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Oil Palm Fiber Composite for Single Point Cutting Tools

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Abstract:
Much emphasis has been placed upon vibrations in cutting tools during recent years because many people have recognized that accuracy, surface finish and, last but not least, production costs are considered. Today we use modern instruments and easy available for the investigation of cutting tool vibration. However, in the final analysis, the completed surface itself will return the dynamic behaviour of the cutting tool.

The scope of this project is to replace the conventional material by using composite material. However, a few or no studies were found to compare the material properties when the parts possess constant stiffness. Composite materials based on constant stiffness structures will provide a better comparison of size, weight damping properties etc., for the cutting tool structure manufactured using alternative composite material suggested for it. For this project oil palm reinforced fibre, steel and cast iron structure exhibiting constant stiffness were modelled analytically and calculated mathematically. A beam with rectangular shape has been select for analysis to simulate the machine tool components such as bed, beam and ram. The analytical (FEM) method was used to arrive at the dimensions of the structures which provide same stiffness. The dimensions calculated analytically were confirmed by testing them numerically.

The recent research on high speed precision cutting tools aims at developing an alternative material for the structures which exhibit good damping and stiffness characteristics.

Key words: *composite, cutting tools, vibration, modelling, analysis*

1. Introduction

Cutting tools have always vibrated and will continue to do so. We will control these vibrations and keep them at or below a tolerable level. This was easier to do in the past than it is today. The older cutting tools had fewer auxiliary mechanisms, lower speed and feed ranges, and wide sliding ways which provided plenty of friction and also acted as vibration dampers. Newer cutting tools often have sliding ways which have been designed for reduced friction in order to keep servo-mechanisms little in size. Several friction dampening property of metal to metal sliders have been eliminated because of the introduction of many anti-friction bearing design features. While higher cutting speeds generally contribute to an improvement of the surface finish obtained, they often excite Components of the cutting tool at their natural frequency. Such resonance conditions can usually be avoided by changing the spindle speed. If the cutting tool were infinitely stiff, it would be possible to predict surface finishes and accuracy of rigid work pieces.

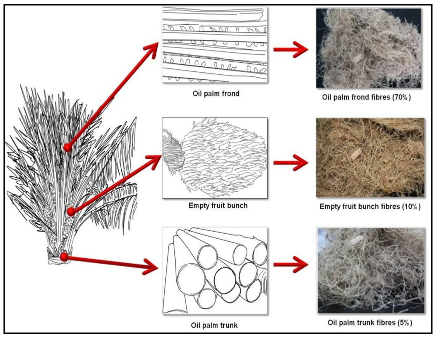
High speed precision cutting tools aims at developing an alternative material for the structures which exhibit good damping and stiffness quality. The best way to find both high damp and high structural stiffness is to employ composite structures having high damping characteristics and moderate stiffness. In this project oil palm reinforced fibre, steel and cast iron structure exhibiting constant stiffness were modelled analytically and tested mathematically In terms of properties such as chemical fight, easiness of production, workability, low thermal conductivity, high strength-to-weight ratio, damping, plastic and composite materials are gradually more used in the manufacture of cutting tools. Modal analysis of cutting tool has to be done with ANSYS for machine tool with conventional and composite material to find the natural frequency and mode shape of the tool. Also harmonic analysis of machine tool has to be done to find the structural response and the vibration behaviour of tool.

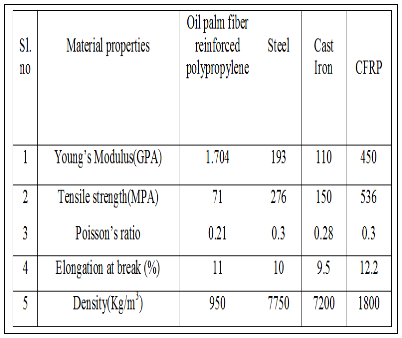
Studies carried out on composite cutting tool structures proved it to be an alternative for the challenge posed by the straight materials. Investigate the characteristics exhibited by polymer concrete structures by varying compositions of ingredients in it. Results indicate that, the oil palm reinforced fiber composite structures provide a higher damping ratio and stiff structure. Also, it is observed that the high rigidity, damping and high coefficient of thermal expansion characteristics of oil palm reinforced fiber as compared to other polymer concrete structures and conventional materials makes it more preferable material for precision cutting tool structures.

2. Experimental Procedure

2.1. Oil Palm Fibres

At present, most of the oil palm biomass are disposed off at the oil palm plantation or burned at the mills to produce oil palm ash powder. Thus, result useful consumption of the oil palm biomass in fabrication of natural fibre based composites/hybrid composites will surely alleviate environmental problems related to the disposal of oil palm wastes.





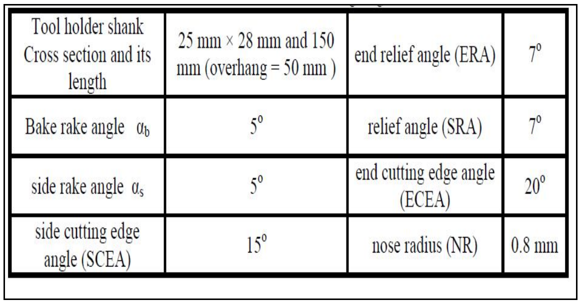
Sl. no	Material properties	Oil palm fiber reinforced polypropylene	Steel	Cast Iron	CFRP
1	Young's Modulus(GPA)	1.704	193	110	450
2	Tensile strength(MPA)	71	276	150	536
3	Poisson's ratio	0.21	0.3	0.28	0.3
4	Elongation at break (%)	11	10	9.5	12.2
5	Density(Kg/m^3)	950	7750	7200	1800

Figure 1: oil palm fibres

Table 1: Material properties of conventional, oil palm and carbon fiber reinforced polymer materials

2.2. Tool Design

Sharp tools are more likely to chatter than slightly blunted tools. In the workshop, the cutting edge is often deliberately dulled by a slight honing. Consequently, a bevelling of the leading face of a lathe tool has been suggested. This bevel has a leading edge of -80° and a breadth of 0.080 inch.



Tool holder shank Cross section and its length	25 mm × 28 mm and 150 mm (overhang = 50 mm)	end relief angle (ERA)	7^o
Bake rake angle α_b	5^o	relief angle (SRA)	7^o
side rake angle α_s	5^o	end cutting edge angle (ECEA)	20^o
side cutting edge angle (SCEA)	15^o	nose radius (NR)	0.8 mm

Table 2: Tool dimensions &cutting

2.3. Modeling of the Tool Using CATIA

2.3.1. Modal 1

Dimensions:
Outer part: 25mm*28mm*120mm
Inner part: 12.5mm*14mm*30mm
Overhang: 30mm

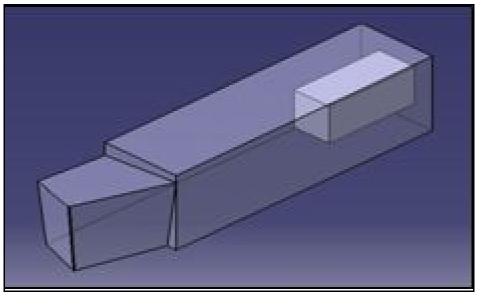


Figure 2: CAD modelling of cutting tool modal

2.3.2. Modal 2
Dimensions:
Outer part: 25mm*28mm*120mm
Inner part: 12.5mm*14mm*60mm
Overhang: 60mm

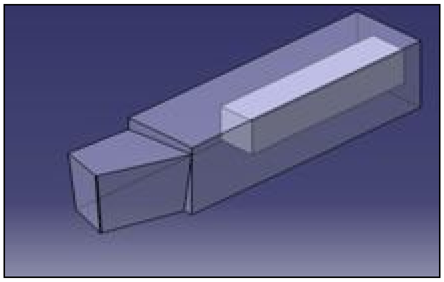


Figure 3: CAD modelling of cutting tool modal

2.3.3. Modal 3
Dimensions:
Outer part: 25mm*28mm*120mm
Inner part: 12.5mm*14mm*90mm
Overhang: 90mm

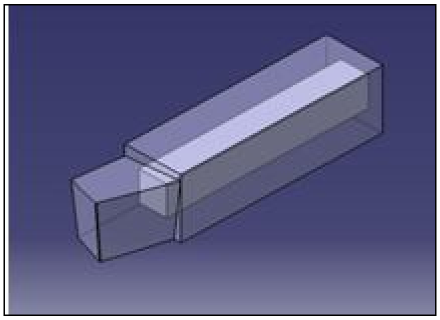


Figure 4: CAD modelling of cutting tool model

2.4. Finite Element Analysis of Tool

The finite element method involves discretising a physical domain into little sub domain, known as basic elements, in excess of which piecewise continuous field variables such as stress, pressure, velocity, or temperature can be estimated. Since the real variation of the ground variable inside the element is not identified, similar to functions are essential to describe this difference. These similar functions are similar to trial functions since they interpolate the field values at the nodal points of every element. Perceptive the numerical geometry and material properties of every element, appropriate field equations such as balance or heat balance can be printed, and the essential stiffness matrix can be obtain, typically by minimize the potential energy of this unit system.

The elements are connected together at the nodal point, form a range for the whole model. The part stiffness matrices are assembling for the whole discretised body to obtain the global stiffness matrix [K]. The new unknowns are the noda1 values of the field variable throughout the grouping of elements. Generally equilibrium equations are customized to account for boundary conditions of the difficulty, which usually yields the universal equilibrium equation in terms of banded matrices.

3. Results and Discussion

3.1. Case 1

For case 1 we are considering 50% of oil palm material with conventional material (stainless steel, cast iron) and carbon fiber reinforced polymer (CFBR) using the following results we can compare and select the efficient material with improved damping.

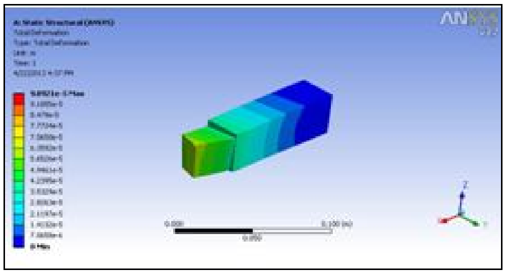
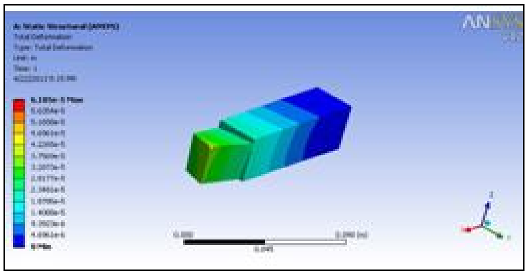



Figure 5: Total deformation of 50% oil palm with cast iron
Figure 6: Total deformation of 50% oil palm with stainless steel

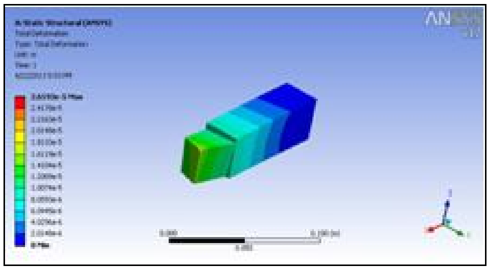
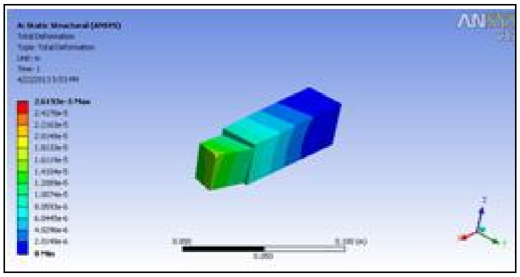



Figure 7: Total deformation of 50% oil palm with CFRP
Figure 8: Von-Mises stress of 50% oil palm with cast iron

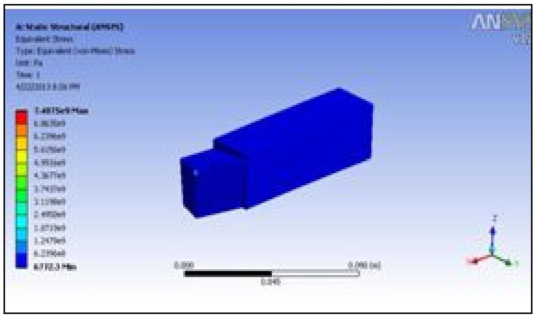
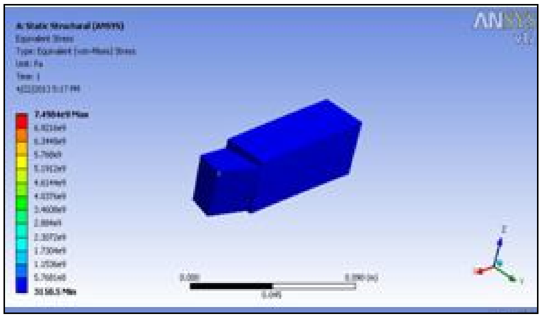



Figure 9: Von-Mises stress of 50% oil palm with stainless steel
Figure 10: Von-Mises stress of 50% oil palm with CFRP

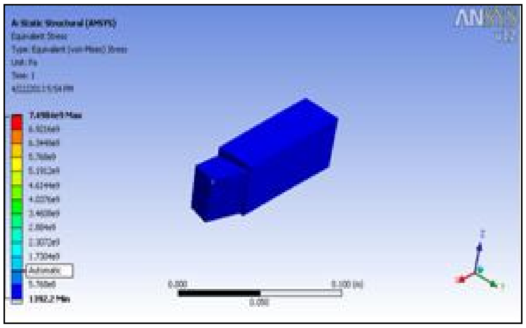
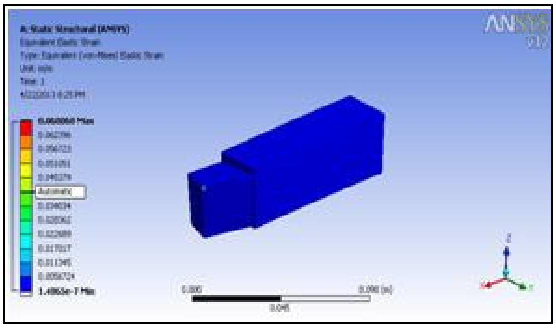
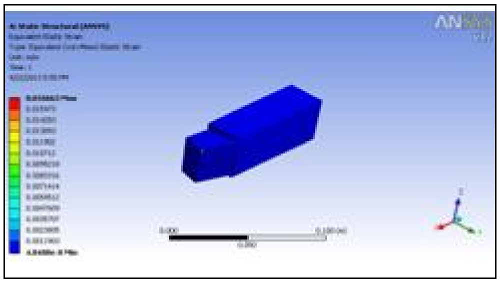



Figure 11: Von-Mises strain of 50% oil palm with cast iron
Figure 12: Von-Mises strain of 50% oil palm with stainless steel



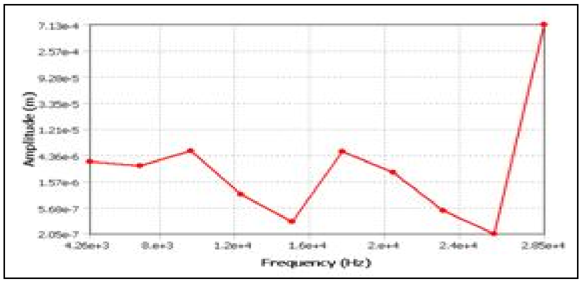
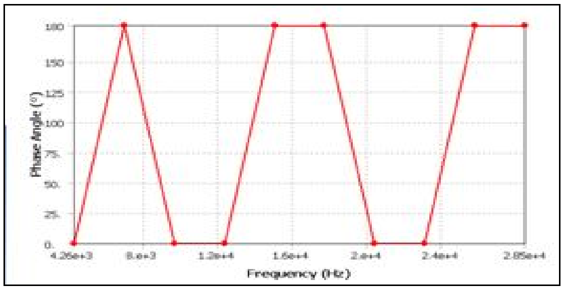


Figure 13: Von-Mises strain of 50% oil palm with CFRP
Figure 14: Amplitude vs. Frequency graph for cast iron 50%



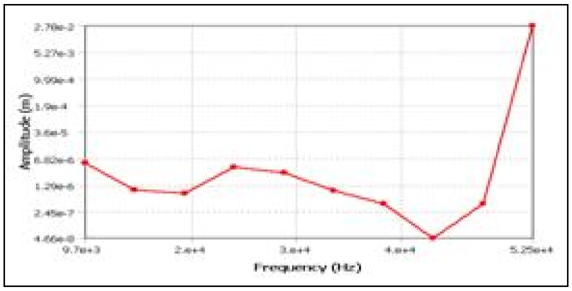
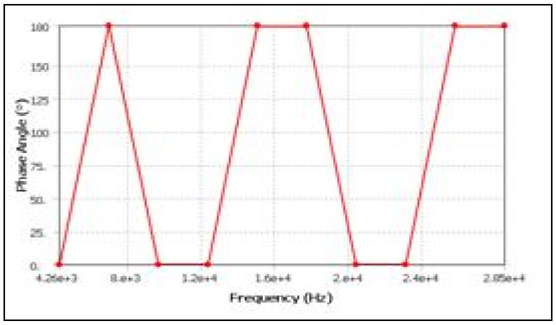


Figure 15: Amplitude vs. Frequency graph for Stainless steel 50%
Figure 16: Amplitude vs. Frequency graph for CFRP 50%



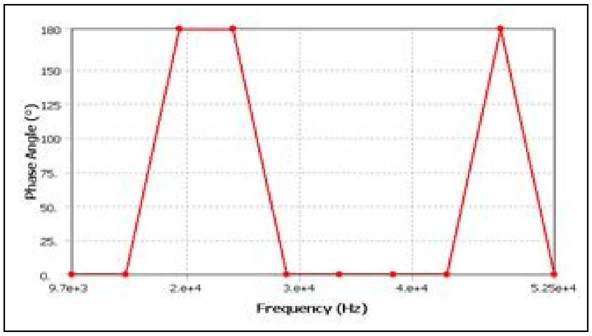
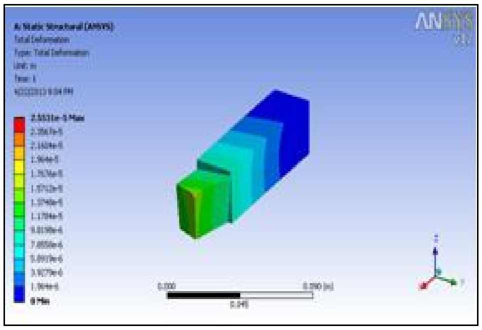


Figure 17: Phase angle vs. Frequency for cast iron 50%
Figure 18: Phase angle vs. frequency for CFRP 50%

2.2. Case 2

For case 2 we are considering 25% of oil palm material with carbon fiber reinforced polymer (CFBR) using the following results.



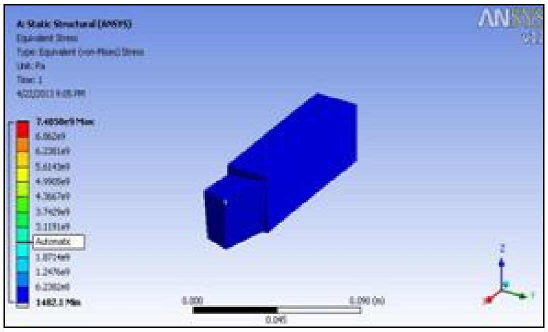
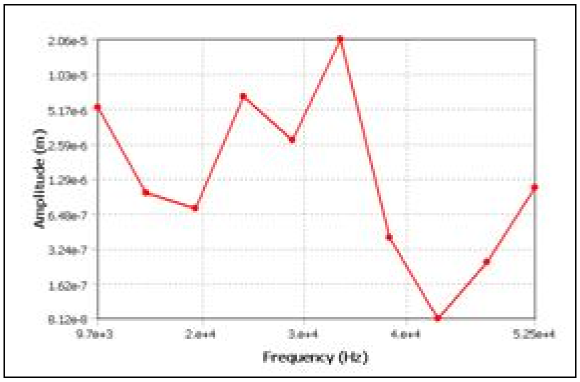


Figure 19: Total deformation of 25 % oil palm with CFRP
Figure 20: total deformation of 25%oil



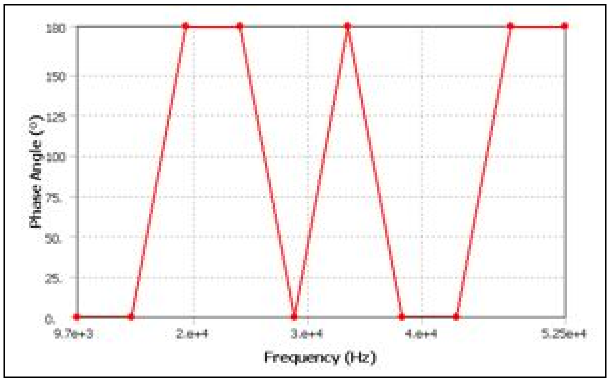
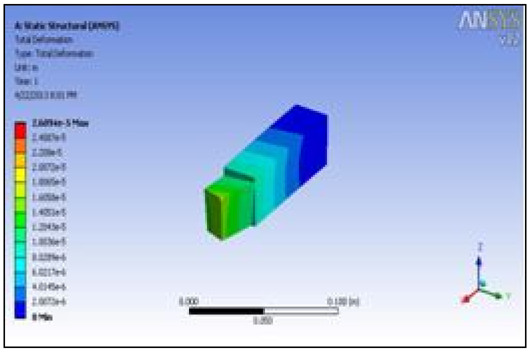


Figure 21: Phase angle vs. Frequency for 25% of oil palm material with CFRP
Figure 22: Total deformation of 75 % oil palm with CFRP

2.3. Case 3.3

For case 3 we are considering 75% of oil palm material with carbon fiber reinforced polymer (CFBR) using the following results.



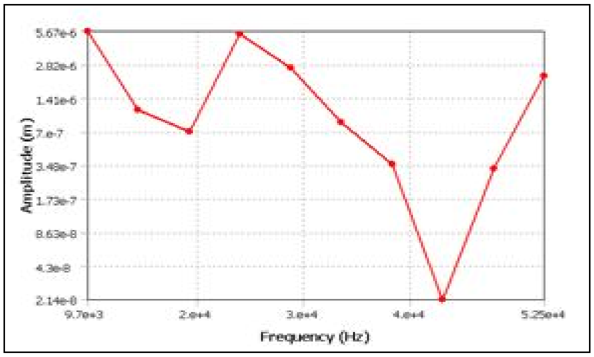


Figure 23: Von-Mises stress of 75 % oil palm with CFRP
Figure 24: Amplitude vs. Frequency for 75% of oil palm material with CFRP

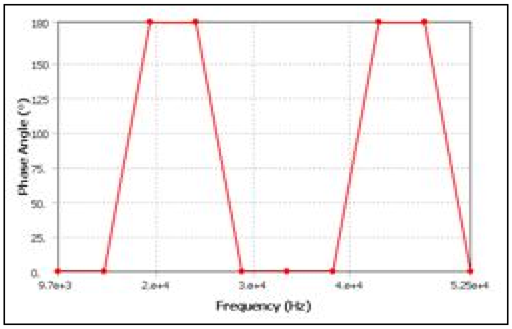


Figure 25: Phase angle vs. Frequency for 75% of oil palm material with CFRP

Material	Total Deformation max (m)	Von-mises Stress (Pa)	Von-mises Strain	First mode frequency (Hz)
Oil palm with Cast iron	9.892e-5	7.4875e9	0.06967	1228.3
Oil palm with Stainless steel	6.110e-5	7.4984e9	0.03852	1568.5
Oil palm with CFRP	2.612e-5	7.4984e9	0.01663	4944.8

s.no	material	Total deformation (m)	Von-mises Stress (Pa)	Von-mises strain	First mode frequency (Hz)
1	Oil palm with 25% CFRP	2.553e-5	7.4858e9	0.016635	4996.8
2	Oil palm with 75% CFRP	2.6094e-5	7.6285e9	0.016952	5031

Table 3: Comparisons of results for 50% of oil palm fiber material with cast iron, stainless steel and CFRP
Table 4: Comparisons of results for 25%and 75% of oil palm material with CFRP

4. Conclusion

Structural materials used in a machine tool have a decisive role in determining the productivity and accuracy of the part manufactured in it. Here in the project the conventional material (Cast iron, Stainless steel) is replaced by using the composite materials (Carbon Fiber Reinforced Polymer and Oil palm). Computer aided engineering has preferred for various design stage for developed the 3D cad model so here the cad model of machine tool is developed by using CATIA V5 R20.This work has been done by using ANSYS, in which it contains three levels. Pre-processor, solvers and post-processor. In case 1 50% of oil palm material with carbon fiber reinforced polymer (CFBR) is efficient for total deformation and mode frequency range when compare to conventional material, so we are selecting CFRP. Further CFRP is analyzed with different percentage (25%, 75%) of oil palm material inserting with length 30mm & 90mm respectively. When Comparisons of results for 25%and 75% of oil palm material with CFRP**,** the efficient result had been found only by using 75% of oil palm material with CFRP.Hence 75% Oil palm with CFRP material which possesses good damping and stiffness has to be developed as structural materials.

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