Applying Glass Fiber-Reinforced Composites with Microsphere Particles to UAV Components

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Nomenclature

GC	Glass fiber chopped strand mat
GM	Glass microsphere
GP	Glass fiber plain-woven fabric
UAV	Unmanned aerial vehicle
wt%	Percent of weight

1 Introduction

UAVs are widely employed in urban and remote areas due to their specific ability. UAVs are developed and improved to provide better responsiveness by using mathematical models (i.e., fuzzy control system, PID control) and equipping them with mission-specific equipment to perform a variety of missions (Sudtachat et al., 2017; Kerdphol et al., 2021; Phunpeng & Kerdphol, 2021). The structure and surface of the UAV must be lightweight to reduce the load on the UAV, leading to longer operating and more productive UAVs.

The design and material selection for UAV manufacturing has a significant impact on operational efficiency. Polymer-based composites have strength-to-

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weight advantages over other materials. As a result, polymer-based composites are used to make various parts for UAVs including landing gear and wings. Reinforcement fibers such as carbon, aramid, and glass fibers are also employed in polymer composite materials. According to Wong et al., plain weave laminates have higher tensile, bending, and inter-sheet shear strength than chopped strand mat (Wong et al., 2018).

One approach to improve composite properties is to combine fibers with fillers. Carbon nanotubes and glass microspheres have been widely used as fillers to enhance characteristics and satisfy application requirements (Megahed & Megahed, 2017; Phunpeng & Baiz, 2015). To reduce the cost of composite components, accessible fillers might be utilized. Glass microspheres (GM) are used in the epoxy matrix because they have a lower density than epoxy, resulting in a lighter product. The fracture and impact behavior of hollow microsphere/epoxy resin composites were investigated by Kim et al. The results show that the amount of GM content affects the properties of composite materials (Kim & Khamis, 2001). J.A.M. Ferreira studied the mechanical performance of epoxy matrix composites using hollow glass microsphere fillers and short fiber reinforcement. According to previous research, increasing the filler content in unreinforced composites reduces the flexural impact including absorbed energy (Ferreira et al., 2010; Huichao et al., 2018).

A multitude of techniques may be used to manufacture composite materials. Hand lay-up comes out as a standout approach due to its inexpensive cost and less complex technology (Chandramohan et al., 2019). In terms of cost and time reduction, the hand lay-up method is the most outstanding choice in student UAV. Mohan et al. present a hand lay-up technique using glass fibers and polyester resins. According to the results, the composite had an ultimate tensile strength of 306 MPa, flexural stress of 209 MPa, and impact strength of 151 MPa (Mohan et al., 2018). In terms of production, vacuum bagging techniques are equivalent to hand lay-up. Vacuum is used to aid in resin dispersion (Arpitha et al., 2017; Saensuriwong et al., 2021). This study presents a hand lay-up and vacuum bagging process at 100 °C to fabricate glass fiber-reinforced laminated composites with GM. The flexural characteristics of glass fiber-reinforced laminate composites with GM were compared. The flexural characteristics of the specimens fabricated are investigated by a universal testing machine (UTM).

2 Method

This section covers the materials utilized in composite fabrication, manufacturing process, and flexural testing according to ASTM D790.

2.1 Material Preparation

Chopped strand mats are randomly oriented and have similar strength in all directions. Chopped strand mats are less expensive than plain weave mats and have a lower strength. Because of its flexibility and strength, a plain weave mat is ideal for reinforcing materials. Glass fibers in the form of chopped strands and plain weave mats are used as reinforcing materials in this experiment, and ER550 epoxy resin and hardener are used as a matrix. Glass microspheres (GM) are used as a filler particle to evaluate the flexural properties when the filler content is modified.

2.2 Experiment Preparation

The polymer composite is produced by mixing the particles with epoxy resin (0%, 5%, 10%, and 15% by weight) and stirring by hand for 30 minutes with a glass rod before adding the hardener (100:35). Fiber-reinforced plastic laminates consist of eight layers of glass fiber oriented in the direction of $[0]_8$, following the hand lay-up approach. The curing temperature will be varied to perform the vacuum bagging process. The peel ply collects any excess resin before a vacuum pump connection to press the resin at −0.8 bar pressure. The temperature at 100 °C is used in the curing process (Table 1).

2.3 Flexural Test

Test specimens are prepared in accordance with ASTM D790. The subsequent procedure for testing is a three-point bend test. The universal testing machine is used for flexural testing with a displacement velocity of 5 mm/min. The rectangular test specimen is 191 mm × 20 mm × 2 mm.

Table 1 A designed method for experimental study (Phunpeng et al. 2022)

Fiber type	Glass microspheres as particles (wt%)	Specimens
Glass fiber chopped strand mat (GC)	0	GCF00
	5	GCF05
	10	GCF10
	15	GCF15
Glass fiber plain-woven fabric (GP)	0	GPF00
	5	GPF05
	10	GPF10
	15	GPF15

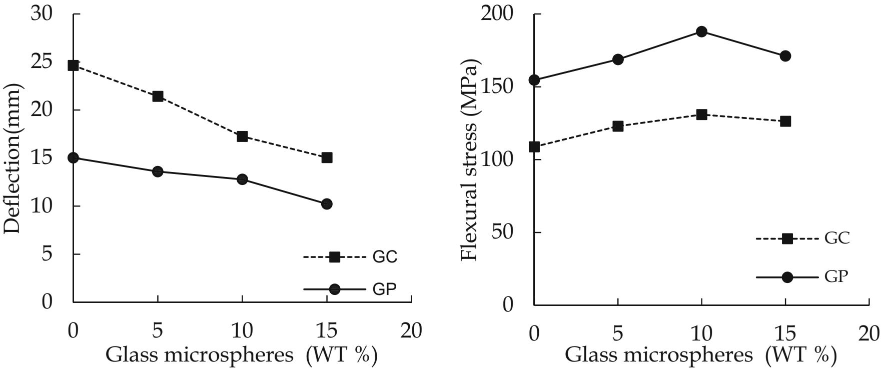
3 Results and Discussion

A study of the influence of GM particles on the bending properties of glass fiber-reinforced composites is performed using UTM in accordance with ASTM D790. In a flexural test, the force applied to the specimen causes strain and bending stress. This is because the strength value is affected by the amount of filler used and the curing temperature. The fillers generate more flexural stress, which improves fiber and matrix adhesion in the composite (see Fig. 1b).

The effect of GM on the deflection behavior of glass epoxy composites is shown in Fig. 1a. The composite deflection without GM filler is 25 mm. The stress behavior of fiber-reinforced epoxy composites is enhanced by adding 5% GM. On the other hand, when the GM content of the composites increases, the deflection behavior of the composites decreases. This might be due to the fact that fillers and resins interact less.

The addition of GM particles to glass fiber-reinforced composites increases the load tolerance of the composites significantly. This is due to the composite glass fiber and particle working together. The load is initially received by the matrix and transferred to the particles and fibers during the bending test. The fibers are supported by fillers that distribute the load throughout the network fillers. The interfacial bonding between fibers and fillers could effectively support the matrix in epoxy composites to endure bending strength. Figure 2 presents the load and strength values of materials obtained from flexural testing. Aluminum alloy has the maximum loading capacity (225 N), followed by GPF10 (100.93 N) and GCF10 (89.45 N). GPF10 has the ultimate flexural strength (189.24 MPa), followed by aluminum alloy (174.12 MPa) and GCF10 (131.23 N).

The landing gear of UAVs is generally produced by the aluminum alloy. Flexural tests are performed on it. Aluminum has a greater load tolerance and strength than



(a) **(b)**

Fig. 1 (**a**) Flexural stress variation with the percentage of GM content. (**b**) Flexural deflection variation with the percentage of GM content

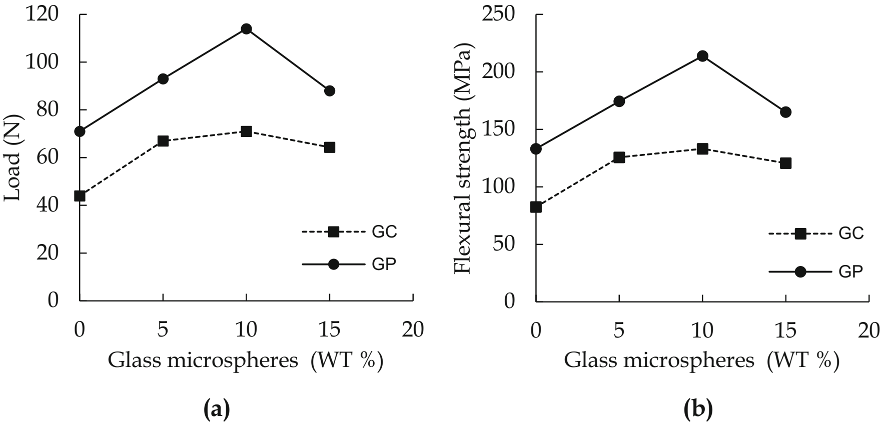


Fig. 2 (**a**) Flexural load variation with the percentage of GM content. (**b**) Flexural strength variation with the percentage of GM content

glass fiber-reinforced composites with GM particles when compared to the previous composite material flexural test. The UAV structure weighs 4 kg with a payload capacity of 1 kg. The material is utilized to create the landing gear support at least 5 kg of its weight. The glass fiber-reinforced composite with GM particles has a maximum load capacity of 10 kg, which is enough to support the weight of a 5 kg UAV.

4 Conclusion

The influence of glass microspheres on the bending characteristics of glass fiber-reinforced composites (chopped strand mat and plain-woven fabric 1 × 1) is investigated in this research. This work is carried out using UTM in compliance with ASTM D790 standards. The impact of adding glass microsphere particles is studied. It is found that adding microparticles could enhance the flexural strength. Glass fiber plain-woven fabric is found to be more effective than chopped strand mat. Adding glass microspheres to glass fiber-reinforced composites dramatically improves the load performance of the composites. Also, the glass fiber plain-woven fabric attributes the interaction between glass fibers and glass microspheres. This enables the composite to support greater payloads. The maximum load capacity of conventional glass fiber plain-woven fabric composites with GM particles is 10 kg, which is sufficient to support the weight of a 5 kg UAV. As a result, the alternative material can be glass fiber plain-woven fabric composites with GM particles. The landing gear is made of a composite material rather than T6 aluminum alloy. This reduces the UAV production costs and weight, allowing more extended operation with more efficiency.

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