Composite Materials and Environmentally Friendly Alternatives for Use in Aircraft Applications, Including Furniture

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In this study, the importance of the materials and designs used in aircraft furniture is considered, and products are recommended for material selection for sustainable aircraft interiors. The type of composite material produced from waste paper, a type of material that has never been used in aircraft before, has potential as a material choice that can be used in the aviation industry in terms of its contribution to recycling, cost, lightness, and water resistance. Conditions such as flammability, durability, compatibility with other materials and lightness of the materials used in aircraft equipment are important, and some alternative material options have been evaluated.

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INTRODUCTION

In order to meet the need for wood materials, new wood-based, alternative, and recyclable raw materials have emerged. Composite materials created by combining different materials are becoming increasingly important. Composite materials with different physical and chemical properties are created by combining two or more micro or macro components (Erol 2007). They have advantages such as flexibility, lightness, high fatigue capacity, resistance to impact and moisture, easy transformation into the desired form, easy processing, and easy recycling (Arslan and Kaman 2002).

Because of their low density, composite materials provide speed in vehicles and ease of transportation and mobility in military equipment. With developing technology, high-tech composites will become a preferred material in unmanned aerial vehicles, liquid armor on landing and take-off runways (Eker and Eryıldız 2015).

Recently, composite materials have been used in the aircraft industry at a proportion of approximately 30%. Boron-epoxy, graphite-epoxy, carbon-epoxy, nickel-aluminum based composites are examples used in the aircraft industry. Composite materials are seen as a unique solution to meet the material needs of developing technology (Erbay 2009).

The goal of composite materials is to improve the known properties of traditional materials in the desired direction. Honeycomb sandwich composites consist of core structures created by repeating regular hexagonal cells inspired by the honeycomb structure produced by bees and the surface layer joined to them. They are the preferred materials when resistance to corrosion, high strength, and lightness are required (Kurt 2021). Composites vary depending on matrix and reinforcement element types.

The materials used in aircraft must have low weight and high strength. For this reason, composites are among the most widely used materials. Honeycomb sandwich materials, among the composite material types, are the most commonly used materials in cabin kitchen equipment (Önüt 2016).

This study aims to bring a different perspective to the limited variety of materials used in aircraft furniture and show that other, more economical and environmentally friendly composites can also be used.

AIRCRAFT INTERIOR FURNITURE AND COMPOSITE MATERIALS USED

Aircraft interior components, furniture, seating and walls, are mainly composed of composite structures. They are covered with different materials such as wood, paint, synthetic laminates, fabric, and leather.

Honeycomb sandwich panels on ceilings, walls, and furniture (cabinets, doors and partitions). Glass or aluminum reinforced, honeycomb structured aramid fiber paper and fiber paper core panels are being used. Again, wood veneers and hard woods coated with polyurethane, polyester or acrylic lacquers, high-pressure laminates (decorative paper processed with melanin resin on kraft paper layers impregnated with phenolic resin) are used in furniture.

Although the importance of environmentally friendly design and materials is known, systematic studies on these materials and methodologies to support aircraft product development remain lacking. Honeycomb sandwich panels are generally used by aircraft interior manufacturers. These are also essential for the functional performance of furniture pieces (Santos *et al.* 2016).

Fig. 1. Sink equipment, kitchen, overhead cabinets, and seats (TCI Aircraft Interiors 2016)

Fig. 2. In-flight kitchen bar design (Hexagonstudio 2024)

In-flight equipment, ovens, and luggage racks are exposed to high loads due to their weight. Additionally, the addition of emergency loads that occur under flight conditions requires that the materials used here have properties such as light weight, high strength, and non-flammability (Petras 1998).

TCI Cabin Interior Systems Inc. established in 2010 with the partnership of Turkish Airlines, Turkish Airlines Technical Inc. and Turkish Aerospace Industry companies successfully carries out the production and design activities of kitchen equipment and cabinets of narrow and wide body aircraft. The most commonly used in-flight cabin equipment are overhead cabinets, sink systems, kitchen equipment, cabinets, and seats. Examples of these are shown in Fig. 1 (TCI Aircraft Interiors 2016). The in-flight galley bar design is shown in Fig. 2. Using composite materials in the aviation industry provides a great advantage in terms of lightness. The vast majority of aircraft built during the Second World war had fabric-covered wooden structures. The most important issue facing aircraft designers was weight efficiency. In terms of ultimate tensile strength, the best woods, especially spruce, had weight efficiency superior to all but the strongest specialty steels. At the same time, manufacturers who support metal construction have admitted that metal wings are heavier than wooden wings (Schatzberg 2004).

Nomex Honeycomb is a high-temperature resistant material made of phenolic aramid papers, the most widely used among non-metallic core (intermediate) materials, especially in advanced composite applications such as aerospace (Kompozitnet 2024).

Honeycomb composites consist of two thin, hard, strong layers at the bottom and top that will meet the initial load to be applied to the material, a thicker and lower density main structure and an adhesive layer between these two structures (Rupani *et al.* 2017). Honeycomb composite material layers are shown in Fig. 3.

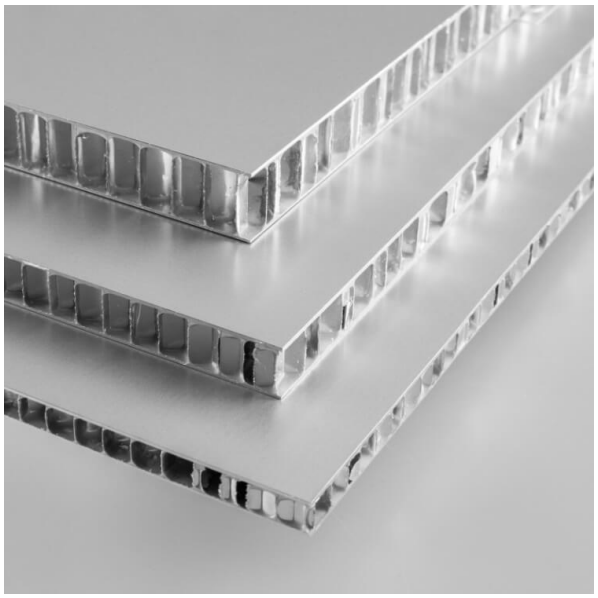

Fig. 3. Honeycomb composite material layers (Arrow Dragon Metal Products co., Ltd. 2024)

The surface layer in honeycomb composite materials may contain aluminum and other components such as carbon/epoxy or aramid/epoxy. In their core structures, titanium alloys are widely used in aviation due to their good corrosion resistance and high damage resistance In addition, aluminum alloy foils with the highest strength/weight ratio are preferred for the core part (Kurt 2021).

Honeycomb sandwich structures are primarily used in civil and military aircraft due to their high rigidity and lightness. Honeycomb sandwich is preferred on many aircraft parts, floors, and door construction, including the civil aircraft industry. Honeycomb structure composites are more expensive than other sandwich construction materials because they require precise workmanship. For this reason, honeycomb composite panels are mostly used in the aircraft, mega yacht, boat, ship and special furniture industry to produce panels of different shapes with the help of oval molds, taking advantage of their lightness and elasticity. In addition, they are preferred for mechanical strength and resistance to moisture (Güler and Ulay 2009).

The average bending strength and density of composites produced from Tetrapak waste papers are 11.7 N/mm^2 and 0.60 g/cm^3, respectively. Tetrapak material, which contains cardboard, polymers and aluminum, is cut into small pieces and combined with the help of binding chemicals and transformed into composite panels under temperature and pressure. These composites are also resistant to pests such as fungi and insects (Bülbül 2018). They can be preferred in in-flight equipment that requires resistance to moisture and where metal parts add unnecessary weight. Waste paper composite sample panels are shown in Fig. 4.

The density value of carbon fiber composites, which are frequently preferred in the aviation industry, is 1.86 g/cm^3 (Lecture Notes, 2024), while the density value of honeycomb sandwich composites shows the lightest value with 0.043 g/cm^3. The bending strengths of carbon fiber composites are approximately 490 N/mm^2 (Karol 2017). Flexural strength of Honeycomb-honeycomb Sandwich Composites is approximately 13.8 N/mm^2 (Güler and Ulay 2009). The densities and bending strengths of these materials are given in Table 1.

Fig. 4. Waste Tetra Pak composites

Table 1. Composite Types and Some of their Features

Composite Types	Average Density (g/cm^3)	Bending Strength MOR (N/mm^2)
Honeycomb Sandwich Composite	0.043	13.77
Carbon Fiber Composite	1.86	490
Waste Paper Composite (Tetra Pak)	0.60	11.73

In addition to the values shown above, the density value of aluminum is 2.7 g/cm^3 (selcuklukonalsan.com.tr, 2024). In this case, composite materials produced from waste paper can be considered a good alternative in place of aluminum sheets for usage in aircraft. A plywood-covered wooden aircraft called Beech AT-10 was produced by the Beech Aircraft company (Rawdon 1945). Since 1952, graphite epoxy, carbon epoxy, and boron epoxy-based composites have been introduced to the market and have been widely used in radomes, propellers, floor coverings, doors, tail, wings, and main body structure. The use of advanced composite materials in commercial aircraft gives rise to the expectation of significant cost reduction due to reduced structural weight (Ercan 2006). Table 1 shows that MORs of carbon fiber composites used in the wing, body, and tail areas of aircraft need to be higher than other materials. However, in this article, it is predicted that recycling-friendly waste paper composites (WPC) can be preferred in aircraft interior furniture, such as kitchen furniture and cabinets, where their low density can be regarded as an asset. Such items are not subjected to high loadings and do not require high resistance to bending. When coating is applied on the WPC, its moisture and mechanical resistance will also increase. In addition, the energy consumed for carbon fiber production is higher than for WPC materials.

The most important factor affecting the cost of carbon fiber is high raw material prices. It also aims to reduce production costs and develop environmentally friendly technologies. Therefore, the targeted priority to reduce the cost of carbon fiber production should be to reduce raw material prices. The search for cheap and environmentally friendly raw materials for carbon fiber continues (Özsin and Pütün 2018). On the other hand, raw materials for WPC materials are constantly available as waste all over the world.

An example of a cabin designed with the concept of future customers and their needs and inspired by bionic principles is shown in Fig. 5 (Hall *et al.* 2013).

Weight is one of the most important features in an aircraft. Since it affects fuel consumption while the aircraft is in motion, it means more resources are used and more pollution (airbus.com, 2024).

Fig. 5. Future cabin design

CONCLUSIONS

1. Composites that incorporate either waste paper or wood materials can be regarded as favorable for certain applications in aircraft, including the furniture. Their usage can offer cost-reductions and an environmentally friendly approach. Innovative and easily recyclable aircraft interior designs can offer a competitive approach in aviation in today's world.
2. The use of coatings that improve cabin air quality and reduce the spread of harmful components is preferred for environmentally friendly designs.
3. In the aviation industry since 2006, programs focusing on aircraft recycling are being carried out. Composite materials produced from waste paper also become moisture resistant thanks to the added water-repellent chemicals. Thanks to the coatings on them, they can be preferred on the covers of aircraft galleys.
4. Today, patented solutions are available in the form of using natural fibers (coconut fiber, castor, *etc*.) instead of glass fiber reinforced panels (Chandler *et al.* 2010). Since the use of composite materials constitutes an important criterion for aviation in terms of cost and performance, it can also be preferred in unmanned aerial vehicles.
5. In 2022, 1,200,000 tons of Tetrapak waste were collected under the responsibility of recycling (Tetrapak.com, 2024). These materials, which contain aluminum and plastic, can be an environmentally friendly alternative to other composite materials used in aviation with their lightness and mechanical resistance.
6. Waste paper composite materials also resist corrosion. Thus, they can be used as trendy materials in aircraft furniture.
7. Balsa wood, which is famous for its lightness, can be preferred for both veneer and

honeycomb composite materials.

8. Considering the resistance properties of honeycomb composites, WPC materials in the form of honeycomb structures can sometimes be preferred in the aviation industry.

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