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Composites: A Recurrent and Simuttaneously Current Innovation in the Aeronautics and Automobiles Sectors

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Abstract

Composite materials are the union of two (or more) materials in order to optimize and combine the best characteristics of both, offering superior properties to the remaining components, having versatility, lightness and performance, which boosted their use in the aeronautical and automakers, which in turn have always been synonymous with progress and innovations in various technological fields. In this sense, regarding the materials segment, this work aims to present a brief discussion on the importance of composites and their application in the mentioned industries. Therefore, a bibliographic review was conducted in books, articles and other academic works relevant to the subject. It was found that, in contrast to traditional metallic materials, composites currently account for more than 50% of the weight of modern aircraft, reflecting positively on the aircraft's efficiency, cost, efficiency and greater flight autonomy. Also, when evaluating the Advances of Appliance of Composites in the Automotive Sector, Modern Applications stand out mainly for ballistic and collision protection purposes, referring to alumina dispersed in LDP and tempered laminates of polymer matrix, respectively.

Keywords: composites; aeronautics; automaker; laminated design; polymer.

1. Introduction

Since the dawn of civilizations, longings for efficient, fast, safe means of transport that allow displacements with greater flows of inputs, food, people and materials over short periods of time have come together.

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Even before modern technologies such as automobiles and planes, when horses, other animals in general and wooden vessels were used for transport, ideas of progress and technological, military and economic vanguards were already suggested [1].

Therefore, since the creation of the first vehicle (fardier à vapeur), it was noticed that some factors were impeding its use on a large scale and functionality, judging by the low speeds and high weights of these means of transport. Thus, the incorporation of smaller and more powerful engines has brought considerable advances to the automotive sector (such as reaching current speeds of up to 1227,985 km/h with the Thrust SSC vehicle), it is noteworthy that such improvements have only become possible through development and use of better construction materials, including: composites, making progress in the military, automotive and aviation areas [2, 3].

In summary, composites are materials joined by two (or more) components with different properties. In this sense, these have their microstructure formed by a combination of the best characteristics of a matrix and a reinforcement (Figure 1). The first (of polymeric, ceramic and/or metallic origin) appears to support the second (which in turn may have a particulate or fibrous nature), as well as ensuring its correct positioning, a bulkhead for the corrosion of the composite, promoting a better distribution of forces between the reinforcement, in addition to optimizing the behavior of the material to shear [4].

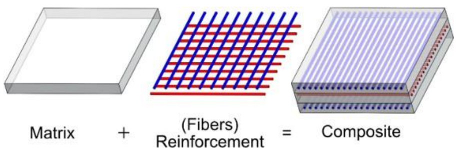

Figure 1: Scheme of formation of composites. Source: Adapted from [5].

It is noteworthy that there are also natural composites (such as bone and wood), but most of them occur by synthesis, where the choice of matrix is closely linked to the application that the composite will have [4], [5]. Therefore, considering that in composite materials, one of the constituents guarantees the bond (matrix) and the other the resistance (reinforcement), this is subdivided into several classifications, as well as shown by the map shown in Figure 2 [6].

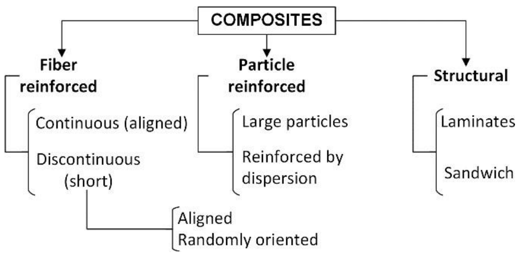

Figure 2: Classification of composites. Source: Adapted from [6].

Furthermore, in terms of an alternative classification of composites, this can be done as a function of their matrix, taking into account the division of solid materials into four groups: polymeric matrix composites (PMC);

metal matrix composites (MMC); carbon matrix composites (CACM) and ceramic matrix composites (CMC) [7].

Above all, it was with the intensification of post-World War II technology and industry, more precisely after the 1960s, that high-performance composite materials gained visibility (with their lightness, fatigue resistance, rigidity, and corrosion resistance) against metallic materials in the aeronautical and automobile industries, both due to the lighter weight and the versatility in the production of their parts, offering designers greater flexibility in their structural projects and still meeting the requirements of performance in flights and in vehicles used for re-entry [8,9].

In this context, this work aims to develop a brief discussion about the notoriety of composite materials and their applications in the aeronautical and automobile industries, as well as to relate the advances in the structure and performance sector.

2. Methodologie

For the elaboration of this work, a literature review was carried out, concentrated in books, articles and other academic works whose main theme was the use of composites in the aeronautical and automobile industries. The search keywords used were “composites”, “automobile industry” and “aeronautical industry”.

The search period was restricted between 1995 and 2021 and the search bases were: Scopus, Springer, American Society of Metals (ASM), Science Direct, Google Scholar, Capes Periodicals and Brazilian Digital Library of Theses and Dissertations (BDTD). Thus, researches related to composites applied to the automotive and aeronautical sectors were chosen for the study, as well as those that demonstrate a prospect for new solutions (innovations) and a summary of the advances made in recent years in these two production sectors.

3. Results and discussions

3.1 Notoriety of Composites

The use of composites dates back to the prehistoric period, when clay was joined to dry grass, aiming at producing bricks with greater strength. Similarly, in the area of metallurgy, the junction of copper and tin produced bronze (high compressive strength) [5].

Furthermore, with the demands in the industrial sectors, as well as the aeronautics, they needed new materials that were lighter and at the same time, durable, with good performance, versatile, with greater flexibility and low cost, the notoriety in the application of composites to meet such needs, with significant evolution in the mid-1960s, by the military sector after the result of the intense search for innovations and technologies during the space race period (Figure 3) [5,10,11].

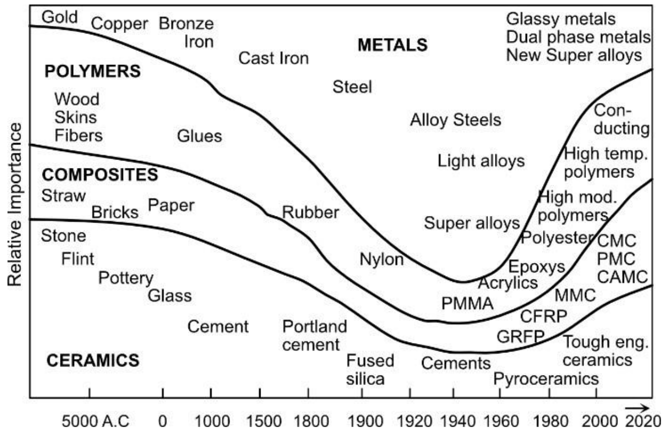

Figure 3: Relative importance of materials over time. Source: adapted from [10].

Deepening in the military aeronautical industry, this distributed the use of composites among supplementary compartments such as: fairings and control facets, taking advantage of polymer composites reinforced with carbon fibers (CFRP) and those reinforced with boron fibers in their elements structural. With the intensity of technology, its use has expanded to wings, stabilizers and fuselage. Thus, the positive results instigated the application of composites to commercial aviation, obtaining instantaneous advantages, such as: reduced use of fuel, increased durability, and increased load capacity [5, 11].

Currently, CFRPs are massively used in sports and entertainment apparatus (such as: fishing rods, bicycles and golf clubs), in protection of jet engines produced through filament packaging, in small reservoirs of automotive pressure and bumpers, as well as silicon carbide and aluminum oxide fibers, are used for tennis rackets and rocket cones, for example. In view of the above, the justification for such notoriety is due to the properties already mentioned briefly: high resistance to adverse environmental conditions (aggressive and high temperatures), has low weight, corrosion resistance, is more rigid and withstand large loads, they offer diversity in shapes and finally absorb high degrees of vibration in parity to metallic materials [6].

In contrast to the above, there are composites reinforced with quartz fibers, built to be subjected to extreme thermal situations and the erosion of frontal rocket cones, in supersonic aircraft and in external transport elements intended for re-entry into the atmosphere from the ground, demonstrating strong performances and facilitating its ramification for other missile industries, aircraft with complex shapes and rockets [10]. Other types of composites are: those reinforced with glass fibers, one of the most applied due to its lower cost and density, corrosion resistance and excellent mechanical behavior, in addition to favoring handling, thus strategically competing with aluminum [13].

3.2 Application of composites in the aeronautical sector

In summary, the evolution and incorporation of composites (mainly polymeric ones) in the structural elements of aircraft has occurred and continues to occur, in an accentuated manner over the years (Figure 4), this is due to their mechanical properties. lightness, rigidity, flexibility and versatility in the execution of projects that demand more complex parts and with specific local characteristics, judging by the exchange of aluminum for structural polymeric composites, which grants a reduction of about 20 to 30% of the weight, this linked to a lower final cost in the acquisition of the pieces [10].

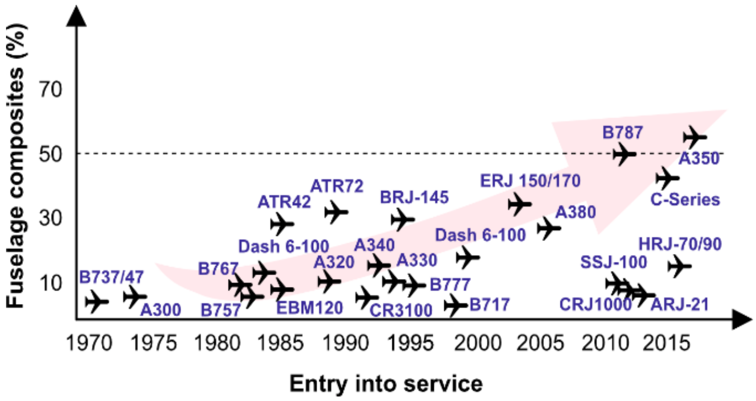

Figure 4: Evolution in percentage of composites used in aircraft. Source: Adapted from [14].

Another evidence of the evolution of composites in the aeronautical sector is the gradual replacement of aluminum alloys in aircraft production, as validated with Figure 5, which illustrates the percentages of components used in a series of Boeing aircraft compared to traditional materials, such as aluminum (aluminum alloy) and titanium (titanium) [15].

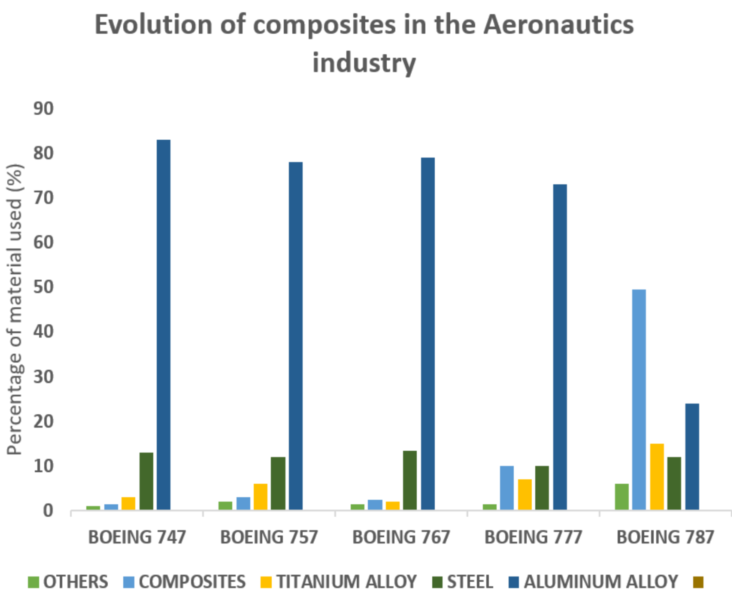

Figure 5: Percentage of constituents present in Boeing aircraft. Source: Adapted from [15].

According to Huifeng Tan [16], the percentage of composites as a function of the total weight of the aircraft jumped from approximately 1% in 1965 to more than 50% in the last two decades, as already presented and also visualized in Figure 6, in which can be noted that from the 80's onwards, composites started to play a more significant role in the industry and with that to be more explored in the aeronautical segment.

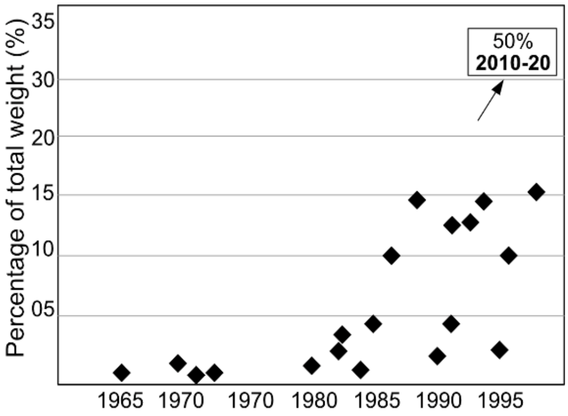

Figure 6: Evolution of the percentage of composites in the total weight of aircraft. In black, the representation of the number of commercial aircraft models. Source: adapted from [16].

It can also be noted in Figure 7, that the insertion of composites in aircraft has already reached the 50% range, as well as highlighted in the Boeing 787 Dream liner typology and in other brands such as Airbus A350 - XWB, for example, the first is shown in Figure 7 with the specification of the parts consisting of composites represented by the color blue (also displayed by the percentage pie chart) [12, 14,17].

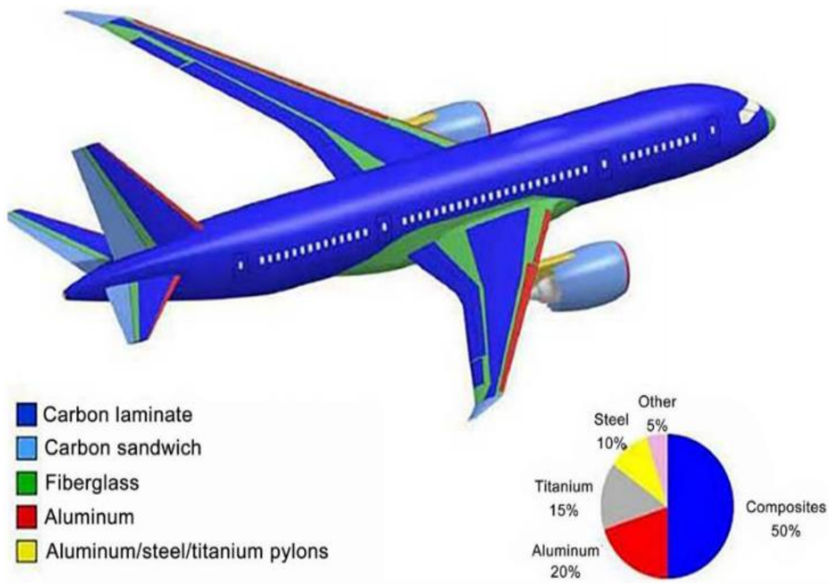

Figure 7: The use of composites in the Boeing 787 aircraft. Source: Adapted from [17].

It is admitted that the constituents of aircraft in which composites are most used include: wings, keel beam, horizontal and vertical stabilizers and parts of the fuselage, including flight control components, interior design (floors, doors, lining cabins) and fairings [18]. In this sense, the Airbus A380 has great prominence in modern aeronautics, as it was the first to use the CFRP in the ribs present on the wings, in addition to its use in the floor support beams and in the rear bulkhead [17].

In parallel, the aforementioned Airbus A350 also makes use of this type of composite in its parts: frames, fuselage, clips, window and door frames and the Boeing 787 composed of 23 tons of carbon fibers, which by in turn it has a higher strength/weight ratio than that of many standard aircraft materials (aluminum) and also aids in a lower thermal expansion coefficient and lower density, resulting in around 32,000 kg of CFRP disposed. on the wings, doors, fuselage, tail and interior design, also visible in Figure 4 [13,17,19].

Therefore, it is also emphasized that the correct selection of materials is the key point for a good aeronautical project, which must be esteemed for lightness so that its performance is not compromised. As a result, weight is a fundamental factor and directly affects operating, flight, taxiing, speed, payload, fuel consumption and gas emission conditions. Thus, a reduction in the total mass of the aircraft means an increase in the final profits of airlines and companies in the transport sector, in addition to contributing to a reduction in the emission of polluting gases into the atmosphere [20].

In this way, to minimize failures due to high working temperatures in turbines, bypassing the application of materials with high densities, such as metals, currently being used for these purposes, polymeric matrix composite materials (PMC) and composites of ceramic matrix (CMC) in the construction of scramjets [21]. These have excellent corrosion resistance and are approximately three times lighter than the nickel superalloys previously widely used by the aeronautical industry. This "weight/efficiency" ratio for these new composites resulted in a 50% decrease in the total weight of the turbine components of the company General Electric (GE) in 2019 and a 2% savings in fuel consumption [22]. CMCs also have typical applications in brake discs, emergency operating systems for rotary axes and friction pads for clutches. They are usually reinforced with fibers (glass, aramid, carbon, fabrics) embedded in a matrix of aluminum oxide, zirconium oxide or silicon carbide. This combination (fibers and ceramics) is responsible for the increase in crack resistance, ductility, resistance to thermal shock [23].

3.3 Application of composites in the automotive sector

Clearly, it is not just in the aeronautical industry that composites stand out. In the automobile industry, the application of polymeric and plastic composites in vehicles developed gradually during the 70s and 80s, establishing advantages such as: reduced weight (around 50% mainly in body and chassis systems), smaller emission of pollutants such as carbon dioxide (CO2), possibility of modern designs, increased safety, reduced costs and greater resistance to corrosion [24, 25].

Thus, Table 1 presents some of the elements that can be produced based on CFRP to replace steel (a material traditionally used in vehicles), denoting the great potential of composites in the automotive sector. Furthermore, it is also noticed that, in comparison with weights, those made with CFRP stand out in terms of lighter weight, reducing the vehicle's total weight by up to 566 kg [26].

Table 1: Weight reduction of a CFRP car.

Component	Steel (kg)	PRFC (kg)	Reduction (kg)
Bodywork	192,3	72,7	115
Chassis-Suspension	128,6	93,6	35
Wheels	41,7	22,3	19,4
Hood	22,3	7,8	14,7
Floor	19,5	6,5	13,1
Doors	64,1	25,2	38,9
Bumpers	55,9	20	35,9
Steering bar	9,6	6,8	2,8
Total vehicle weight	1705	1138	566

Weight in kg* Source: Adapted from [26].

In addition, other elements not listed in Table 1 can be seen in Figure 8 confirming the applications of fiber-reinforced plastics in automotive elements, such as the sports accents produced in Aramid (Kevlar), which for in turn, it provides better resistance to flames [27, 28].

Figure 8: Examples of applications of fiber reinforced plastics in automotive components. Source: Adapted from [28].

Recently in the work of Oliveira et. al [29], applications with alumina dispersed in a matrix of low-density polyethylene (LDP) enabled the creation of a composite with a promising low density in shielding ballistic applications. The researchers verified the penetration of the projectile as a function of the percentage of alumina in the composite and the results can be seen in Figure 9.

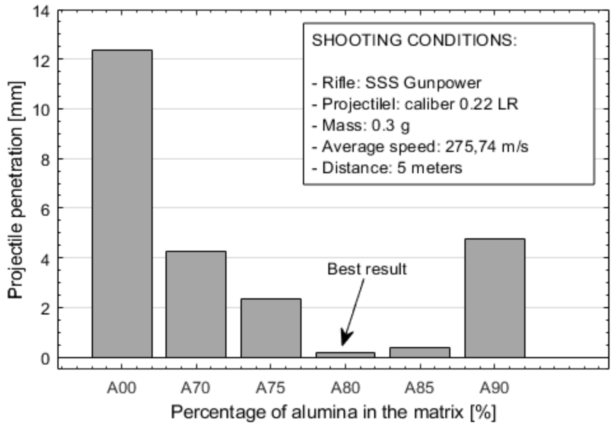

Figure 9: Penetration as a function of the percentage of alumina present. Source: adapted from [29].

It can be seen in Figure 9 that the A80 sample with 80% alumina and 20% LDP obtained the best results for shielding. 80% of that in the composite represents the "optimal point" with maximum efficiency.

Furthermore, greater safety for cars is due to the application of tempered and laminated glass on windshields, providing protection for drivers and passengers in collision situations, that is, when the composite is subjected to shock, the glass tempered shatters into countless small fragments (common glass that shatters into sharp shapes), the base polymer binds them together, preventing the conductor from being reached [30].

It should be noted that vehicles entirely made of CFRP type composites (much debated in this article) is already a reality, and it is possible to visualize it with Figure 10, a Regera model of the Koenigsegg brand produced without painting, with high performance (1500 hp power) and more resistant to deterioration such as risks, deformations and climate change [31].

Figure 10: Model Regera Koenigsegg made entirely of carbon fiber. Source: [32].

4. Contributions of this article

Research on the evolution and improvement of composites is under continuous development, due to the great desire for structural efficiency on the part of industries in the transport sector, in order to enable great advances in a short period of time. Thus, it is expected that with the control of the properties of the constituents of the composites, a new class of more efficient materials will prevail in the coming years and, consequently, aircraft and automobiles with greater constructive quality.

5. Conclusions

It is concluded that composites have a great reputation compared to traditional materials, such as titanium, aluminum and steel in the aeronautics and automobile industries, bringing the possibility of replacing these in favor of lower costs, easier project execution and complex designs and, above all, lighter weights.

From this perspective, it was also possible to see the importance of composites in improving the characteristics of the final product, reducing maintenance costs and increasing safety. Even validating its applications in more than 50% of the weight in aircraft, positively reflecting in lower densities, reduction in fuel consumption and consequently greater flight autonomy.

When evaluating the advances in the application of composites in the automotive sector, it is highlighted that modern applications were found mainly for ballistic and collision protection purposes, referring to alumina dispersed in LDP and tempered laminates of polymer matrix, respectively.

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