

RESEARCH ARTICLE | DECEMBER 11 2023

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AIP Conf. Proc. 2941, 020029 (2023)

<https://doi.org/10.1063/5.0181354>



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Uses of Aero Graphene and CNT in Modern Aircraft

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Abstract. This paper focuses on aero graphene and carbon nanotube (CNT) aerogel, both of which will find applications in aircraft, including the battery, the engine, the pitot probe, the wings, the fuselage, and the front glass of the plane. Because of the buoyant force, these materials will also protect the aircraft from rain and wind. There Aero graphene is made by decreasing a graphene oxide solution to produce a hydrogel. Freeze-drying replaces solvent in pores with air. 3-D printing can produce aero graphene. This is a scientific breakthrough. Graphene in gel makes resin. UV LED light may turn graphene resin into a solid in a furnace. Next-generation aircraft will have aero-graphene-coated hull, wings, and cockpit glasses. Aero-graphene gives planes a strong, light structure.

INTRODUCTION

Aero graphene

Aero graphene is the thinnest solid material ever created (light enough to be balanced on plants of small size). Aero graphene is strong, malleable, electrically conductive, and a solvent. After being compressed, graphene aerogels retain their transparency and elasticity. Absorption is enhanced on low-density graphene planes (the point where it can absorb more than 850 times its own weight). After absorbing oil spill material, aerogels can be recovered. It has several applications, including chemical, magnetic, thermal, and electrical superconductors. Aero-strength, graphene's lightness, and elasticity make it useful in modern aviation. This futuristic material can improve our aircraft and structures. Figure 1 shows the outline of aero graphene's structure.



FIGURE 1. Aero graphene

Wang and his team developed Graphene-based aerogel in 2009, a novel carbon aerogel [1]. The process of making aero graphene, which involves carbonizing the chemically bonded graphene oxide aerogel by ultrasonic gelation, was detailed in an article published by Worsley and his team in 2010 [2]. In order to simplify the preparation of graphene aerogel, Zhang and his team recommended employing L-ascorbic acid to decrease graphene oxide dispersion and dry

the wet gel [3]. Since rich graphene-aerogel does not need any further pyrolysis treatment, it was compared to CRF aerogel by Worsley et al. in 2011 [4]. In terms of density, aero graphene is even less dense than helium and is the universal carbon molecule. Because it does not float in the air and has a density that is just 7.5% that of air, it is an excellent material for airplanes.

Graphene (one-atom-thick hexagonal lattice of carbon atoms)

Graphene is a two-dimensional lattice of carbon atoms arranged in a honeycomb pattern. Nanotubes, graphite nanowires, and fullerenes are all possible outcomes of this structure's malleability. Graphene, a form of carbon, has several useful and unique features. It's harder than diamond, stronger than steel, and lighter than aluminum, and it has a theoretical thickness of only one atom [5]. To better understand the nature of other carbon-based materials, graphene is frequently employed. After 40 years, it was found that graphene is a better compact analog of 3D quantum electrodynamics [6], making it a popular theoretical toy model. Two-dimensional crystals have atomic structures, while one hundred layers of a molecule should be studied as a thin film. When the number of hidden layers is greater than ten, it has been found that the electrical structure rapidly evolves beyond the three-dimensional limit of graphite shafts [7]. While graphene and its monolayer have simple electronic bands, the valence and conduction bands become more complicated with an increase in layer count [9]. Graphene was first isolated and named in 2004 [8], and since then, many different varieties of this material have been found. The most promising near-term use for graphene is in composite materials because of their scalability in production and low production costs [9]. The initial focus material underwent mechanical exfoliation through the utilization of "Scotch tape." This innovative creation has the potential to facilitate the development of contemporary spacecraft and unmanned aerial vehicles. Researchers are currently engaged in the endeavor. The primary objective is to produce it in a manner that is commercially viable and widely utilized as plastic. While graphene may not possess the same remarkable properties as plastic, it has the potential to be produced in a cost-effective manner through thorough laboratory research. Due to the fact that plastic is not comparatively lighter than graphene. Ongoing research is being conducted on the utilization of graphene in space. The visual depiction of the fundamental structure of graphene is presented in Figure 2. Graphene is a planar allotrope of carbon that exhibits remarkable mechanical, electrical, and thermal properties, making it a versatile building block for a wide range of carbon-based materials. One-dimensional (1D) nanotubes, three-dimensional (3D) graphite stacks, and zero-dimensional (0D) buckyballs can be formed by manipulating the material in question. Data centers play a crucial role in various industries. Due to the cost-saving benefits, a considerable number of research endeavors concentrate on the design and operation of data centers for efficient data management [10].

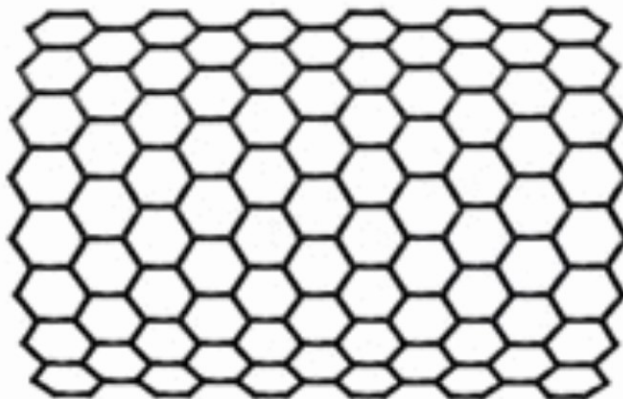


FIGURE 2. Fundamental structure of graphene

Graphene can be found in many forms [11]. CVD graphene, nanocomposite, graphene-oxide, and GRM (GRaphene-based/related Materials) are all types of materials that have been developed recently. GRM has the ability to either slow down or deflect the propagation of cracks, which improves the short fracture toughness and damage tolerance of composite materials used in aviation components. The incorporation of GRM into the carbon composite resin employed in commercial aircraft, including the A320 and B747, as well as contemporary unmanned aerial vehicles

(UAVs), has the potential to serve as a viable constituent. In such applications, GRM accounts for over 95% of the composite's ultimate load. In light of the current state of radar technology, the problem of designing an effective space surveillance system in a way that is both cost-effective and efficient needs to be tackled [12]. The measure of the component may be subject to modification in forthcoming models of long-range or single-pilot aircraft. In a forthcoming investigation, a comprehensive Battery Management System will be incorporated to ascertain and guarantee secure operational parameters for the battery system [13]. The implementation of GRM has the potential to enhance the caliber of Resin Transfer Molding pertaining to A320 components, specifically the leading edge of the Horizontal Tail Plane (HTP) [14].

Carbon Nanotube (CNT – nanometer-diameter carbon tube)

Scientists used to study carbon-based materials because they were interested in their physical properties. In recent years, however, scientists have become more interested in their chemical properties. The Chemicals Research Accounts' special edition, featuring contributions from esteemed global experts in Carbon Nanotubes, presents a valuable and practical resource for the chemical industry. The functionalization of nanomaterials has enabled distinct properties to be exhibited by their termini and lateral surfaces. The uppermost regions of nanomaterials exhibit a higher degree of sensitivity in comparison to their surrounding walls. When the nanomaterials are processed chemically, the tops are quickly lost because of how they are shaped. Carbon nanotubes' chemical properties have been looked into for about five years. But the current issue of accounts shows that there has been a lot of change at this time.

The CNT aerogel is a fascinating type of carbon aerogel. The production process of the material in question involved the dispersion of carbon nanotubes into a solvent that was free of surfactants, followed by the subsequent steps of gelation and drying, as documented in reference [15]. The incorporation of polyvinyl alcohol has the potential to augment the properties of the aerogel. In 2009, Aliev and colleagues reported the production of aerogel muscles composed of carbon nanotubes (CNTs). The CNTs were arranged in multi-walled trees and utilized to construct the straight-side panels of the aerogel muscles [16]. In contrast to the majority of prior aerogels, the production of CNT forests for mass manufacturing was achieved through a catalyst-driven chemical precipitation method, rather than the sol-gel process. An alternative method for synthesizing aero graphite, also known as carbon-based aerogel, entails the deposition of graphite nanomaterials onto ZnO network substrates. The subsequent step involves the transformation of ZnO into solid Zn while being subjected to a hydrogen atmosphere, followed by the sublimation of Zn at high temperatures [17]. The connection between graphene and a molecular network composed of hexagons is illustrated in Figure 3, chemical chain of interaction Nanotechnology, carbon and other nanomaterials with vector 3D illustration.

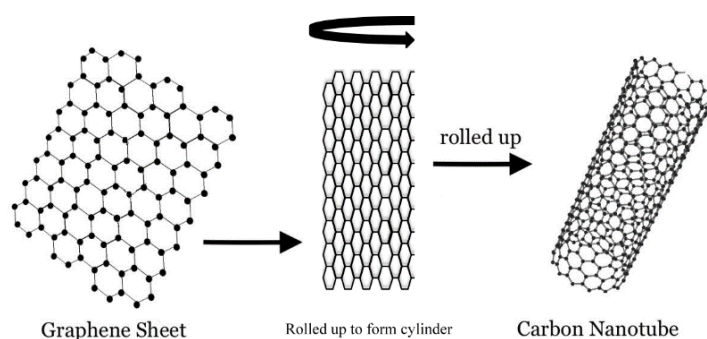


FIGURE 3. Graphene sheet to CNT

DESIGN ASPECTS, RESULTS AND COMPARISON

This study focuses on Aerographene and CNT aerogel, which will be utilized in aircraft wings, fuselages, and cockpit glass to protect from rain and heavy wind. Aero graphene is created by reducing a solution of graphene oxide to create graphene hydrogel. Air is introduced into pores during freeze-drying to replace solvent. The lack of research

opportunities to study this new versatile material, as well as the fact that by using graphene we can have more efficient use of fuel and therefore save money on fuel costs. 3D printing can produce aero graphene. It's a scientific breakthrough. Graphene gel diffusion produces resin. UV LED light may dry graphene resin in a furnace. CNT aerogels were synthesized through the process of CNT assembly in a solution followed by CO₂ drying. The electrical and mechanical properties, surface area, and porosity of CNT aerogels can be substantially enhanced via thermal annealing in air. This process effectively reopens micropores and small mesopores that were previously closed. CNT plates can be utilized on the designed aircrafts fuselage and other aircraft elements.

In this facility, a scale model of an aeroplane serving as a prototype has been built. The aeroplane was designed using a supersonic prospectus and a CATIA 3D model was used to create a virtual image of the plane that people want to fly. Table 1 shows the following measurements.

TABLE 1. Dimensions of the designed aircraft

Description	Fuselage Length	Wingspan	Wing Area	Wing Sweep	Vertical Tail Area
Area	4.812 m	2.8204 m	6.9264 m ²	68°	0.92903 m ²

Following receipt of the dimensions from the CATIA software, an analysis was performed using Autodesk Fusion 360 (shown in Figure 6b) ANSYS software formerly included a visual simulation and provided results for the directional deformation (shown in Figure 4a), the equivalent stress (shown in Figure 4b) and the total deformation (shown in Figure 4c).

For the first simulation, the fuselage of the aeroplane was constructed out of a substance known as aluminum alloy. After applying a force of 600N to the aircraft's wings and another 600N to the frontal area of the aircraft, the fuselage surface was fixed, and the results are given below.

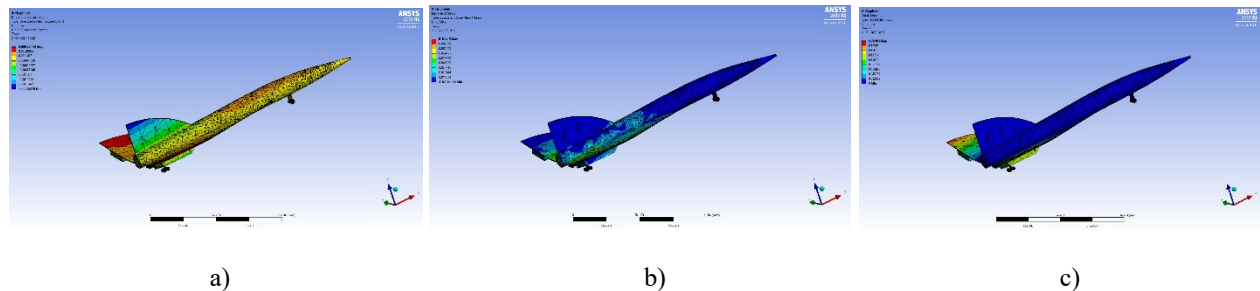


FIGURE 4. a) Directional deformation; b) Equivalent (von-Mises) stress; c) Total deformation of the designed aircraft

Using the context of the directional deformation, the X-coordinate that was used for the simulation, it has demonstrated the effects of pressure and the deformation of the aircraft's wings and frontal area as a result of the pressure. The simulation displays the highest equivalent stress that the aircraft is subjected to, which is then employed as a scaler indicator in the equivalent stress or von Mises theory. The aircraft's yield strength has been found to be smaller as a result of this. The simulation shows the overall deformation of the aircraft as it is run through the entire deformation process. It has demonstrated the overall pressure effects that have been exerted on the aircraft.

The aero graphene material was used to manufacture the airplane's fuselage so that it could be used in this simulation. A comprehensive overview of the fundamental properties characterizing the Aero Graphene material, as documented in reference [18]. The Young's Modulus, a measure of its stiffness, is noted to be approximately 5E+10 Pa. The Poisson's Ratio, indicating its lateral contraction when subjected to axial stretching, is found to be 0.066. In terms of compressibility, the material's Bulk Modulus stands at 1.920_{1E+10} Pa, highlighting its resistance to volume change under pressure. The Shear Modulus, signifying its response to shear stress, is recorded at 2.345_{2E+10} Pa. Moreover, the Tensile Yield Strength, reflecting the maximum stress the material can withstand without permanent deformation, demonstrates an exceptional value of 1E+12 Pa. These properties collectively define the remarkable mechanical characteristics of Aero Graphene, underlining its potential utility in diverse applications requiring exceptional strength and resilience.

In the second simulation, the airplane's fuselage was made from a material called aero graphene. This was done so that the results would be more accurate. The surface of the fuselage was fixed after a force of 600N was applied to the aircraft's wings, and a further 600N was applied to the frontal area of the aircraft. The following is a summary of the findings, which are discussed in greater detail further down.

Following the incorporation of the aero graphene properties in ANSYS, it formerly provided data for the directional deformation (shown in Figure 5a), the equivalent stress (shown in Figure 5b) and the total deformation (shown in Figure 5c).

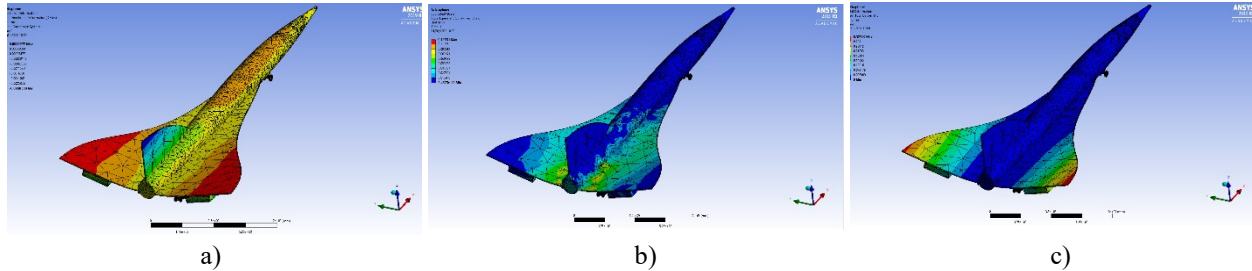


FIGURE 5. a) Directional deformation; b) Equivalent (von-Mises) stress; c) Total deformation with aero graphene

Using the X-coordinate utilized for the simulation, it demonstrated the effects of pressure and the deformation of the aircraft's wings and frontal area. The simulation illustrates the aircraft's highest equivalent stress, which is used as a scaler in von Mises theory. This reduces the aircraft's yield strength. The simulation describes the overall deformation of the aircraft with the aero graphene, as it goes through the complete deformation process. It has shown the overall pressure effects that have been applied to the aircraft.

The following Table 2 presents a comparison between aero graphene and aluminum alloy based on the results of ANSYS simulations.

TABLE 2. Comparing the deformation of two materials

Deformation		Directional (X Axis)	von-Mises stress	Total
Aero Graphene	Maximum	0.0012272 mm	0.12551 MPa	0.32749 mm
	Minimum	-0.0030588 mm	3.4575E-12 MPa	0 mm
Aluminum Alloy	Maximum	0.00079448 mm	0.10415 MPa	0.20591 mm
	Minimum	-0.0020278 mm	1.3002E-12 MPa	0 mm

The results and concept of the theory of employing the Aerographene material and CNT on the aircraft surface body and other parts have demonstrated that it is possible to construct the desired ultra-light weight aircraft in the near future, and it might show a major impact in several domains of modern aviation. A demonstration model of an aircraft has been constructed in the lab (shown in Figure 6a) based on the idea of using aero graphene in aircraft. This small model will be ideal for incorporating aerographene material into the body of the aircraft.



FIGURE 6. a) 3D printed of the designed aircraft; b) Visualization of desire aircraft

Some unique materials such as Transition Metal Dichalcogenides (TMDCs), Black Phosphorus (BP), Hexagonal Boron Nitride, Layered Double Hydroxide (LDH) and Phosphorene can improve light-matter interaction to develop light emission, detection, modulation, and manipulation applications [19]. The prospects for developing 2D materials will depend on their efficiency, unique advantages, and capabilities, as well as their ability to be mass-produced at a low cost and integrated into existing photonic and electronic platforms. The popularity of 2D materials will depend on their performance, advantages, and capabilities, among other small details [20].

FUTURE GOAL & EVALUATION

In this project work, we developed a concept for the potential use of Aerographene material on another type of designed aircraft. We modified the [Tupolev TU-144](#) supersonic passenger aircraft by adding some new features and made some calculations during my internship, in future the proposed plan is to use Aerographene material on this newly modified supersonic commercial aircraft and more details further down.

TABLE 3. Review of design dimensions

Lengths	Values
Overall length	59.50 m
Height from ground (ground to top of fin)	11.35 m
Height from lowest point (engine)	10.80 m
Fuselage max Width (external)	3 m
Fuselage max Height (external)	3 m
Wingspan	27.65 m
Wing length (root chord)	35.60 m
Wing area	438 m ²
Tail fin height	6.50 m
Tail fin length (root chord)	15.40 m

Weight calculations,
 Empty weight = 85,000 kg
 Takeoff weight = 180,000 kg
 Loaded weight = 120,000 kg

The takeoff weight W_{to} is calculated as follows,

$$W_{TO} = W_{OE} + W_{PL} + W_{mfuel} \quad (1)$$

W_{OE} : using empty weight, W_{PL} : commercial load weight, W_{mfuel} : mission oil weight.

The aircraft's using empty weight as a reference from Eq. (1),

$$W_{OE} = W_E + W_{tof} + W_{crew}$$

(2)

W_E : empty weight, W_{tof} : weight of lubricating oil and unusable fuel, W_{crew} : weight of the aircraft occupant

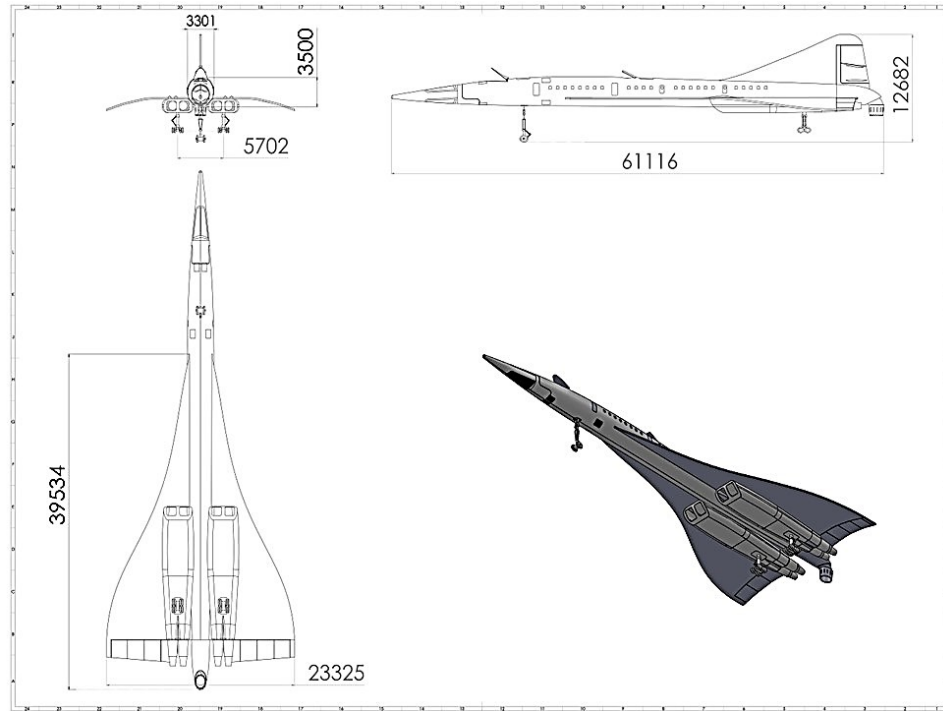


FIGURE 7. Modified design of TU-144 (Skipper M2)

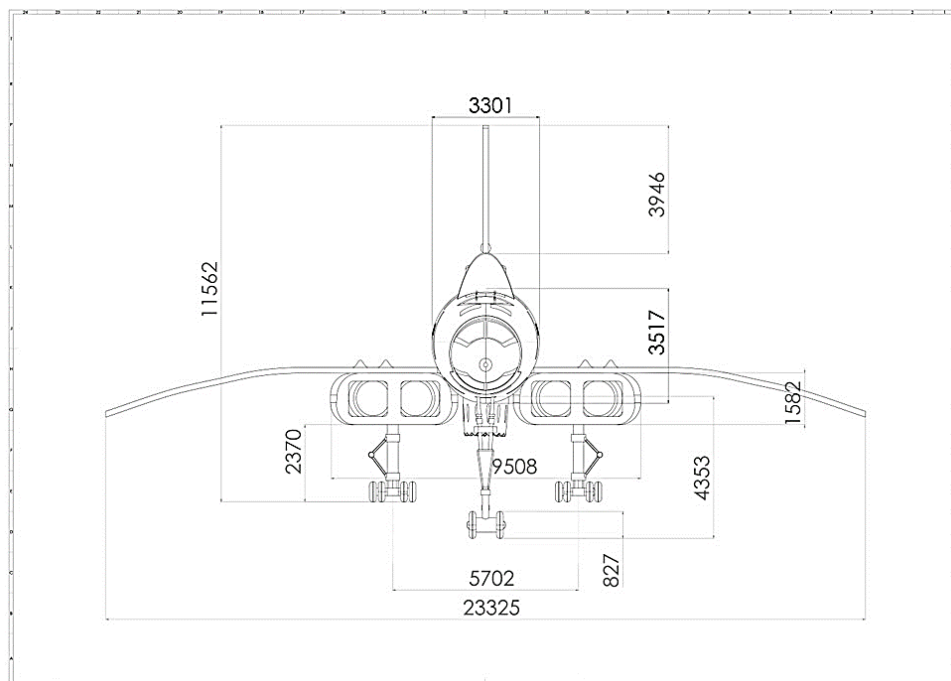


FIGURE 8. Front view of Modified TU-144 (Skipper M2)

Take off speed,

$$V_{LOF} = V_{s1} = \sqrt{\frac{2W}{\rho S C_{Lmax}}} = 1.556 \sqrt{\frac{W}{\rho S C_{LTOF}}} \quad (3)$$

W : weight, assumed constant in N, ρ : air density in kg/m³, S : reference wing area in m².
 C_{LTOF} : magnitude of the lift coefficient of T-O configuration as a reference from Eq. (3),

$$V_{LOF} = V_{s1} = 1.556 \sqrt{\frac{850000}{\rho \times 438 \times 1.1}} = 284 \text{ km/h} \quad (4)$$

Landing speed,

$$V = k_{APP} \times \sqrt{S_{LFL}} = 1.70 \times \sqrt{2176ft} \quad (5)$$

$$S_{LFL} = S_A + S_F + S_{FR} + S_{BR} \quad (6)$$

Load factor,

$$n = \frac{1}{\cos\phi} = \left(\frac{T}{W}\right) \left(\frac{L}{D}\right) \quad (7)$$

T : thrust, W : weight, assumed constant in N, L : lift of the airplane in the landing configuration, D : turn diameter.

After studying graphene material, it could make a great impact on our aviation industry in near future. This concept will work through different aerodynamic sectors of aircraft too. But the concepts and received results from lab work show that, if we can use this universal material in our aviation industry in future, it has the ability to make the new era of modern aviation.



FIGURE 9. 3D visualization of Modified TU-144 (Skipper-M2)

CONCLUSION

Our investigation shows that the concept of using Aerographene and CNT on aircraft surface body and other parts of the ultra-lightweight aircraft can be built in the near future. It could have a major impact on modern aviation. The utilization of aero graphene and carbon nanotubes has the potential to yield aircraft that are characterized by their lightweight, robustness, and contemporary design. Such aircraft possess the advantages of fuel efficiency, aerodynamic stability, and cost-effectiveness. This holds significant importance for the future aviation sector.

The application of aero graphene in aircraft is multifaceted, encompassing enhancements to the plastic utilized in the amalgamation of carbon fiber within the wings, assessment of the strain experienced by the wings, and substitution of copper wire and heating coils with a lighter alternative to mitigate the formation of ice on the wings. In addition, it serves as a de-icing mechanism by substituting conventional copper wire and heating coils with a comparatively lighter alternative.

Carbon nanotubes (CNTs) have been identified as the optimal material for use in space aircraft and space elevators. Stable aerogels have been produced through the creation of a 3D assembly of solution carbon nanotubes (CNTs) and the utilization of supercharged drying of carbon dioxide. The process of thermal regeneration has the potential to enhance the thermal and mechanical characteristics of materials, while also increasing their surface area and porosity.

Finally, it is hoped that aerographene may be replaced in the wings, battery, engine, pitot probe & fuselage. The project will take at least 20 years to complete.

ACKNOWLEDGEMENT

Special thanks to Mr. Balogh Gábor & Mr. Kostyák Ferenc for their assistance in the fabrication of aircraft and kind assistance during the measurements of aircraft performance.

REFERENCES

- [1] M. W. Wang, J.; Ellsworth, “Graphene aerogels,” vol. 19, no. ECS Trans., pp. 241–247, 2009.
- [2] M. A. Worsley, P. J. Pauzauskie, T. Y. Olson, J. Biener, J. H. Satcher, and T. F. Baumann, “Synthesis of Graphene Aerogel with High Electrical Conductivity,” *J. Am. Chem. Soc.*, vol. 132, no. 40, pp. 14067–14069, Oct. 2010, doi: 10.1021/ja1072299.
- [3] X. Zhang *et al.*, “Mechanically strong and highly conductive graphene aerogel and its use as electrodes for electrochemical power sources,” *J. Mater. Chem.*, vol. 21, no. 18, p. 6494, 2011, doi: 10.1039/c1jm10239g.
- [4] P. J. Pauzauskie *et al.*, “Synthesis and characterization of a nanocrystalline diamond aerogel,” *Proc. Natl. Acad. Sci.*, vol. 108, no. 21, pp. 8550–8553, May 2011, doi: 10.1073/pnas.1010600108.
- [5] P. R. Wallace, “The Band Theory of Graphite,” *Phys. Rev.*, vol. 71, no. 9, pp. 622–634, May 1947, doi: 10.1103/PhysRev.71.622.
- [6] G. W. Semenoff, “Condensed-Matter Simulation of a Three-Dimensional Anomaly,” *Phys. Rev. Lett.*, vol. 53, no. 26, pp. 2449–2452, Dec. 1984, doi: 10.1103/PhysRevLett.53.2449.
- [7] B. Partoens and F. M. Peeters, “From graphene to graphite: Electronic structure around the K point,” *Phys. Rev. B*, vol. 74, no. 7, p. 075404, Aug. 2006, doi: 10.1103/PhysRevB.74.075404.
- [8] K. S. Novoselov, “Electric Field Effect in Atomically Thin Carbon Films,” *Science* (80-.), vol. 306, no. 5696, pp. 666–669, Oct. 2004, doi: 10.1126/science.1102896.
- [9] S. Stankovich *et al.*, “Graphene-based composite materials,” *Nature*, vol. 442, no. 7100, pp. 282–286, Jul. 2006, doi: 10.1038/nature04969.
- [10] A. Masuk and H. Géza, “Aero Graphene in Modern Aircraft & UAV,” *Recent Innov. Mechatronics*, vol. 9, no. 1, 2022, doi: https://doi.org/10.17667/riim.2022.1/4.
- [11] D. G. Papageorgiou, I. A. Kinloch, and R. J. Young, “Mechanical properties of graphene and graphene-based nanocomposites,” *Prog. Mater. Sci.*, vol. 90, pp. 75–127, Oct. 2017, doi: 10.1016/j.pmatsci.2017.07.004.
- [12] I. Balajti, “Twin VHF radar for european space situation awareness system,” in *2012 13th International Radar Symposium*, IEEE, May 2012, pp. 19–22. doi: 10.1109/IRS.2012.6233312.
- [13] A. Babangida and P. T. Szemes, “Electric Vehicle Modelling and Simulation of a Light Commercial Vehicle Using PMSM Propulsion,” *Hungarian J. Ind. Chem.*, vol. 49, no. 1, pp. 37–46, Sep. 2021, doi: 10.33927/hjic-2021-06.
- [14] X. Du *et al.*, “Graphene/epoxy interleaves for delamination toughening and monitoring of crack damage in carbon fibre/epoxy composite laminates,” *Compos. Sci. Technol.*, vol. 140, pp. 123–133, Mar. 2017, doi: 10.1016/j.compscitech.2016.12.028.
- [15] M. B. Bryning, D. E. Milkie, M. F. Islam, L. A. Hough, J. M. Kikkawa, and A. G. Yodh, “Carbon Nanotube Aerogels,” *Adv. Mater.*, vol. 19, no. 5, pp. 661–664, Mar. 2007, doi: 10.1002/adma.200601748.
- [16] A. E. Aliev *et al.*, “Giant-Stroke, Superelastic Carbon Nanotube Aerogel Muscles,” *Science* (80-.), vol. 323, no. 5921, pp. 1575–1578, Mar. 2009, doi: 10.1126/science.1168312.
- [17] M. Mecklenburg *et al.*, “Aerographite: Ultra Lightweight, Flexible Nanowall, Carbon Microtube Material with Outstanding Mechanical Performance,” *Adv. Mater.*, vol. 24, no. 26, pp. 3486–3490, Jul. 2012, doi: 10.1002/adma.201200491.
- [18] H.-J. YUN* and S. PARK, “Newly Written Physics in Graphene,” *New Phys. Sae Mulli*, vol. 62, no. 12, pp. 1229–1259, Dec. 2012, doi: 10.3938/NPSM.62.1229.
- [19] G. W. Mudd *et al.*, “The direct-to-indirect band gap crossover in two-dimensional van der Waals Indium Selenide crystals,” *Sci. Rep.*, vol. 6, no. 1, p. 39619, Dec. 2016, doi: 10.1038/srep39619.
- [20] R. Vargas-Bernal, “Graphene against Other Two-Dimensional Materials: A Comparative Study on the Basis of Electronic Applications,” in *Two-dimensional Materials - Synthesis, Characterization and Potential Applications*, InTech, 2016. doi: 10.5772/63916.