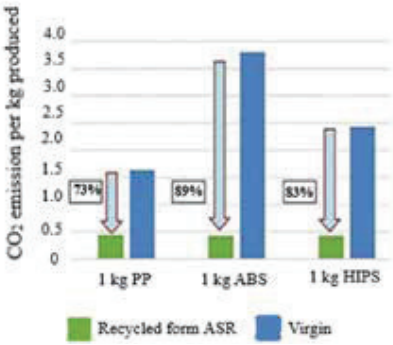

Figure 2. Carbon footprint comparison of virgin and recycled thermoplastic composite materials [12].

4. Sustainability of Composite Materials in the Aviation Sector

Green composites, biodegradability, easy accessibility, low density, affordability, good thermal and acoustic insulation, eco-friendliness, recyclability, biocompatibility, and renewability, among other features, making them an attractive alternative to glass, carbon, and other synthetic fiber-reinforced composites. The use of green composites in aircraft components plays a significant role in achieving goals related to fuel savings, recyclability, and reducing CO_2 footprint. One important issue for the aviation sector is the disposal of end-of-life vehicles, and the recyclability of scraps after vehicle dismantling. The use of green composites will meet ecological and recyclability principles by employing much lower amounts of natural fibers and biomatrices compared to synthetic or glass-reinforced composites. In the 2015 Paris Agreement, countries worldwide committed to reducing CO_2 emissions. Undoubtedly, one of the ways to achieve this is by further popularizing green materials in industrial applications. In today's world, facing global warming, environmental pollution, and the possibility of petroleum depletion, the inevitable use of environmentally friendly alternative materials derived from sustainable sources, with low CO_2 footprints and recyclability, is imperative [5,13]. In this study, the role of green composites in the aerospace industry and current developments were discussed. Emphasis is placed on the importance of new and innovative materials in leading the aviation industry towards sustainable resources and a responsible production model.

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Wear Resistance of Cu/WC/Gr Hybrid Composites Prepared by Powder Metallurgy

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Keywords: composite, wear, copper, WC, graphite

Abstract

The article discusses the effect of different WC contents of Cu/WC/Gr on sintered material's microstructure, density, hardness, and wear. The matrix structure was used to obtain the copper powder (44 µm) with 1 wt% Gr solid lubricant. WC with a particle size of 3 microns was added to the matrix powder mixture. The composite samples were produced by the conventional powder metallurgy method. The wear resistance test was performed using a reciprocating ball-on-disk tribometer under a normal load of 20 N with a total sliding distance of 100 m.

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1. Introduction

Copper-based composites, often alloyed with other materials or reinforced with various additives, exhibit a range of unique properties that make them highly valuable in diverse applications. These composites leverage the inherent conductivity, malleability, and corrosion resistance of copper while enhancing specific characteristics for targeted uses. One notable application of copper-based composites is in electrical components. The excellent electrical conductivity of copper, combined with the enhanced mechanical properties conferred by reinforcements like graphene, carbon fibers, or ceramics, results in high-performance conductive materials.

2. Materials and Methods

The matrix structure was used to obtain the copper powder (44 µm) with 1 wt% Gr solid lubricant. WC with a particle size of 3 microns was added to the matrix powder mixture at 1, 2, 4, and 8 wt% then mixed in a triaxial mixer for 30 min. The powder mixtures were uniaxially pressed under a pressure of 600 MPa to produce 14 mm diameter composite samples. The green compact samples were then sintered at 850 °C for 1 h in argon. The wear resistance test was performed using a reciprocating ball-on-disk tribometer under a normal load of 20 N with a total sliding distance of 100 m.

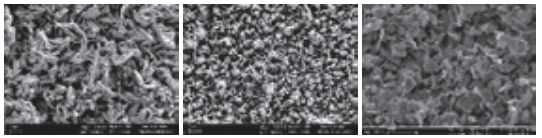

Figure 1. SEM images of Copper, WC, and Graphite powders.

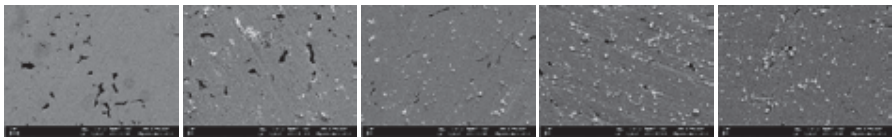

Figure 2. SEM images of the microstructures of Cu/Gr and Cu/Gr/WC (1, 2, 4, and 8 wt.%) composites respectively.

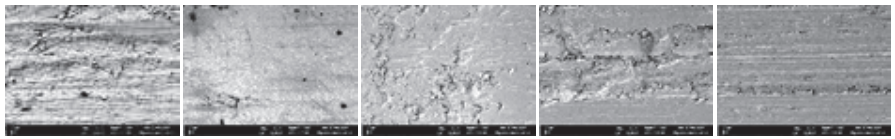

Figure 3. SEM images of the worn surfaces of Cu/Gr and Cu/Gr/WC (1, 2, 4, and 8 wt.%) composites respectively.

3. Conclusion

It was found that the pores in the microstructure decreased in Cu/Gr/WC composites due to the increase in WC reinforcement ratio. The hardness increase caused by the hard phase added to the matrix resulted in a significant increase in the wear resistance of the composites.