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Preface

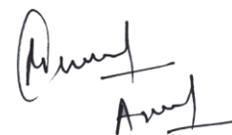
We would like to present, with great pleasure, the inaugural volume-8, Issue-4, April 2022, of a scholarly journal, *International Journal of Engineering Research & Science*. This journal is part of the AD Publications series *in the field of Engineering, Mathematics, Physics, Chemistry and science Research Development*, and is devoted to the gamut of Engineering and Science issues, from theoretical aspects to application-dependent studies and the validation of emerging technologies.

This journal was envisioned and founded to represent the growing needs of Engineering and Science as an emerging and increasingly vital field, now widely recognized as an integral part of scientific and technical investigations. Its mission is to become a voice of the Engineering and Science community, addressing researchers and practitioners in below areas

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Algorithm and Computational Complexity	Artificial Intelligence
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Each article in this issue provides an example of a concrete industrial application or a case study of the presented methodology to amplify the impact of the contribution. We are very thankful to everybody within that community who supported the idea of creating a new Research with IJOER. We are certain that this issue will be followed by many others, reporting new developments in the Engineering and Science field. This issue would not have been possible without the great support of the Reviewer, Editorial Board members and also with our Advisory Board Members, and we would like to express our sincere thanks to all of them. We would also like to express our gratitude to the editorial staff of AD Publications, who supported us at every stage of the project. It is our hope that this fine collection of articles will be a valuable resource for *IJOER* readers and will stimulate further research into the vibrant area of Engineering and Science Research.



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Table of Contents

Volume-8, Issue-4, April 2022

S. No	Title	Page No.
1	<p>Evaluation of Electrical, Mechanical and Wear Behavior of Laminated Epoxy/Carbon Fiber Composite with Different Fillers</p> <p>Authors: Gean Vitor Salmoria, Loise Silva, Rodrigo Acácio Paggi</p> <p> DOI: https://dx.doi.org/10.5281/zenodo.6503707</p> <p> DIN Digital Identification Number: IJOER-APR-2022-1</p>	01-11
2	<p>Design and Manufacturing of X-Shape Quadcopter</p> <p>Authors: Khaled Hassan Mostafa, Ayman Shehata Thabet, Abdelrady Okasha Elnady</p> <p> DOI: https://dx.doi.org/10.5281/zenodo.6503720</p> <p> DIN Digital Identification Number: IJOER-APR-2022-2</p>	12-20

Evaluation of Electrical, Mechanical and Wear Behavior of Laminated Epoxy/Carbon Fiber Composite with Different Fillers

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Abstract— Epoxy resin reinforced with carbon fibers are widely used in applications where requirements of lightness and high mechanical strength are needed. Composites containing fillers with different properties can improve important characteristics of components. In aerospace applications, the use of low removal rate due to the impact of suspense particles must be satisfied in order to reduce maintenance costs of components. Since carbon fibers have low electrical resistivity and are in the range of semiconductors, these composites can be used as radar absorbing materials (RAM). The addition of conductive fillers may increase this intrinsic property of the composite, and also improve the mechanical and wear properties of the laminate. Results showed that the addition of micronized graphite (MG), multi-walled carbon nanotubes (MWCNTs) and short steel fibers (SSF) reduce the weight loss on abrasion test, but reduce values of flexural module (except for the addition of 5% of MG). In terms of electrical properties, fillers showed tendency to increase the electrical conductivity mainly for reduce fraction of fillers added, showing that higher contents can produce a non-homogeneous structure since that the mechanical and wear properties were affect in the same order.

Keywords— Composites, carbon fiber, wear resistance, mechanical properties, conductive filler.

I. INTRODUCTION

Manufacturing techniques and development of composites have attracted increasing interest mainly due to its applications in the aerospace industry, such as military or civil aviation. Composites based on epoxy resin reinforced with directional carbon fiber had presented excellent corrosion and mechanical properties (mainly the high specific strength), allow greater freedom in order to obtain structural parts and are still promising to reduce maintenance and operation costs of aircraft. According to Librantz (2006) [1] the substitution of aluminum for polymer composites can result in a reduction of up to 30% on the final weight and 25% in acquisition costs of structural parts.

Use of fillers can improve mechanical strength and abrasive wear. A frequent question when reinforcing or adding fillers in composite materials is on the improvement of other interesting properties such as mechanical and wear abrasion strength, essential for building aircraft. Very pronounced effect on aircraft crashes due to dust particles, sand, ice that generate significant cost in terms of maintaining the areas exposed to these events. Although the carbon fibers possess sliding characteristics, their structure is different from carbon black or graphite. In this case, the incorporation of these materials on composite laminate can improve the wear characteristics around the failure mechanisms, like a fiber thinning, fiber-matrix debonding and fiber pull-out and low cycle fatigue [2]. The author also refer that the carbon fiber provides less wear resistance and higher coefficient of friction than glass fiber. According to Takeichi (2008)[3] the reinforcement with carbon black decreases linearly the friction coefficient of PTFE composites. Nanometric particles (around 25 to 38nm) were used in this work. The 10% mass of carbon black was the best concentration for the highest wear resistance.

It is the knowledge that the process variables affect the wear and friction of samples. Wan et al (2006) [4] evaluated the wear rate and coefficient of friction of carbon fabric reinforced epoxy resin composites. The results showed that fiber volume fraction and testing conditions (load and velocity) affected the wear more significantly than the friction. It was also found

that fiber–matrix bonding had an impact on the friction and wear of the 3-D composites. Furthermore, the specific wear rate decreased with the increase in the product load and velocity. On the other hand, the addition of different kinds of fillers with sliding characteristics is less studied by the authors. Besides providing slip characteristics, the added particles may have the role of retaining wear or tearing of the material due to its greater mechanical strength when compared to the polymer matrix.

Given the characteristics of conductive carbon fibers used in composites, these materials are also intended for electromagnetic shielding. In general, this class of materials and fillers used for this purpose are known as radar absorbing materials (RAM), which promote the conversion of electromagnetic radiation by heat or by reflection [5]. There are a wide variety of electronic devices that require protection against electromagnetic waves provided by telecommunications companies, for example. The characteristics of higher electrical conductivity in the primary structural parts of an airplane are destined for dissipation of electrical discharges received by the aircraft. Can be also useful to return of electrical current from the generator. In this sense, these devices that perform essential functions during flight need to be isolated by conductive boxes which dissipate the incident waves or even omitted [6]. The absorption is given basically by two distinct categories of absorbers: the dielectric and magnetic. Conductive fillers are used to control only the complex permittivity and can be added in smaller proportions compared with the magnetically fillers absorbing [7] because the characteristics of lower density.

The carbon fibers are promising in this kind of application; they reflect the incident waves due to its high electrical conductivity [8]. Among the fillers with dielectrical absorption, the addition of carbon particles, graphite or metal sprayed into polymer matrices are the materials most commonly used for this purpose [5]. In the work of Kim et al (2009)[7], composite laminates of fiberglass sealed by epoxy resin with addition of carbon nanotubes have been suggested as suitable for absorption of electromagnetic waves. However, a layer of composite carbon fiber/carbon nanotubes intending in this case the reflection of the incident waves. For the structural and physical characteristics, the carbon nanotubes can reach the percolation threshold of the material with more modest concentrations which is interesting due to lower variation change of other material properties, especially mechanical.

The use of alternative fillers such as short steel fibers can be beneficial to composite in terms of the high conductivity observed for most metals and infer better mechanical properties with relative cost often less than some synthetic fillers. Some authors like Mamunya et al (2002) [9] evaluated thermal and electrical properties of composites with copper and nickel powders and obtained improvement on both properties. Studies with low cost and no-powder fillers like short steel fiber are still poor and become interesting since those benefits can be very useful. This work aims to investigate the maintenance of the mechanical properties and improved electrical properties and wear resistance for composite laminates based on carbon fiber and epoxy resin with the addition of conductive fillers, including: micronized graphite (MG), multi-walled carbon nanotubes (MWCNTs) and short steel fibers (SSF).

II. MATERIALS AND METHODS

2.1 Materials

The epoxy resin used in this study was EPOCAST 52-A of Huntsman. Carbon fibers of type "plain wave" in the form of woven oriented alternately, with 0 and 900, respectively. The average thickness of the blanket was 0.095 mm.

In this study we used natural crystalline micronized graphite (MG) of Nacional de Grafite company, with diameter of 5 ± 2 micrometers and purity level exceeding 95%. Multi-walled carbon nanotubes (MWCNTs) from MER corp. company with an average diameter of 140nm and length of 7 μ m. The short steel fibers (SSF) were provided by Bombril company with aspect ratio of approximately 10.

2.2 Sample fabrication

Samples of carbon fiber and epoxy resin were obtained by manual lamination with final dimensions of 100 x 100 mm. The same orientation of the fibers was maintained during the overlap of all layers. To warranty precise control to physical dimensions, the thickness was maintained at a value close to 1 mm with the aid of a spacer obtained through techniques of rapid prototyping. Overlapping layers occurred on a hard flat surface previously covered with a layer of mold release agent in order to facilitate the extraction of the part after cure. The proportion of resin/hardener used was 2:1, mixed with speed and

time previously determined. The conductive fillers were firstly mixed on the hardener because the lower viscosity. Figure 1 shows the experimental procedure of mixture.

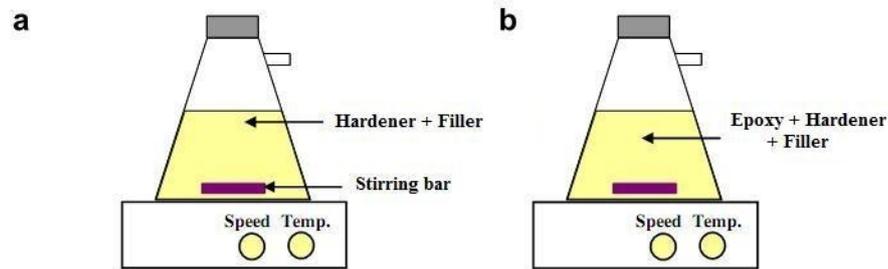


FIGURE 1: Manufacturing process of composites based on carbon fabric, epoxy resin and conductive fillers, showing the prior mixing with hardener (a) and pos-mixing adding the resin (b) (Adaptated from Kim, 2009)[10].

Samples were obtained with five layers of woven carbon fiber soaked with about 1.85 g of resin for each layer. The procedure of cure was conducted in two steps: 1) 24 hours at room temperature under the action of a standard weight and 2) Thermal curing at 60, 85 and 155 °C for one hour at each level.

2.3 Electrical properties

To obtain the electrical conductivity values of samples of epoxy resin with and without fillers reinforced with bi-directional carbon fiber was used a two-probe test. With this method was possible to obtain a direct measure of electrical resistivity knowing the voltage (V) and current (A) that flows through the sample under effect of a dc electrical field. It was necessary in this case the knowledge of geometric dimensions in order to warranty safe results [11]. To measures was used an electrometer Keithley Instruments Model 6517, with a source current DC voltage source Keithley Model 224.

Voltages (V) measures were recorded by applying an electrical current that could vary in the range of nano to milliamps. The dimensions (length, width and thickness) were used to calculate the initial resistivity and then the electrical conductivity of the material. The dimensions set for the test were squares with 10 mm side and a thickness close to 1 mm.

Figure 2 shows a simplified sketch of measuring method used for electrical conductivity acquisition. The current is applied across the sample and the voltage is detected by the equipment. A low pressure was applied on the extremes in order to warranty a good contact between components.

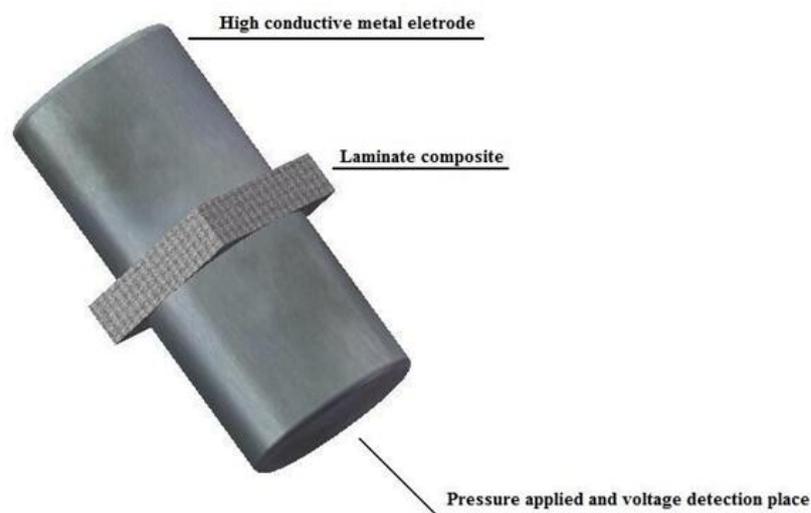


FIGURE 1: Sketch of two probe measure method

The values of electrical conductivity (σ) were obtained using firstly the second law of Ohm represented by electrical resistivity (ρ) ($\Omega \cdot \text{cm}$) of material calculated using the equation 1. This equation considers that electrical characteristics are dependent of geometric dimensions of sample. The σ values discussed in the text were obtained by the inverse of resistivity measures (2) given in $\text{S} \cdot \text{cm}^{-1}$.

$$\rho = RA/L \quad (1)$$

Where R is the resistance (Ω), A is the area of section on direction of current (cm^2) and L is the length (cm) between two points analyzed.

$$\sigma = 1/\rho \quad (2)$$

2.4 Mechanical tests and wear resistance

Mechanical properties of laminated composites with and without fillers were tested in bending mode using a DMA Q800 equipment from TA instruments. Flexural modulus was the main property analyzed. The tests were conducted at controlled force mode with single cantilever clamp, the loading rate used was 2N/min at room temperature.

The abrasive wear strength of each composition was evaluated using the equipment model TABER 3155. The mass loss of the material was evaluated of each 1000 cycles, with a total of 10,000 cycles at the end of the test.

2.5 Morphology

The main objectives of the morphological analysis were the observation of the fracture and the adhesion between fiber and resin, therefore the test pieces were made by the cryogenic fracture of the composite material. The method used to obtain the test pieces was the immersion of the material in liquid nitrogen for 30 seconds, so the material would become considerably brittle, and consecutive application of bending solicitation until the complete fracture of the material.

Afterwards, morphology observations were made on the JEOL JSM-6390LV Scanning Electron Microscope, with magnifications between 70 and 600X, at the 11kV accelerating voltage. The fracture surfaces of the test pieces were observed to analyze the type and reason of fracture, and the regions where were located pull out of the fiber, to analyze the adhesion between the materials.

III. RESULTS AND DISCUSSION

3.1 Electrical behavior

Figure 3 provides a comparison between the electrical conductivities for the composites with different fillers evaluated in this work. At higher concentrations, the conductivity values decreased in all cases. The addition of MG was more favorable in terms of improvements in the electrical characteristics when added small concentrations of filler. In the case of MWCNTs, all fractions had reduced levels compared to composite without adding any filler. Results obtained by Oh et al. (2004) [12] before manufacturing and testing epoxy composites with the introduction of many contents of carbon black (5 to 20%wt) also identified that addition of lower contents of fillers is responsible for better mechanical and electrical properties to the construction of a radar absorbing structure (RAS). The content indicated was 5 and 7% wt, performing a similar result obtained in this work considering the similarity of fillers.

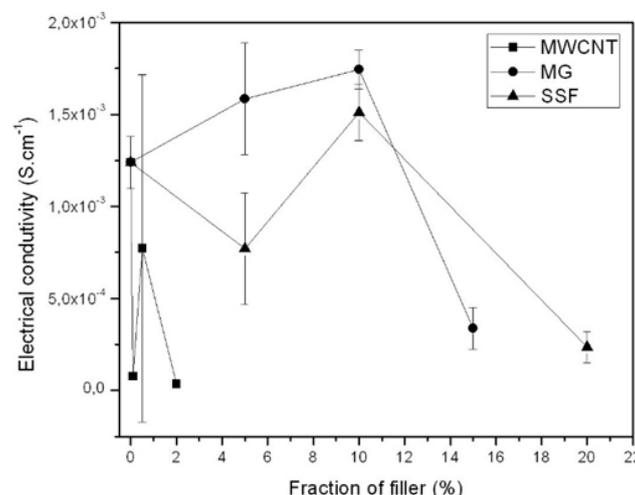


FIGURE 3: Electrical conductivity values for composites with different fillers and contents.

Graphite and carbon black are important fillers when conductive or electromagnetic/radio frequency shielding applications are necessary. Azim et al (2006) [13] evaluated the addition of these fillers to obtain organic-based coatings for referred

applications. The authors determined that high quantities of fillers are necessary to obtain minimum resistivity in order of $2 \times 10^{-5} \Omega\text{m}$. The amount indicated was approximately 40%wt. The results determined in this work revealed that conductivities values are in the semiconducting range and the order of magnitude was not significantly modified when comparing the fillers added. In this case, the carbon fibers can be providing the major conducting capacity. Since that the content of MG added is considerably very low, the behavior of improve electrical properties was proved and major changes can be observed just with introduction of bigger contents of conductive fillers, especially MG.

3.2 Mechanical properties

Figure 4 shows a comparison for the composites with MG added in different proportions. The curves have remained with very low linear distortion due to the rigidity of the material. With 5% by weight of MG has been verified an increase in material stiffness for the material without filler. With the introduction of 10 and 15% in weight it was observed a small reduction in the values of flexural modulus.

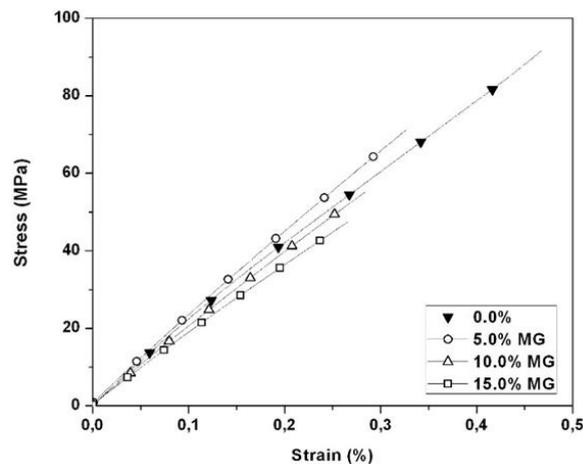


FIGURE 4: Stress X strain curves for different fractions of micronized graphite (MG) and material without conductive fillers.

Figure 5 shows a comparison for the composites with MWCNTs added in different proportions. The addition of growing MWCNTs contents in the laminate composite provided a gradual reduction in the values of flexural modulus. The smaller size characteristic of MWCNTs and consequently the difficult to disperse this material consist on a possible reason of drop on mechanical properties because of the agglomerate's formation. Bigger contents of MWCNTs are subject more easily to this effect. Zhou et. al (2008) [14] obtained an improvement of 15-20% with the addition of 2%wt of CNf. Yet, increments were acquired by a high-intensity ultrasonic liquid processor to disperse the fillers homogeneously. The specimens were manufactured in a vacuum-assisted resin transfer molding consisting of a more favorable processing to obtain composites without structural defects.

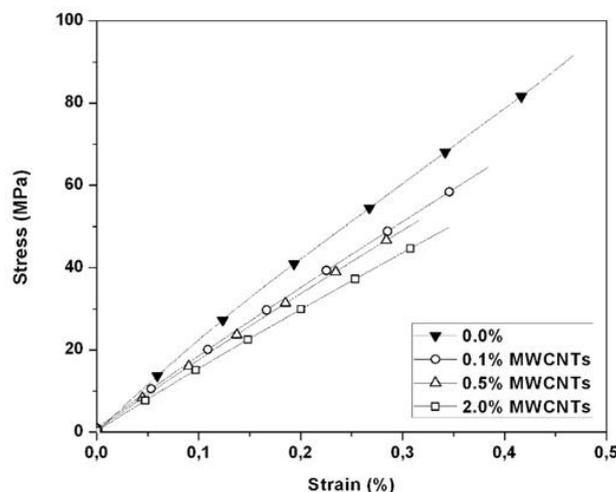


FIGURE 5: Stress X strain curves for different fractions of MWCNTs and material without conductive fillers.

Figure 6 presents a comparison for the composite with added SSF in different proportions. With the incorporation of 5% by weight of SSF the curve and values of flexural modulus remained virtually unchanged, on the other hand the addition of 10 and 20% caused a reduction in stiffness of the material. The difficult to mix and disperse high quantities of filler is a responsible fact to cause this behavior.

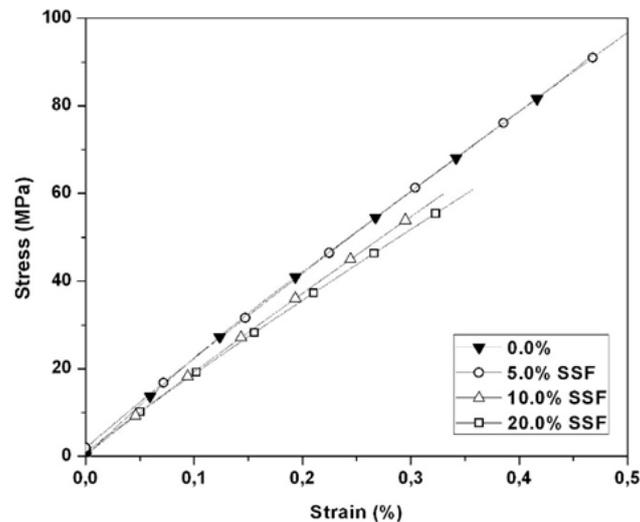


FIGURE 6: Stress X strain curves for different fractions of short steel fiber (SSF) and material without conductive fillers.

Figure 7 presents a compilation of flexural modulus values for all the compositions evaluated. In general, only the addition of 5%wt of MG produced an increase in the values of the module. Another interesting feature was the correlation of increase in the percentage of fillers with the gradual reduction of material stiffness. One of the likely causes for this effect was the difficulty of dispersion found in these cases, which can cause the formation of clusters that reduce the mechanical properties by constituting themselves centers of defects generator.

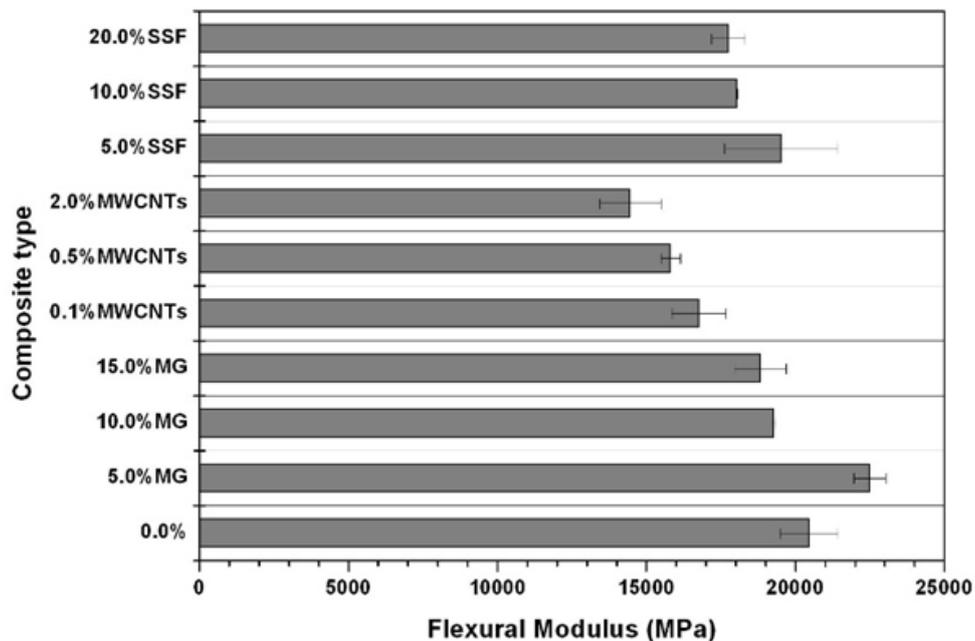


FIGURE 7: Summary of flexural modulus values obtained for composites with and without addition of conductive fillers.

There is a concern around the authors about the difficult on introduce and mainly disperse the nano-scaled fillers. Work produced by Fiedler (2006) [15] evaluated the characteristics and properties generated by filler of different sizes given more attention for CNTs as nano fillers in polymers, but also the limitations and challenges one has to face dealing with nanoparticles. A necessity of a proper dispersion as well as a possibility of orientating CNTs was shown, in order to attain the

best possible properties. These limitations were verified in this work since that the MWCNTs do not presented their expected potential. The same incorporation method practiced for all fillers show that the nano fillers are more suitable to agglomeration comparing to the others.

3.3 Morphology

Figure 8 shows both laminate carbon fiber composite without filler incorporation and the same composite with different fractions of MG. The addition of MG did not change the level of porosity on the resin matrix, showing that the mixture step was successfully developed for all contents. Considering that the specimens were laminated without vacuum-assisted system, some residual closures were expected, as verified on the SEM analysis. It was clearly verified the layered structure of pure resin and resin plus carbon fibers, indicating that the resin flow during the curing step created an intermediate layer located between two fibers woven. On higher magnifications it is possible to see the pull-out of carbon fibers, representing a satisfactory moliability by the resin. It is also revealed places where delamination was more pronounced, like on the composite with 5.0% wt of MG (fig. 8d). By analysis of the fracture behavior, the start of crack was observed on fig. 8b, evidencing that the contact place between fiber and resin is critical for failures.

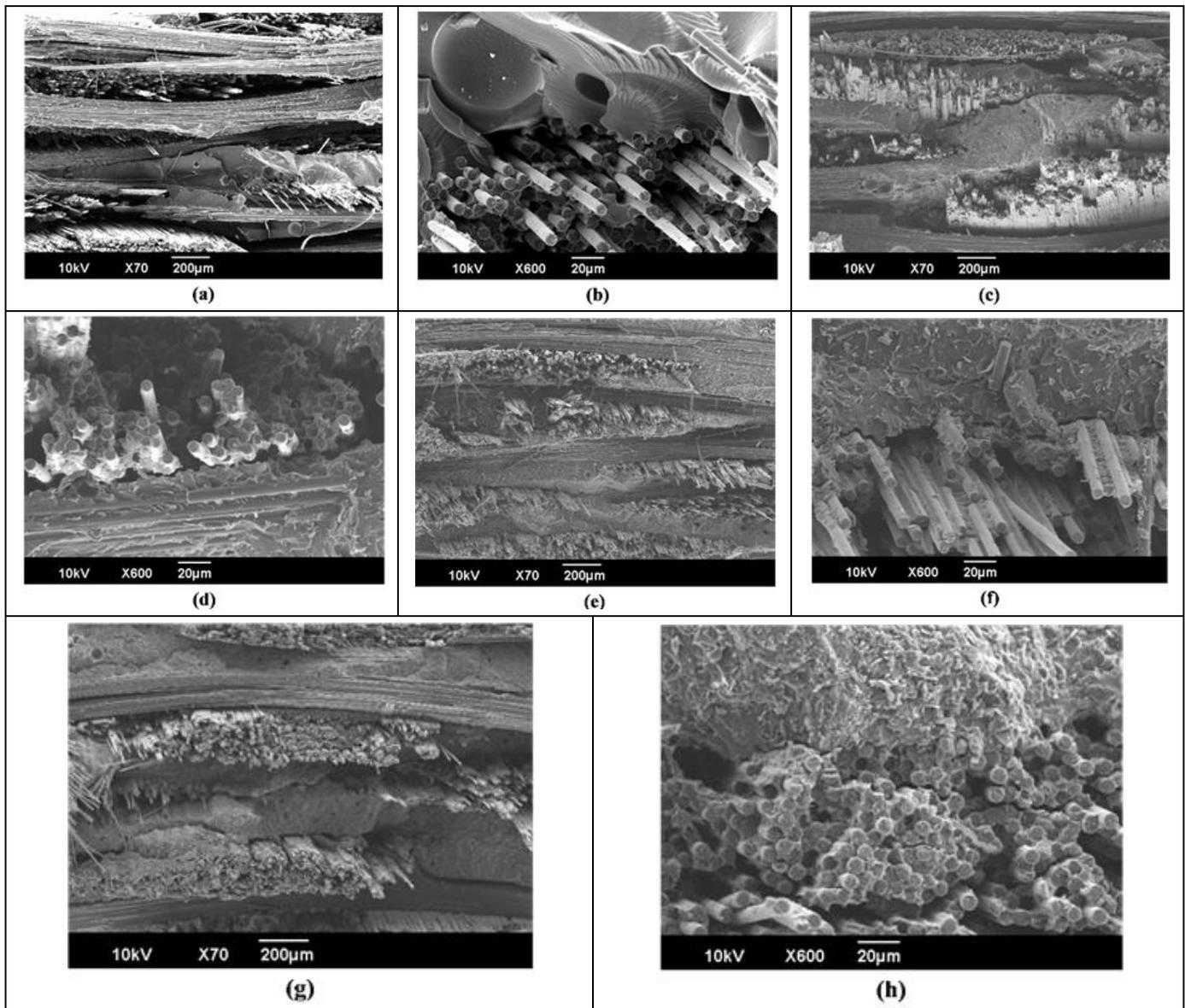


FIGURE 2: Microstructure comparison between laminate (CF) without fibers (a and b) and with addition of 5.0%wt MG (c and d), 10.0%wt MG (e and f) and 15.0%wt MG (g and h) under different magnifications

Figure 9 shows the comparison between laminate carbon fiber composite without filler incorporation and the same composite with different fractions of MWCNTs. The layered structure obtained presented more uniformity when added 0.1 and 0.5% wt of MWCNTs, in contrast with the composites containing 2.0% of MWCNTs, which shows the difficulty in the mixture step. The delamination was more pronounced with higher fractions of filler, both in between matrix-fiber and fiber-fiber. The porosity distribution was practically unaltered.

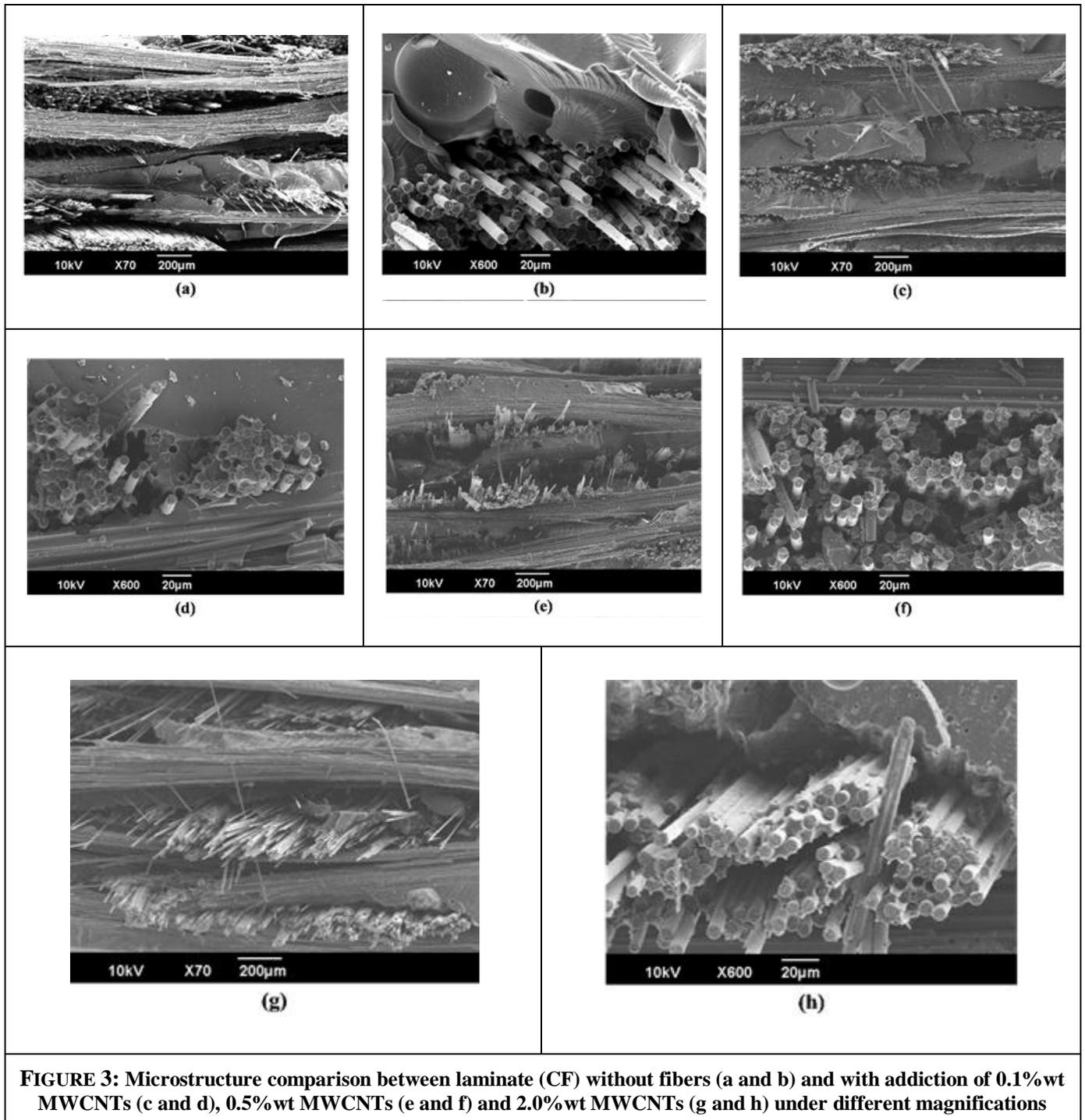
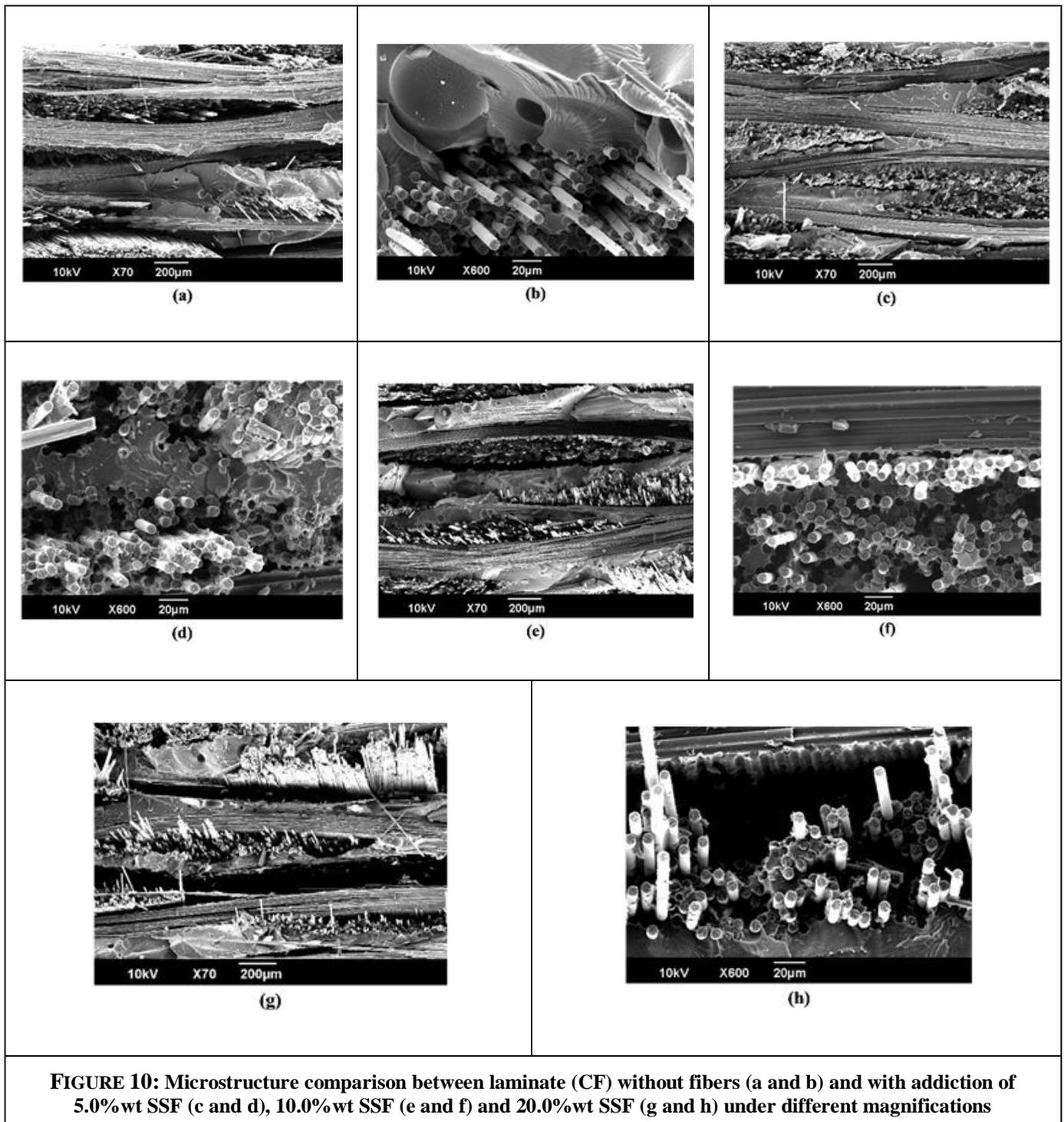


FIGURE 3: Microstructure comparison between laminate (CF) without fibers (a and b) and with addition of 0.1%wt MWCNTs (c and d), 0.5%wt MWCNTs (e and f) and 2.0%wt MWCNTs (g and h) under different magnifications

Figure 10 compares laminate carbon fiber composite without filler incorporation and the same composite with different fractions of SSF. It was not verified great changes on uniformity and porosity across the sectioned specimens. Increasing the fractions of SSF added on the matrix, the adhesion between fibers and resin became poor, mainly with the incorporation of 20.0% wt SSF, shown in fig. 10h.



3.4 Wear behavior

Figure 11 shows the respective weight losses for the composites with and without addition of MG. For all ratios of fillers, the weight loss at the end of 10,000 cycles was approximately 0.005 g, amount considerably less than their loss to the composite without fillers, which was about 0.030 g. The crystalline structure, characteristic of graphite, that present character of slip and therefore self-lubricating, can be the explanation for the reduction in weight loss. Since the wear behavior has not changed with the increase in the percentage of the fillers, it appears that the addition of 5% by weight already promotes a saturation property. It was possible to notice that the change of weight loss behavior was verified before 3,000 cycles, indicating that the initial time is responsible for accommodating the wheels over the sample and removing the residual mold release agent. This phenomenon was observed in all experiments realized.

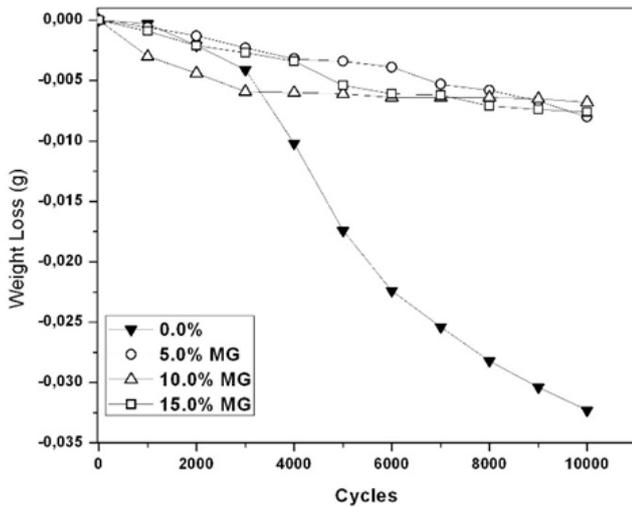


FIGURE 4: Comparison of mass loss for different concentrations of micronized graphite (MG) in relation to the composite without filler

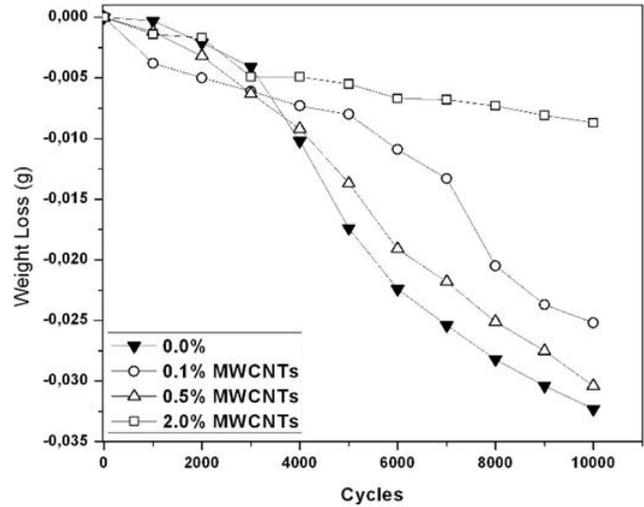


FIGURE 5: Comparison of mass loss for different concentrations of MWCNTs in relation to the composite without filler

Figure 12 shows the corresponding weight loss for the composites with and without the addition of MWCNTs. The loss with addition of 0.1 and 0.5% by weight does not change significantly the values of weight loss comparing with the composite without added charges. Only with the addition of 2.0% by weight, the values were close to those obtained with the 5.0% MG addition with maximum loss of 0.005 g. The crystalline nature of MWCNTs can explain the results if compared with addition of MG.

Figure 13 shows the corresponding weight loss for the composites with and without addition of SSF. The addition of 5% of SSF reduces significantly the weight loss, from 0.030 to about 0.010 g. Only at 10 and 20% weight the losses were near the samples with addition of 5.0%MG.

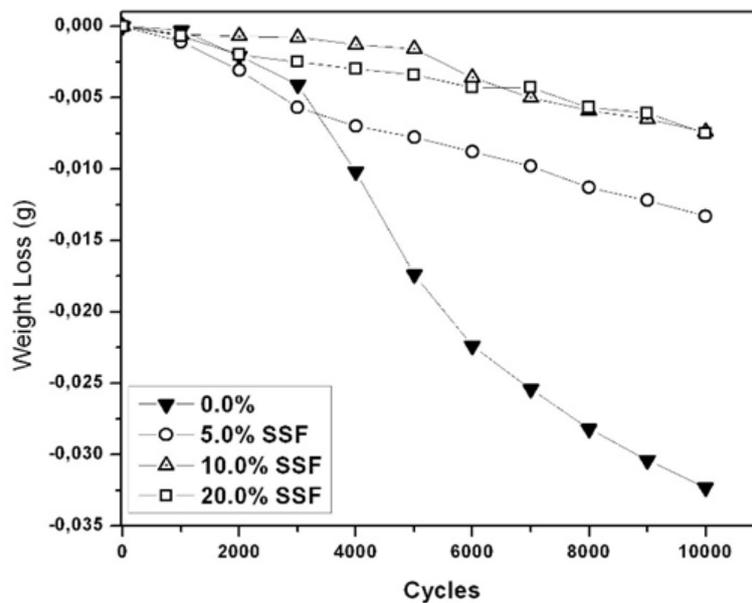


FIGURE 13: Comparison of mass loss for different concentrations of short steel fiber (SSF) in relation to the composite without filler.

The general analysis of the results of wear strength and their weight loss, the minimum values of 0.005 g were obtained with different fillers and concentrations, as follows: 10 and 20% of SSF, 2.0% of MWCNTs and from 5.0% of MG. In this sense the graphite has better wear characteristics with lower amounts of filler related to the cost of material.

Research developed by Chen et al (2007) [16] studied different mixture methods and surface treatments on carbon nanotubes. Among other results identified, acid treatment and coupling agent are not necessary because the as-received MWCNTs are already responsible for good results for tribological properties. In this case, the tribological results verified in this work are not correlated with the dispersion level of MWCNTs. SSF and MG generated lower loss weight because of structural or physical properties.

IV. CONCLUSION

Considering the effect of adding fillers for improving mechanical and electrical properties, the percentage of 5%wt of MG composite produced the best combined properties. In all three cases, the addition of high concentrations of filler caused a decrease in electrical conductivity and flexural modulus values, indicating a poor dispersion in the resin matrix and likely increasing the distance between the layers of carbon fiber, expected like most responsible for conduction. The percentage of MWCNTs evaluated at this work did not present a significant change in the electrical conductivity.

Morphological analyzes showed that the increasing of filler fraction made the adhesion more difficult, resulting in problems of delamination. The fillers added cannot be seen by electron scanning microscopic, attributing a successfully mixture method, therefore the bundles of fillers were not verified on the cross section of cryogenic fractured specimens.

The wear strength for weight loss had similar results for the addition of MG and SSF, with a mean value of 0.005 g. With the addition of MWCNTs, occurred a larger loss of mass of the order of 0.030 g. The difference in the chemical structure between the graphite and MWCNTs may explain the changes on properties analyzed. The MG material has sliding characteristics and MWCNTs, with their crystalline structure, does not have functionally slip planes.

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Design and Manufacturing of X-Shape Quadcopter

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Abstract— A quadcopter is a form of unmanned aerial vehicle with several rotors. Surveillance, military operations, fire detection, agriculture, spyware, and a variety of other applications are all new to it. Because of their dependability, cost effectiveness, and multi-functionality, they are frequently used in many locations. This article details the design process, including component selection and manufacturing of X-shape quadcopter.

Keywords— 3D printing, manufacturing, Quadcopter, x-shape.

I. INTRODUCTION

A quadcopter, often known as a quad rotor helicopter or quad rotor, is a multicopter with four rotors that lift and propel it. Quadcopters are categorised as rotorcraft rather than fixed-wing aircraft since they employ a set of rotors to generate lift (vertically oriented propellers). Quadcopters, unlike most helicopters, have two sets of identical fixed pitch propellers: two clockwise (CW) and two counter-clockwise (CCW) (CCW) as shown in Fig. 1. The lift and torque are controlled by varying the RPM. Changes in the rotation rate of one or more rotor discs change the torque load and thrust/lift characteristics of the vehicle, allowing it to be controlled [1].

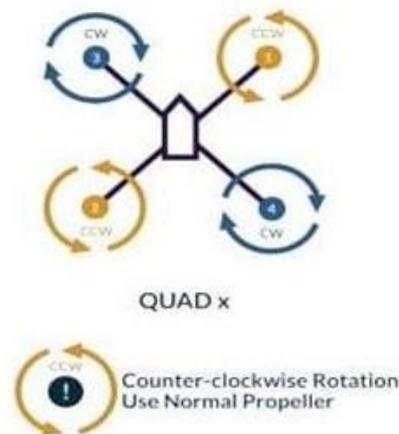


FIGURE 1: Propeller configuration of quadcopter

II. QUADCOPTER FRAME TYPES

There are a variety of frame styles, all of which are determined by the position of the arms as well as the size and shape of the electronics carriage. Each frame type is described in detail below, along with a graphical sample [2]

2.1 True-X shape

The X-frame is the most symmetrical, with more weight concentrated at the centre of gravity, which improves stability but also increases the quadcopter's vulnerability to aerodynamic disturbances. Because the arms are sandwiched between the main plates, this design necessitates the use of more material. In this design, there isn't much room for hardware. This will be a problem for the project because the motor and fuel tanks will take up a lot of room, and the flight controls and cargo must also fit in. Because the flight controller and camera are so close to the motor, the X-frame would compel all of these components to be virtually on top of each other, increasing the vibration problem. Stacking all of the components will

necessitate more structural material, increasing the quadcopter's weight. The shortage of space around the motor would make it difficult to integrate the components that drive the rotors, despite the design's simplicity. The True X is shaped in the same way it sounds, with X geometry and a motor at each end of the arms. As shown in Fig. 2, the perpendicular distance between the centres of each motor is equal, giving the quadcopter the same amount of stability on all axes [3].

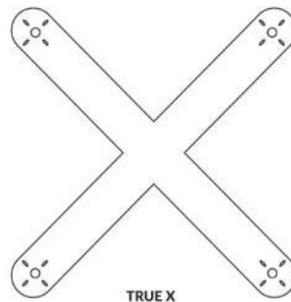


FIGURE 2: True X-shape quadcopter

Table 1 lists the benefits and drawbacks of the True X-shape quadcopter

**TABLE 1
BENEFITS AND DRAWBACKS OF THE X-SHAPE QUADCOPTER**

Description	Pro	Con
Little space for hardware		X
Good stability and control	X	
Higher derivation complexity due to lack of mounting space		X
More weight due to sandwiching mounting structures		X

2.2 Dead Cat

Larger quadcopter designs tend to embrace the dead cat look. Its goal is to obscure the propellers from view of the on-board HD camera by increasing the perpendicular distance between the two frontal motors, as shown in Fig. 3.



FIGURE 3: Dead Cat-like quadcopter



FIGURE 4: H style quadcopter

2.3 H-Shape

Another antique quadcopter design style is the H style. The arms of a H quad are positioned in front of a long "bus" shaped carriage as shown in Fig. 4. The H quad has recently fallen out of favour due to its hefty dimensions and odd configuration.

2.4 Hybrid (Stretch) X Quadcopter

The stretch X is a wide X that has been rotated as shown in Fig. 5. Racers that want additional stability on the pitch axis, which might help with control when the quadcopter is racing at high speeds, prefer the stretch X.

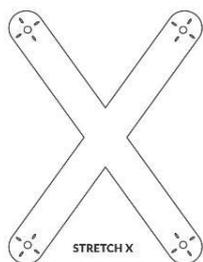


FIGURE 5: Stretch X quadcopter



FIGURE 6: Plus shape quadcopter

2.5 Plus Shape Quadcopter

The footprint of a plus frame is the same as that of an X frame flipped 45 degrees as shown in Fig. 6. A plus frame has the advantage of each motor being responsible for rotating movement in only one axis, theoretically allowing for finer control. Plus frames, on the other hand, are more prone to breaking because most impacts only involve a powerful contact to the front arm.

III. COMPONENT'S SELECTIONS

3.1 DC Brushless Motors

The propellers are spun by the motors to provide lifting thrust to the drone. Brushless DC motors are almost always used in drones because they give better thrust-to-weight ratios than brushed DC motors. Kv ratings and current ratings are the most common ratings given to motors. For 1V of applied voltage, the Kv rating shows how rapidly the motor will spin (RPM). The maximum current that the motor can safely draw is indicated by the current rating. As a result, we chose a Brushless DC motor of type (MT 2204-2300 Kv) for our project. Also, there are two types of brushless motors: in-runner (shown in Fig. 7) and out-runner (shown in Fig. 8), each with its own set of characteristics. In-runner brushless dc motors have low torque and high speed, whereas out-runner brushless dc motors have high torque and low speed. Since we require high torque but not high speed, we will use an out-runner brushless motor [4].



FIGURE 7: in-runner brushless motor



FIGURE 8: out-runner brushless motor

The characteristics of the chosen motor are listed in Table 2.

3.2 Propeller

A propeller is a fan that uses rotational motion to generate thrust. Propellers are generally characterized by their diameter and pitch, and are represented as a product of diameter and pitch. There are several varieties of propellers, the most common of which are nylon and carbon. For our project, we chose a plastic propeller. The dimensions of each propeller are inscribed on it, for example, 10 *4.5, which implies the length is equal to 10 and the pitch is equal to 4.5, as seen in Fig. 9 [5].

**TABLE 2
CHARACTERISTICS OF THE SELECTED MOTOR**

Motor KV (RPM/V)	2300 KV
Maximum Thrust	450 gm
ESC	18A
Li-PO Batteries	2-3S
Propellers	6 - 8 inch
Weight (gm)	25gm
Power	51 Watt



FIGURE 9: Propeller of type (10*4.5)

3.3 Electronic speed controller

The electronic speed controller regulates the motor's speed or tells it how fast to turn at a specific time. Four ESCs are required for a quadcopter, one for each motor. Through either control appropriation board, the ESCs are officially connected to the battery. Each ESC has a current rating that indicates the maximum current it can provide to the motor without overheating. ESCs must be chosen carefully to guarantee that the motors receive enough current. Based on our estimates, we chose Simonk 30A ESC (Fig. 10) for our project. The characteristics of the chosen ESC are listed in Table 3.



FIGURE 10: ESC 30A

**TABLE 3
CHARACTERISTICS OF THE ESC**

cont. Current	30A
BEC Output	5V 2A
LiPO Batteries	2-3S
Weight	25gm
Size (L*W*H)	32*24*7mm

3.4 Battery

The battery provides electrical power to the aircraft's motors and electronic components. Lithium polymer batteries (Li-Po) are the most common battery used in drones due to their small weight, high energy density, longer run periods, and ability to be recharged, but they have the drawback of not waking up if the charge is totally depleted. We choose Battery (Zippy 3300) in Fig. 11 based on our calculations. Table 4 lists the characteristics of the chosen battery [6].



FIGURE 11: Battery

TABLE 4
CHARACTERISTICS OF THE CHOSEN BATTERY

Capacity	3300mah
Voltage	3s/11.1V
Discharge	40c constant/50c Brust
Weight(gram)	286g
Dimensions(L*W*H)	136*45*24mm

3.5 Video link

In order to do image processing, we must utilize a camera as well as a video link. For our project, we used a video link of type (Ts 832) as shown in Fig. 12.



FIGURE 12: Ts 832-video link

3.6 Remote control

The basic goal of R/C is to control the quadcopter remotely, and there are two conditions to consider while choosing the right one. The first is the amount of channels you'll require; in our case, we'll require four [X for Roller, Y for Pitch, Z for Yaw, and Throttle (to control motor speed)]. The range of control is the second criterion. It's a budget-friendly six-channel transmitter for models that require it. The transmitter contains an easy-to-reach retract switch and proportional flap dial, as well as elevon and V-tail mixing and servo reversing [7]. The R/C transmitter and receiver are shown in Fig. 13. Its main characteristics were as follows:

- (1) 6-channel 2.4GHz transmitter.
- (2) Servo reversing function.
- (3) Elevon and V-tail mixing options.
- (4) Built-in antenna.
- (5) Basic models control.
- (6) FHSS 2.4 GHz Technology.
- (7) 6-channel receiver.



FIGURE 13: R/C receiver and transmitter

3.7 Camera

Micro FPV Camera is selected; it has an input voltage of 5V, a resolution of 1024, a dimension of 21*19*17 mm, and a weight of 8 gm.

IV. PRELIMINARY DESIGN

4.1 General equation

A rough weight estimate is calculated in this section. The general weight estimate equation is

$$WGL = WE + WF + WPL + WCrew \quad (1)$$

WGL stands for the ground launch weight. WE is the empty weight. WF stands for "Weight of Fuel". The Payload Weight (WPL) is the total weight of the payload. The crew weight is W_{Crew} .

In drones, the weight of the fuel and the weight of the crew will be zero. As a result, equation (1) becomes:

$$WGL = WE + WPL \quad (2)$$

The empty weight (WE) includes the following components:

$$\text{Weight of Battery} = 286\text{gm}$$

$$\text{Weight of 4 Dc motors} = 4 \times 25 = 100\text{gm}$$

$$\text{Weight of ESC} = 4 \times 25 = 100\text{gm}$$

$$\text{Weight of 3D Printed Frame} = 526\text{gm}$$

So, the total empty weight becomes $WE = 1012\text{gm}$

The payload W_{PL} components includes:

$$\text{Wight of video link} = 22\text{gm.}$$

$$\text{Wight of camera} = 8\text{ gm.}$$

So, the total weight of the payload $WPL = 30\text{ gm}$

The ground lunch load W_{GL} will equal:

$$W_{GL} = 1045\text{gm.}$$

4.2 Estimation of brushless DC motor

$$W_{GL} = 1045\text{gm}$$

$$\text{The total thrust} = 2090\text{ gm}$$

$$\text{Thrust for each motor} = \text{Total thrust} / \text{Number of motors} = 522.5\text{ gm}$$

V. FRAME DESIGN

The difficulty lies in selecting the appropriate material for the quadcopter's construction, as it is necessary to obtain a material with sufficient strength and hardness to withstand the impact of motors, as well as the weights that will be carried by the quadcopter, such as the camera, battery, and other items, and to be able to take off without difficulty.

The frame design process is split into two parts: the first is choosing the material, and the second is choosing the fundamental dimensions. Another consideration in the design process is to make the angle between the axes of the motor positions 90 degrees, since this will improve the quadcopter's balance and stability. As shown in Fig. 14, the quadcopter's dimensions are 35 cm (Width)*35 cm (Length)*8.6 cm (Hight).

The quadcopter arm's frame is truss-style; a truss provides a solid form capable of carrying significant external load over a long span, with component sections strained predominantly in axial tension or compression. Individual parts meet at truss joints, also known as panel points. The top and bottom chords are the connected sections that comprise the top and bottom of the truss, respectively. The web of the truss, as shown in Fig. 15, is made up of sloping and vertical parts that link the chords.

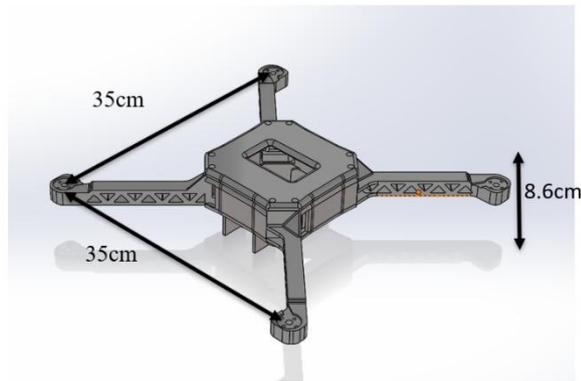


FIGURE 14: Configuration of Quadcopter

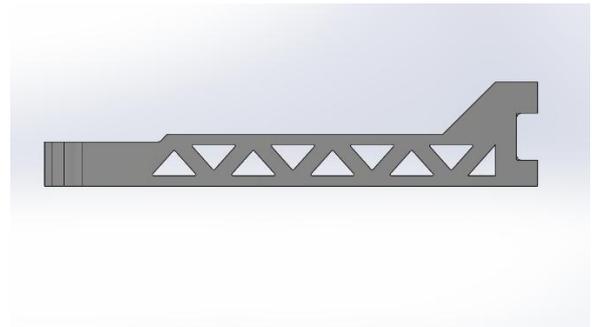


FIGURE 15: Quadcopter arm's frame

The motor's base requires some space to be more stable because of the vibrations that may occur during flight, and we provide space for the motor's wiring as illustrated in Fig. 16.

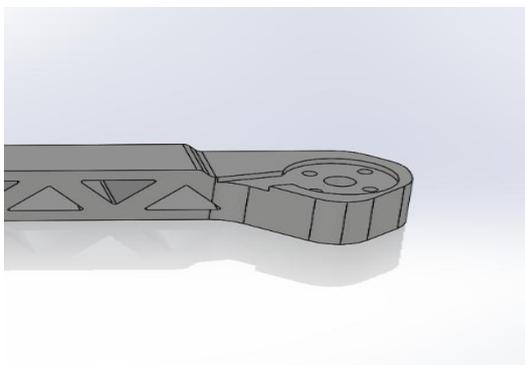


FIGURE 16: Motor's base

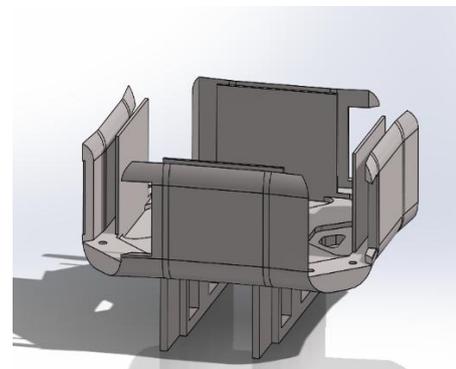


FIGURE 17: Quadcopter body

The main body of the quadcopter is designed as indicated in Fig. 17, and the battery is placed in the gap between the skirts. In the main body, drone accessories such as ARDUPILOT, ESCs, and cameras are coordinated.

The final arrangement of our drone is shown in Fig. 18.



FIGURE 18: Final arrangement of our drone

VI. AIRFRAME MANUFACTURING

The quadcopter airframe is manufactured using 3D printing technology. The 3D printing process builds a three-dimensional object, usually by successively adding material layer by layer, which is why it is also called additive manufacturing.

6.1 3D Printing

3D printing is a new way of manufacturing products. The general term used to describe 3D Printing in all its guises is Additive Manufacturing. As mentioned previously a product is built by adding layers. The definition and quality of the

product is dependent on the size of the extruder or layering height as well as the resolution of the design software [8]. The 3D model of the airframe is drawn using Solid Works 2018.

In this Project PLA material is used for Quadcopter frame manufacturing. PLA is a common thermoplastic polymer derived from natural sources such as corn starch or sugar cane, in contrast to many other thermoplastics which are produced from non-renewable sources such as petroleum. From automotive to food packaging, a range of industries are using PLA to produce 3D printed products [9, 10]. The advantages of PLA are:

- Low printing temperature
- Ease to use
- Variety of color and blending options
- Easy post-processing

Although 3D printer (Fig. 19) settings vary depending on the type and blend of PLA filaments, there are some basic requirements and specifications listed below to ensure a successful printing process:

- PLA melting point: 150-160°C
- PLA printing temperature: 180-230°C
- Heated print bed: optional
- Cooling: part cooling fan is necessary
- Enclosure: not necessary
- Filament storage: airtight container



FIGURE 19: 3D printer

Fig. 20 shows some components of airframe using 3D Printer. Fig. 21 shows the final arrangement of the present X-Quadcopter.



FIGURE 20: 3D printed airframe parts



FIGURE 21: Final arrangement of the present X-Quadcopter

VII. CENTER OF GRAVITY ESTIMATION

The suitable location of the center of gravity is to be in mid of drone that's make control on drone easier and it make drone stable.

So, depending on components weight, it distributed on the drone such that position of center of gravity remains at mid point. The isometric view is shown in Fig. 22.

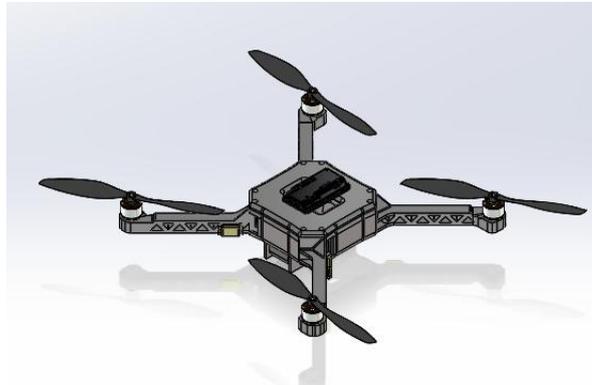


FIGURE 22: Isometric view

VIII. CONCLUSION

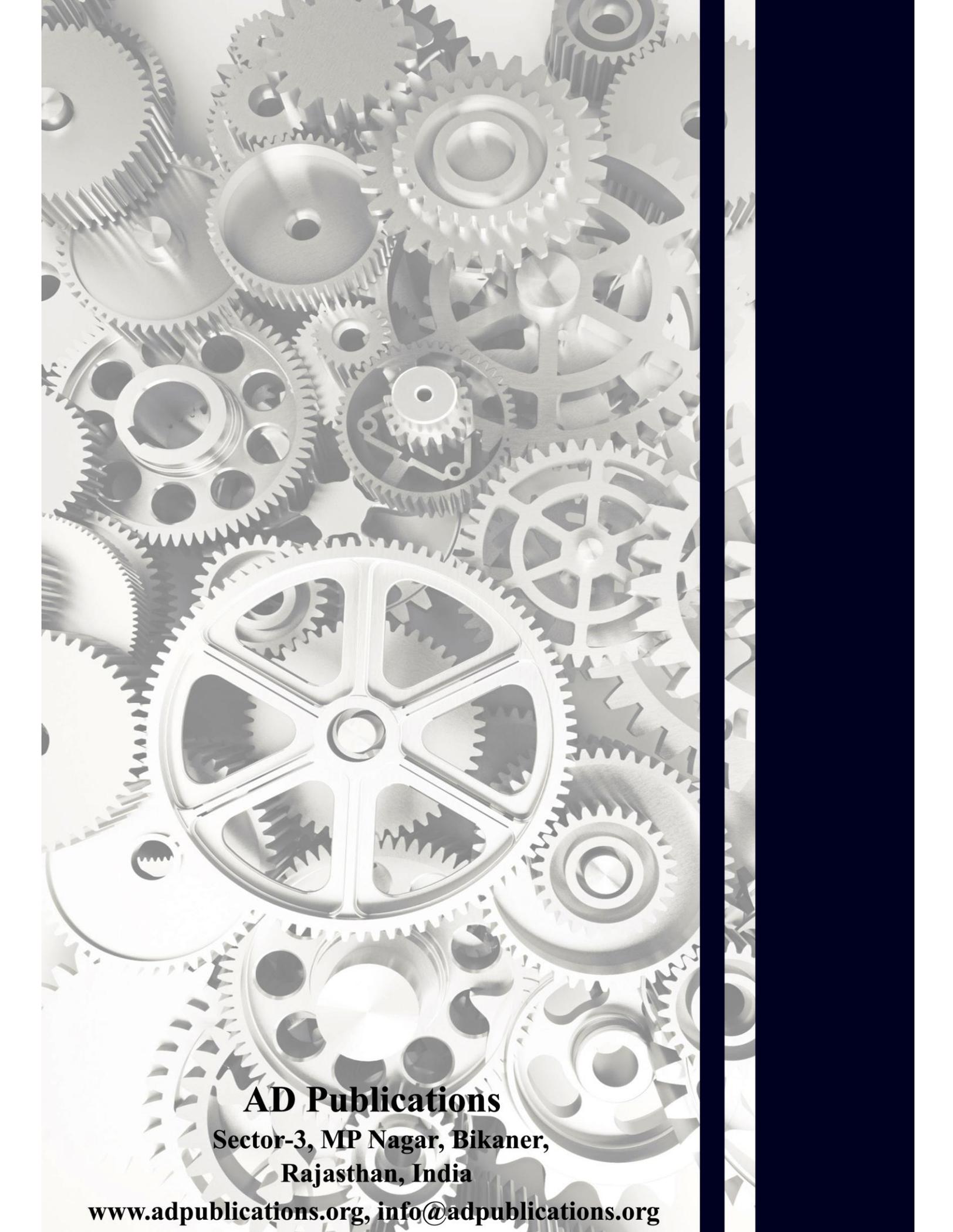
Using Solid Works 2018, the frame of quadcopter is designed and manufactured using 3D printing technology with PLA-Plus filament. The main components are chosen depending on calculations. Based on the calculations, the suitable distribution of the components is done to reach the best center of gravity point to get the best balance possible.

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