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Recycled Wood Dust Polypropylene Composite (r-WoPPC) Material Selection for Drone Frame Structures by using TOPSIS

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ABSTRACT

Conceptual design and natural fibre composite filament for fused deposition modelling (FDM) has gained enormous interest in recent years. Therefore, this paper presents the multi-criteria decision making (MCDM) method to select the best design concepts generated and best natural fibre composite filament materials for the drone frame structures. The conceptual design process includes product design specification, morphological method, and finite element analysis (FEA) before the selection process using Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method. Next, the natural fibre composite filaments produced with different weight percentage and mechanical treatment were printed and their mechanical properties were used in the Ansys software to get their stress, strain, and displacement using FEA method. The results obtained then were analysed using TOPSIS method to get the best materials for the drone frame structure. Five design concepts were generated and the results from TOPSIS method shows that design concept 2 outperformed others with a performance score of 0.0893 while the best material is 1% r-WoPPC NaOH Silane treated with the score of 0.9864 compared to the other different r-WoPPC filaments. It can be concluded that by using the TOPSIS method, researchers can select the best concept design and best materials for the drone frame structures.

1. Introduction

The term "wood-plastic composite" (WPC) is frequently used to describe composite materials made from wood-based components such as timber, veneer, fibre, particles and polymers. It is a widely used term, and thus wood elements can be combined with either thermosetting or thermoplastic polymers [1, 2]. Similar to other composite materials, the constituent materials are kept in their original forms and combined to create a new composite material with acceptable

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mechanical and physical qualities at a low cost. [3]. It is shaped into planks or beams that can be used for a variety of applications, including outdoor deck floors, railings, park benches, vehicle seat backs, door and window frames, fences, timber plate constructions, and indoor furniture [4].

The most important issue related to WPC fabrication is its capability to exploit wood and plastic wastes to produce a new product with enhanced properties [5]. The primary issue of using organic fibre in WPC is that they have a propensity to aggregate during processing. Additionally, its poor resistance to moisture causes voids to form, which compromises the WPC dimensional stability and mechanical attributes. Moreover, the degradation of organic fibre in harsh sunny environments affects the reliability of WPC. A high wood content also causes a dramatic decrease in the toughness of WPCs because of poor interfacial adhesion between the hydrophilic wood and hydrophobic polymer, which significantly reduces processability in addition to the sharp loss in toughness [6, 7].

The three main methods of producing wood-plastic composites are extrusion, injection moulding, and compression moulding or thermoforming (pressing). Fused deposition modelling (FDM) and laser sintering are two more recent manufacturing processes for WPCs [3, 8–10]. FDM is a technology whereby the melt extrusion method is used to deposit filaments of thermal plastics according to a specific pattern as illustrated in Figure 1. FDM key advantages are low cost, relatively fast speed, and ability to reinvent the design process [11].

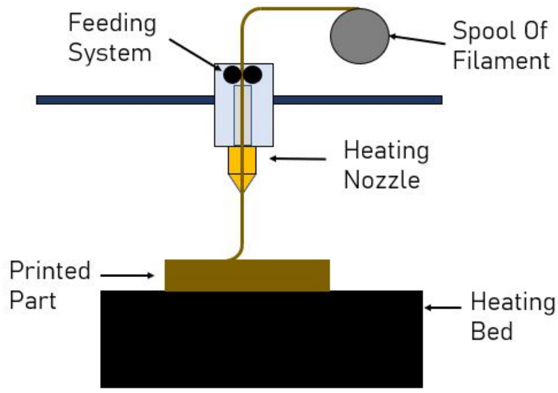


Fig. 1. FDM Illustration

The application of fully bio-based composites to filament extrusion FDM printers has the following challenges. Firstly, the filler content poses a barrier because it may significantly raise the filament melt viscosity, making it difficult to be use in the existing FDM processes. Secondly, composites have issues during the deposition process, such as feeding issues and nozzle clogging that are caused by rough surfaces, size inhomogeneity, and fragility of extruded filaments [12]. Finally, although crystalline bio-based material composites can be successfully prepared into filaments, their inherent anisotropy causes the printed parts warpage, and thus printing cannot be completed [13]. In general, the available information about the application of composite 3D printing is rather scarce. There are descriptions of potential possibilities for applications in biomedical engineering, electronics and aerospace engineering [14].

In this paper, a frame of a small unmanned aerial vehicle (UAV) is offered as an example of specific application for the natural fiber composite additive manufacturing processes. The aim of this study is to select the best design and materials for the drone frame structures by using Multi Criteria Decision Making (MDCM) method which is Technique for Order Preference by Similarity to Ideal Solution (TOPSIS).

2. Literature Review

2.1 Chemical Treatment for FDM Composite Filament

Additionally, another significant issue with mineral filler-reinforced composites is the aggregation that arises from poor mineral filler dispersion in the matrix. The physical qualities of the composites are severely diminished by aggregation and incompatibility. To overcome the disadvantages (incompatibility and aggregation) presented in bio-filler reinforced composites, the chemical modifications with alkali and coupling agents have been frequently applied [15]. Chemical treatment techniques are widely used to enhance the interfacial properties between polymer and wood fibre that overcome the hydrophilic nature of wood fibres. Such treatments are used to motivate hydroxyl groups on fibre surfaces to enhance the fibre surface characteristics [16].

Torrado Perez *et al.,* [17] stated that the use of silanes in addition to surface modification after the alkaline treatment improved some of the minor factors such as dispersion and adhesion of reinforcement and polymer matrix. In a previous experiment, Petchwattana *et al.,* [18] stated that a silane coupling agent enhanced the bonding interaction between wood flour hydrophilic and polylactic acid (PLA) polymer hydrophobic. Fouladi *et al.,* [19] found that alkaline treatment was targeted to separate lignin content in the fibre, and thus more cellulose could be exposed for the binding process as it helped to enhance interfacial adhesion in the composite.

2.2 Multi Criteria Decision Making (MCDM) Method

Multi-criteria decision-making (MCDM) is one of the main decision-making problems which aims to determine the best alternative by considering more than one criterion in the selection process. MCDM has manifold tools and methods that can be applied in different fields from finance to engineering design.

The TOPSIS method (Technique for Order Preference by Similarity to Ideal Solution) is used to get the explanation that is closest to the ideal solution and farthest to the negative ideal solution. This way requires data about the relative status of the attributes considered in the alternative process [20] . Table 1 shows the previous work that utilize TOPSIS as MCDM method in decision making for their study [20–24].

Table 1
Previous Work TOPSIS as MCDM

Purpose of TOPSIS	Findings	References
Comparing Materials for Biomedical Applications used in Additive Manufacturing	- Factor considered: Tensile Strength, Temperature, Density, Material Cost. - CFRP are the best and suitable material according to TOPSIS.	[20]
Comparing Metal Matrix Composite Used in Design and Structural Application	- AHP & TOPSIS - Factor Considered: Tensile Strength, Density, Hardness, Melting Point & Cost	[21]
Selection of Industrial Arc Welding Robot by using TOPSIS	Criteria: Mechanical Weight of the robot, Repeatability in mm, Payload Capacity of the Robot, Maximum Reach of The Robot, Average Power Consumption	[22]
Develop solid management waste model by utilize TOPSIS and VIKOR	Combination of TOPSIS and VIKOR method helps to identify the most appropriate and the improper scenarios for municipal waste management	[23]
Life Cycle Assessment (LCA) and MCDM method for food waste composting management	The finding underscored that the combined LCA with MCDM and cost complementary methods is the highest being studied at 45% in decision support tools. Furthermore,	[24]

2.3 Drone Frame Design Considerations

A UAV frame must satisfy the constraints imposed on the structure geometry and load carrying capacity under minimum mass. Mass re- duction enables us to increase payload, flying range and/or flight duration. Thus, taking into account specific features of composite 3D printing process and advantages of lattice structures, we can conclude that such design concept is the most suitable for a small size UAV frame [25]. According to Muralidharan *et.al.,* [26] the forces acting on a frame are calculated for conducting Finite Element Analysis, such as the frame weight and all the electrical components on it are common for the ground, the direction of the lift force is a product of thrust and vertical take-off, the thrust produced by propeller and engine in the direction of motion and movement, drag force working in reverse direction of motion. Table 2 shows the previous work that use FEA to analyse the drone frame structures.

Table 2
Previous Work Drone Frame Finite Element Analysis

Process & Types of Analysis	Findings	References
Material: CFRC Structural Analysis Software: Siemens NX Max Load = 30 kg (simulation) Parts: Drone Frame	- 30 kg load does not affect the drone frame structure in real experiment. - Data taken: VMS, Displacement & Interlaminar Shear Stress	[25]
Structural Analysis Software: s Parts: Drone Frame	- Maximum stress 7.240 x10^{-10} MPa obtained at the drone arms - Data taken: VMS, Displacement & Strain	[26]
Structural Analysis Software: SolidWork Load: 3N Material: ABS & Carbon Fibre' Parts: Drone Frame	- Data Taken: VMS, Displacement, Strain & Frequency - Maximum displacement is obtained at the end of the arms where it is connected to the propulsion system.	[27]
Structural Analysis Sofware: ANSYS Load: 20 N Material: PA66GF30 Parts: Drone Frame	Data taken: VMS and deformation	[28]
Structural Analysis Software: ABAQUS Parts: Boom	Data taken: VMS and Deflection	[29]

3. Methodology

Figure 2 shows the complete process for this research starting from product design specifications generated to material selection by using TOPSIS. The drone frame structure concept design generated by using morphological chart. Then, the design was further analysed by using ANSYS software in this study to select the best design concept for the drone frame structure. Lastly, the best design selected were further analysed by using the mechanical properties data from (r-WoPPC) and simulated in ANSYS software and by using TOPSIS the best material and design were selected.

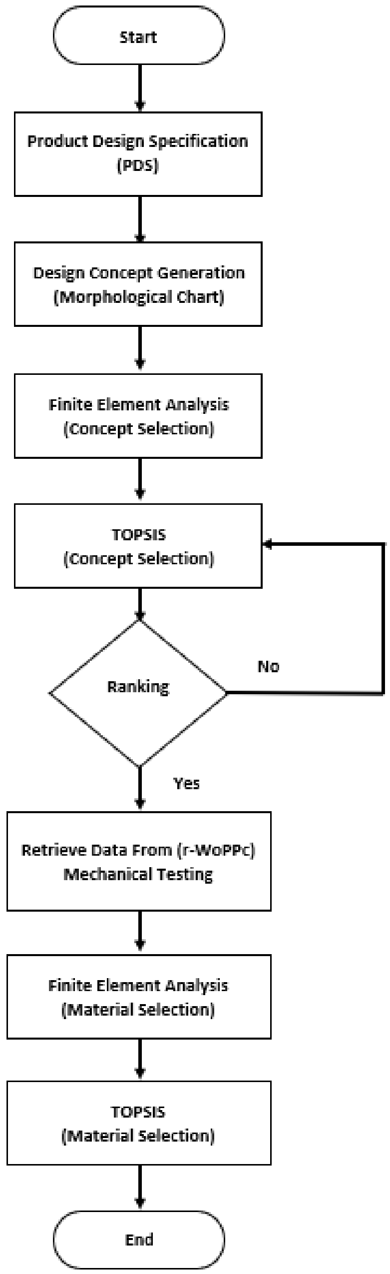
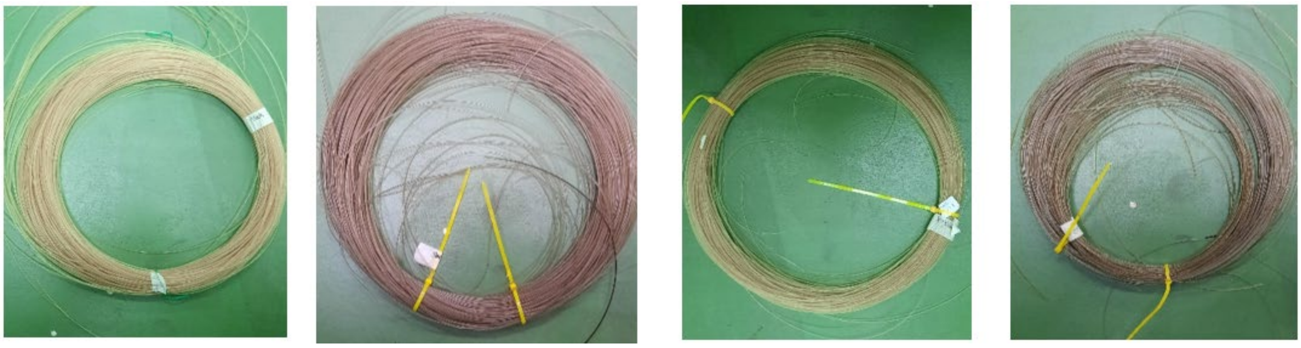


Fig. 2. Research Flowchart

3.1 Material

The material used for this research is recycled wood dust polypropylene composite (r-WoPPC) FDM filament fabricated by Azali *et al.,* [30]. There are 12 different materials which is consist of three different wood composition 1%, 3% and 5%. As shown in Figure 3, there are four types of treatment for each of the different wood composition which is treated by using NaOH (a), Silane (b), combination of NaOH and Silane (c) and also untreated (d) FDM filament composites.



(a) (b) (c) (d)

Fig. 3. Chemical Treatment on FDM Filament (a) NaOH, (b) Silane, (c) NaOH and Silane and (d) Untreated

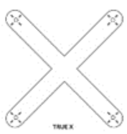
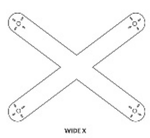
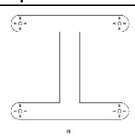
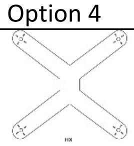
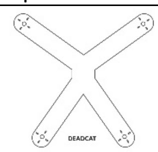
3.2 Product Design Specification (PDS)

Table 3
Product Design Specification (PDS) for Drone Frame Structure

Criteria	Definition
Performance	High Strength, Lightweight and Optimum size
Size and Weight	Smaller size, to increase its portability and flexibility of the drone frame structures
Aesthetics and Finishing	Good Surface finishing from fused deposition modelling (FDM) process.
Materials	Recycled Wood Dust Polypropylene Composites (r-WoPPC)
Quality and Reliability	High strength of material is being selected by using TOPSIS for FDM process.
Testing	Material Being tested by using Flexural and Tensile test. For better finishing FDM parameters are being tested to get the best finishing.
Standards and Specifications	(r-WoPPC) material are being tested by using Flexural ASTM D790 and Tensile test ASTM D638.
Environment	Material are environmentally friendly, Wood dust are being used to be reinforced with recycled polypropylene.

3.3 Morphological Chart

Table 4
Morphological Chart for Concept Design Generation

	Option 1	Option 2	Option 3	Option 4	Option 5
Drone Frame Style					
Wing Design Structure	Triangle	Straight Slot	Rectangle	Curved Slot	
Drone Frame Body	Unibody	Separate Arms			
Drone Center Structure	Round	Square	Rectangle		

3.4 FEA Simulation (ANSYS)

Finite element analysis (FEA) is the use of calculations, models and simulations to predict and understand how an object might behave under various physical conditions.

3.4.1 CAD modelling

The CAD design of the drone frame structure are design in the SolidWork. The CAD file then imported to the ANSYS software by using IGES format. The drone was design by following a few guidelines which is the box dimension does not exceed 250 mm x 250mm, the drone was design separately for the fabrication process purposes and the design concepts were generated by following the morphological chart

As shown in Figure 4, the design concept of the drone frame was generated by using morphological chart.

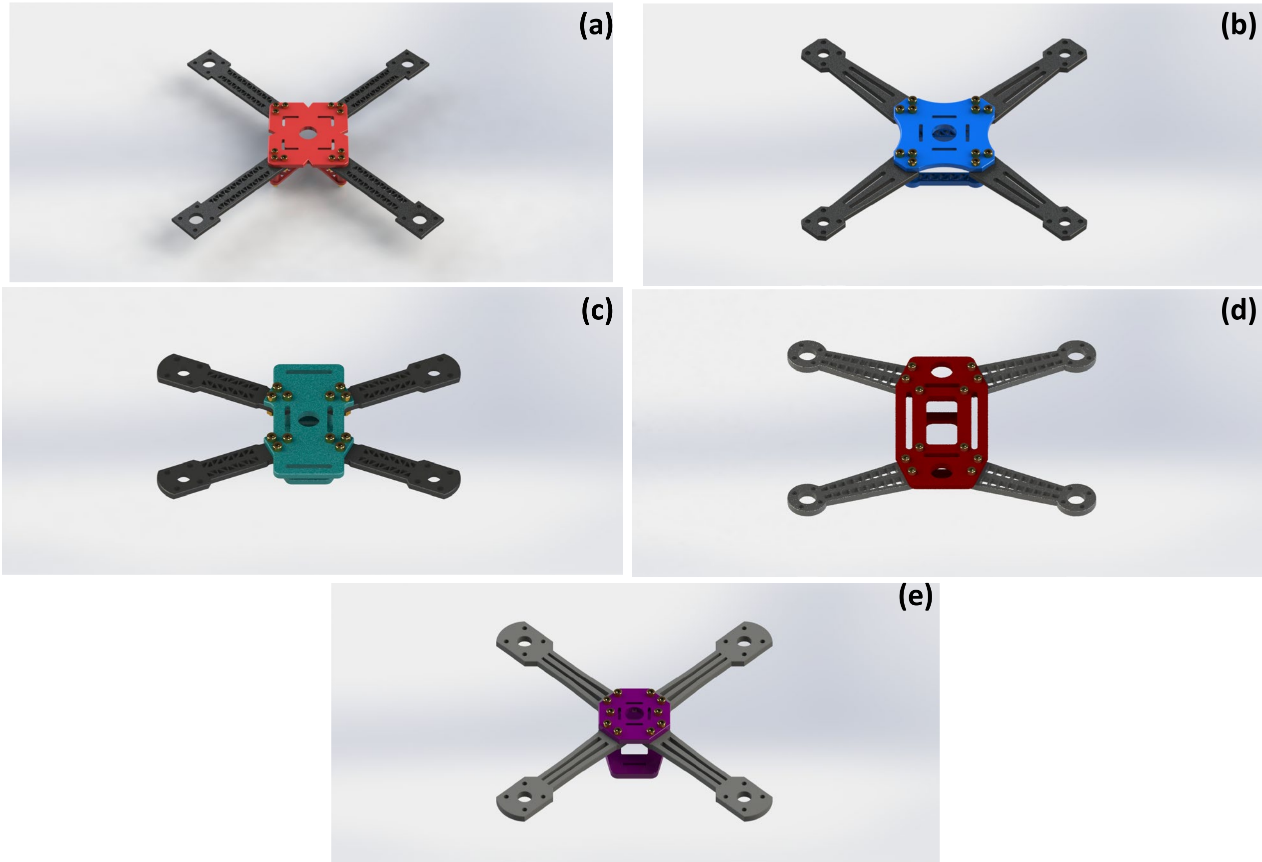


Fig. 4. CAD Design for Drone Frame Structures (a) Design Concept 1 (b) Design Concept 2 (c) Design Concept 3 (d) Design Concept 4 and (e) Design Concept 5

3.4.2 Structural analysis

Structural analysis is type of FEA analyses a scaled model based on proportions. The test maintains that any structure that is sound on a small scale will be able to handle the same interactions with the full-scale structure and produce the same results.

Figure 5 shows the step procedure in ANSYS software to conducting the structural analysis which is starting from insert material properties in the library or choose existing material in the library, followed by import CAD geometry by using IGES format, Assign Material to the geometry, Mesh Geometry until Generate Results which is the Von Misses Stress, Strain and also Displacement

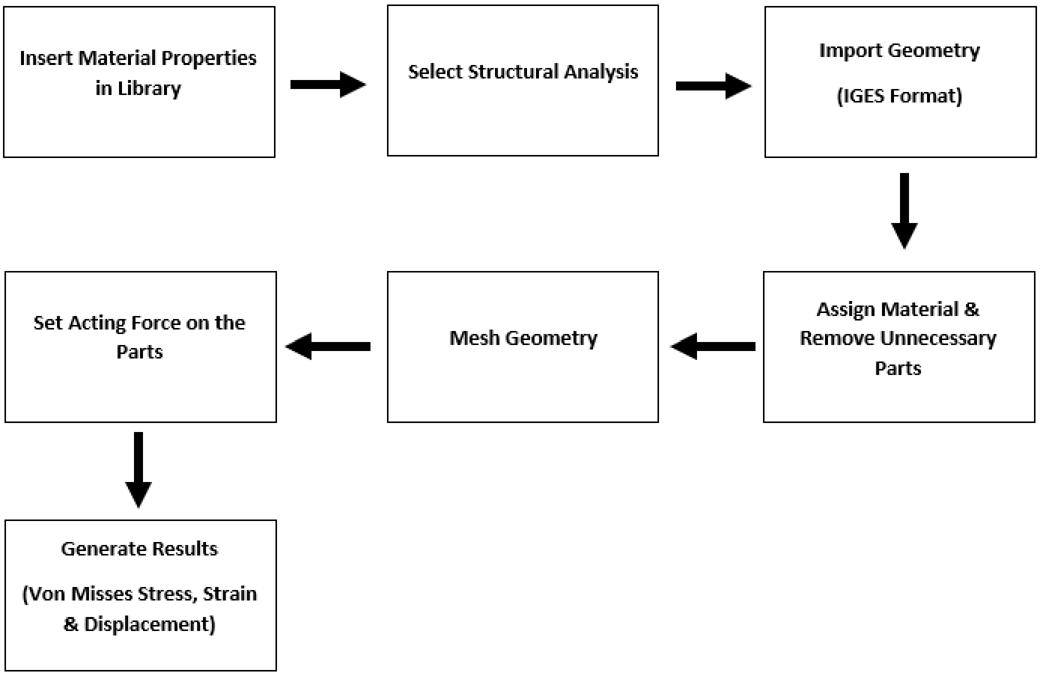


Fig. 5. Procedure in ANSYS for Finite Element Analysis

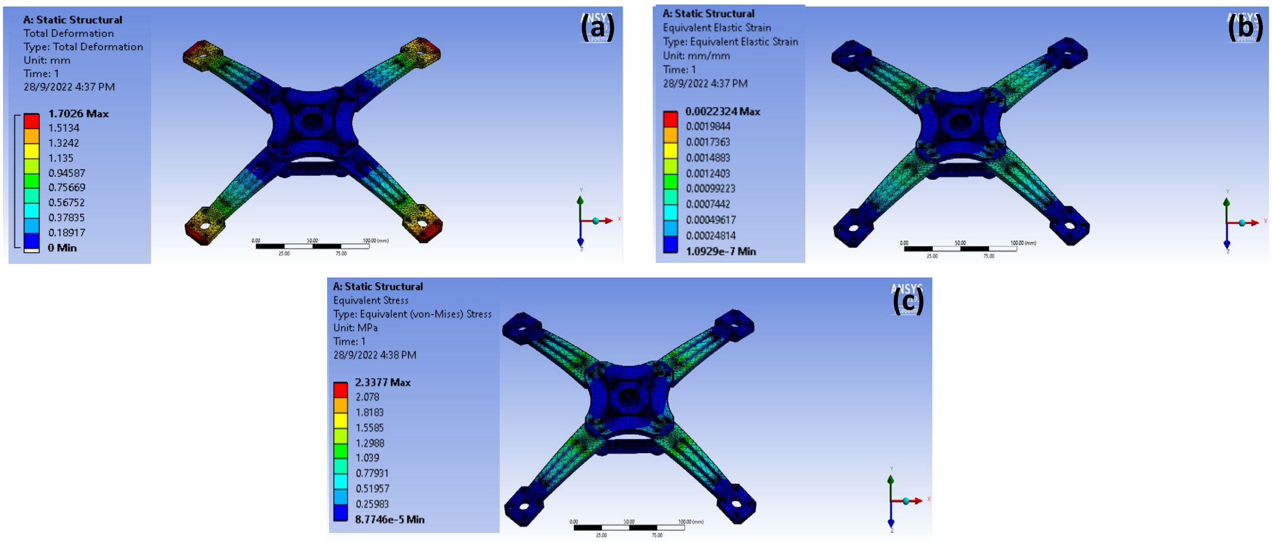


Fig. 6. Finite Element Analysis (FEA) Results (a) Deformation (b) Strain and (c) Von Misses Stress

3.5 Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

Step one**:** Construct standardized decision matrix A. For the comprehensive assessment questions with *n* evaluation units and m evaluation indexes, its decision matrix A is:

$$A = \sqrt{\sum_{j=1}^{n} x_{ij}^{2}} \quad (1)$$

Step two: Construct weighted and standardized decision matrix V, weight vector W= (W_1, W_2, …, W_n)

$$\bar{x}_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{n} x_{ij}^2}} \tag{2}$$

Step three: Determine the ideal solution X^+ and minus ideal solution X^- is:

$$x^+ = \{\max v_{ij} | j \in J), (\min v_{ij} \mid j \in J') | i = 1,2, \ldots, n\} = \{x_1^+, x_2^+, \ldots x_m^+\}$$

$$x^- = \{\min v_{ij} | j \in J), (\max v_{ij} \mid j \in J') | i = 1,2, \ldots, n\} = \{x_1^-, x_2^-, \ldots x_m^-\}$$

Step four: Calculate distance. The distance of each project to the ideal solution X^+ is:

$$s_i^+ = \sqrt{\sum_{j=1}^{m} \left(V_{ij} - x_j^+\right)^2} \tag{3}$$

The distance of each project to the minus ideal solution X^- is:

$$s_i^- = \sqrt{\sum_{j=1}^{m} \left(v_{ij} - x_j^*\right)^2} \tag{4}$$

Step five: Calculate the relative proximity index of each project to the ideal solution C^i:

$$C_i = {s_i^-}\big/{(s_i^- + s_i^+)} \tag{5}$$

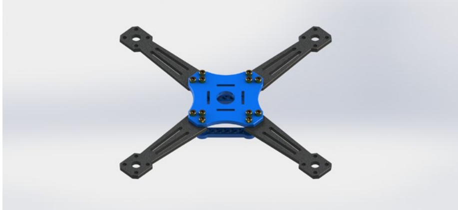
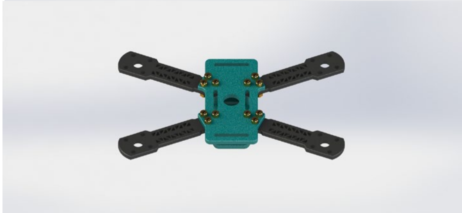
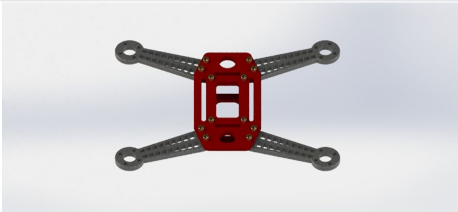
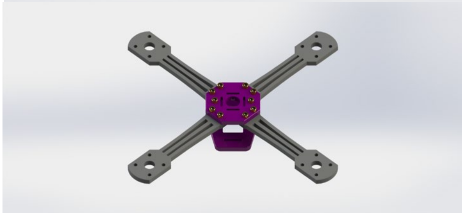
Step six: Rank the priority of the projects in descending order of C_i.

4. Results and Discussion

4.1 Design Concept Generation

This section shows the design concept generated by using morphological chart for drone frame structures and designed by using CAD software which is SolidWork.

Table 5
Design Concept for Drone Frame Structures

Design Concept	Criteria				
	Drone Frame Style	Wing Structure	Drone Frame Body	Drone Center Structure	Illustration
1	True X	Triangle	Separate Arms	Square	
2	True X	Straight Slot	Separate Arms	Square	
3	Wide X	Triangle	Separate Arms	Rectangle	
4	HX	Rectangle	Separate Arms	Rectangle	
5	True X	Curved Slot	Separate Arms	Square	

4.2 TOPSIS Design Concept Selection

This section shows the TOPSIS process for design concept selection. Table 6 shows the value of Von Misses Stress (VMS), Deformation and Strain for every design concept of the drone frame structures. First step before conducting FEA simulation, the material used is polypropylene that existed in the ANSYS material library.

Table 6
TOPSIS (Step One)

Design Concept	Deformation (mm)	Von Misses Stress (MPa)	Strain
	Max	Max	Max (x 10^{-3})
1	3.0028	5.4106	7.253
2	2.1073	2.2395	3.460
3	1.9919	3.6576	4.006
4	2.5859	6.0715	7.010
5	4.5278	9.1876	12.007
A	14.2157	26.5668	33.735

The weightage shows in Table 7 for the criteria is 0.333 which is equal because of all the result from the FEA simulation are equally important.

Table 7
TOPSIS (Step Two)

Design Concept	Deformation (mm)	Von Misses Stress (MPa)	Strain
	Max	Max	Max
1	0.2112	0.2037	0.2150
2	0.1482	0.0843	0.1026
3	0.1401	0.1377	0.1187
4	0.1819	0.2285	0.2078
5	0.3185	0.3458	0.3559
WEIGHTAGE	0.333	0.333	0.333

In this step, Table 8 show the best and worst value for each criterion is selected in order to identify the ranking of the design concept as shown in Table 9.

Table 8
TOPSIS (Step Three)

Design Concept	Deformation (mm)	Von Misses Stress (MPa)	Strain
	Max	Max	Max
1	0.070	0.068	0.072
2	0.049	0.028	0.034
3	0.047	0.046	0.040
4	0.061	0.076	0.069
5	0.106	0.115	0.119
V+ BEST	0.047	0.028	0.034
V- WORST	0.106	0.115	0.069

From Table 9, it clearly shows that design concept 2 have the highest performance score which is 0.0893, followed by design concept 1 with 0.0705, followed by design concept 3 with 0.0695, followed by design concept 5 with 0.0592 and followed by design concept 4 with 0.0525.

Table 9
TOPSIS (Step Four)

DESIGN CONCEPT	SI +	SI-	PERFORMANCE SCORE C_i	RANK
1	0.0233	0.0472	0.0705	2
2	0.0024	0.0869	0.0893	1
3	0.0003	0.0692	0.0695	3
4	0.0136	0.0389	0.0525	5
5	0.0591	0.0002	0.0592	4

4.3 TOPSIS Material Selection

This section shows the TOPSIS process for material selection for drone frame selection. Table 10 shows the value of Von Misses Stress (VMS), Deformation and Strain for every material r-WoPPC with different wood percent composition and also chemical treatment. First step before conducting FEA simulation, the material used is recycled wood dust polypropylene composite (r-WoPPC) that obtained by conducting mechanical testing which is Tensile and Flexural Testing. The design concept 2 model were used in this process as the design outperformed others in previous TOPSIS design selection as shown in Table 9. Table 10 shows the FEA simulation results by using different mechanical properties of the r-WoPPC.

Table 6
FEA Results by using ANSYS (Design Concept 2)

PERCENT	DESIGN CONCEPT 2			
	MATERIAL	DEFORMATION (mm)	VON MISSES STRESS (MPa)	STRAIN (x 10^{-3}) (mm)
1%	NaOH	1.7026	2.3377	2.2324
	Silane	1.5574	2.3504	2.0421
	NaOH Silane	1.5910	2.3524	2.0862
	Untreated	1.7604	2.3338	2.3082
3%	NaOH	1.9432	2.3377	2.5479
	Silane	2.0198	2.3504	2.6483
	NaOH Silane	1.9595	2.3524	2.5693
	Untreated	1.8467	2.3338	2.4214
5%	NaOH	2.2672	2.3377	2.9728
	NaOH Silane	2.0946	2.3524	2.7465
	Untreated	2.0548	2.3338	2.6942

As shown in Table 11, the first step, all the criteria value is tabulated which Tensile Strength (TS), Tensile Modulus (TM), Flexural Strength (FS), Flexural Modulus (FM), Deformation (DEF), Von Misses Stress (VMS) and Strain (STR).

Table 7
TOPSIS (Step One)

Treatment	Material	TS	TM	FS	FM	DEF	VMS	STR (x 10^{-3})
UNT	1%	13.567	1128.31	21.20	567.14	1.7604	2.3338	2.3082
	3%	10.777	1075.57	14.06	384.18	1.8467	2.3338	2.4214
	5%	9.287	966.65	15.17	433.88	2.0548	2.3338	2.6942
NAOH	1%	14.383	1168.62	17.11	457.24	1.7026	2.3377	2.2324
	3%	13.320	1023.92	13.81	397.94	1.9432	2.3377	2.5479
	5%	10.277	877.57	9.27	299.82	2.2672	2.3377	2.9728
SIL	1%	14.780	1284.54	28.35	672.61	1.5574	2.3504	2.0421
	3%	10.940	990.51	21.68	574.17	2.0198	2.3504	2.6483
NS	1%	16.037	1309.57	22.48	601.79	1.591	2.3524	2.0862
	3%	12.500	1021.81	16.80	411.63	1.9595	2.3524	2.5693
	5%	8.500	955.91	14.63	338.85	2.0946	2.3524	2.7465
A		134.367	11802.98	194.553	5139.270	20.797	20.797	25.773

As shown in Table 12, The weightage for the criteria is 0.143 which is equal because of all the result from the FEA simulation and the mechanical properties are equally important.

Table 8
TOPSIS (Step Two)

Treatment	Material	TS	TM	FS	FM	DEF	VMS	STR
UNT	1%	0.101	0.096	0.109	0.110	0.085	0.091	0.085
	3%	0.080	0.091	0.072	0.075	0.089	0.091	0.089
	5%	0.069	0.082	0.078	0.084	0.099	0.091	0.099
NAOH	1%	0.107	0.099	0.088	0.089	0.082	0.091	0.082
	3%	0.099	0.087	0.071	0.077	0.093	0.091	0.093
	5%	0.076	0.074	0.048	0.058	0.109	0.091	0.109
SIL	1%	0.110	0.109	0.146	0.131	0.075	0.091	0.075
	3%	0.081	0.084	0.111	0.112	0.097	0.091	0.097
NS	1%	0.119	0.111	0.116	0.117	0.077	0.091	0.077
	3%	0.093	0.087	0.086	0.080	0.094	0.091	0.094
	5%	0.063	0.081	0.075	0.066	0.101	0.091	0.101
Weightage		0.143	0.143	0.143	0.143	0.143	0.143	0.143

In this step, Table 13 show the best and worst value for each criterion is selected in order to identify the ranking of the material for the drone frame structure as shown in Table 14.

Table 9
TOPSIS (Step Three)

Treatment	Material	TS	TM	FS	FM	DEF	VMS	STR
UNT	1%	0.014	0.014	0.016	0.016	0.012	0.013	0.012
	3%	0.011	0.013	0.010	0.011	0.013	0.013	0.013
	5%	0.010	0.012	0.011	0.012	0.014	0.013	0.014
NAOH	1%	0.015	0.014	0.013	0.013	0.012	0.013	0.012
	3%	0.014	0.012	0.010	0.011	0.013	0.013	0.013
	5%	0.011	0.011	0.007	0.008	0.016	0.013	0.016
SIL	1%	0.016	0.016	0.021	0.019	0.011	0.013	0.011
	3%	0.012	0.012	0.016	0.016	0.014	0.013	0.014
NS	1%	0.017	0.016	0.017	0.017	0.011	0.013	0.011
	3%	0.013	0.012	0.012	0.011	0.013	0.013	0.013
	5%	0.009	0.012	0.011	0.009	0.014	0.013	0.014
V+ BEST		0.017	0.016	0.021	0.019	0.011	0.011	0.013
V+ WORST		0.009	0.011	0.007	0.009	0.016	0.016	0.013

From Table 14, the TOPSIS method shows that 1% r-WoPPC NaOH Silane treated have the highest performance score which is 0.9864, followed by 1% r-WoPPC Silane treated with 0.7822, followed by 1% r-WoPPC Untreated with 0.5104, followed by 3% r-WoPPC NaOH treated with 0.3323 and followed by 3% r-WoPPC NaOH Silane treated with 0.2718.

Table 10
TOPSIS (Step Four)

Material		SI +	SI -	PERFORMANCE SCORE		RANK
				(SI+) + (SI-)	C_i	
UNT	1%	0.0025616	0.0026702	0.005232	0.5104	3
	3%	0.0055309	0.0020311	0.007562	0.2686	6
	5%	0.0071166	0.0007116	0.007828	0.0909	9
NAOH	1%	0.0153075	0.0031586	0.018466	0.1710	8
	3%	0.0028242	0.0014053	0.004230	0.3323	4
	5%	0.0060630	0.0003677	0.006431	0.0572	11
SIL	1%	0.0012704	0.0045630	0.005833	0.7822	2
	3%	0.0053571	0.0010006	0.006358	0.1574	7
NS	1%	0.0000671	0.0048662	0.004933	0.9864	1
	3%	0.0036968	0.0013798	0.005077	0.2718	5
	5%	0.0079539	0.0005814	0.008535	0.0681	10

5. Conclusion

In this paper, a frame of a small unmanned aerial vehicle (UAV) is offered as an example of specific application for the natural fibre composite additive manufacturing processes. The aim of this study is to implement the product design and development process, which includes design, structural analysis and also material selection for the drone frame structures by using Multi Criteria Decision Making (MDCM) method which is Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The results from TOPSIS shows that Design Concept 2 outperformed others with performance score 0.0893, followed by design concept 1 with 0.0705 and followed by design concept 3 with 0.0695. Then, by using design concept 2, for material selection TOPSIS process the highest performance score is 1% r-WoPPC NaOH Silane treated which is 0.9864, followed by 1% r-WoPPC Silane treated with 0.7822, followed by 1% r-WoPPC Untreated with 0.5104. Therefore, from the TOPSIS calculation it can be the design concept 2 were selected and the best material for FDM printing process is 1% NaOH Silane treated. It can be concluded that by using the TOPSIS method, researchers can select the best concept design and best materials for the drone frame structures.

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