EXPERIMENTAL INVESTIGATION AND VIBRATIONAL BEHAVIOUR OF LAMINATED HYBRID COMPOSITES

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Abstract: *The aim of the present work taken to study the mechanical and vibration behavior of epoxy polymer matrix composites of Kevlar and basalt by varying the orientation of the fiber* ($0^0/0^0/0^0/0^0/0^0/0^0$), ($0^0/-30^0/+30^0/-30^0/+30^0/0^0$), ($0^0/-45^0/+45^0/-45^0/+45/0^0$), ($0^0/-60^0/+60^0/-60^0/+60^0/0^0$)*.The tensile strength, tensile modulus, flexural strength, flexural modulus and natural frequencies were found after preparing the samples by hand layup method. For the achievement of the above goal, experiments UTM and COCO-80 (FRF Analysis) setups with all necessary inputs were utilized. The variations in properties with respect to change in orientations were obtained and represented by graphs. The composite with,* ($0^0/-45^0/+45^0/-45^0/+45/0^0$) *fiber have shown improved performance in terms of flexural strength, tensile strength, tensile modulus and higher natural frequency indicating high stiffness value.*

Keywords*: Composite beams, Kevlar& basalt fibre, vibration analysis, tensile and flexural test.*

Introduction: A composite material can be defined as a combination of a matrix and a reinforcement materials, which when combined gives properties superior to the properties of the individual components. The fibre in woven mat form is added to matrix element with varying stacking sequences of symmetrical laminates. Six types of hybrid laminate composites having basalt and Kevlar fibres as the reinforcements in varying stacking sequences are produced using hand lay-up technique followed by compression moulding. [1]. Increasing the number of layers of basalt fibre increases the thermal conductivity of hybrid laminates. The Kevlar shows the lower thermal conductivity [2]. In recent years, basalt fibers have often been proposed as an alternative to glass, in view of some significant advantages which include the fact that basalt is directly spun from the molten rock, and then finished with the application of sizers not dissimilar from those applied on glass fibers. In addition, the surface of basalt fiber fibers contains groups taking part in ionic exchange, such as hydrogen-bound silanol, which form active adsorption sites and can interact with components of the sizing agent [3]. Investigation of the various mechanical properties like tensile strength, flexural, strength of epoxy material using the materials used are basalt and Kevlar fibres as reinforcement is performed and compared with other composite materials like natural and artificial fibres [4]. Kevlar is one of the most favorable composite material. Properties of Kevlar include high rigidity modulus, toughness, thermal stability and most importantly strength. Moreover, the properties of Kevlar composite can be increased by applying the different hybridization and treatment process [5]. Currently, a large interest and considerable research activity is dedicated to elicit solutions to minimize the environmental impact in the production and use of composite materials, leading therefore to their improved sustainability [6]. New environmental regulations and evolving governmental attitudes are a powerful key-driver, stimulating the research of more environmentally friendly products and processes [7].The "partial substitution" of glass fibers is normally obtained by hybridization, normally achieved by stacking layers reinforced with basalt fibers with other layers reinforced with other fibers, such as Kevlar [8].

Kevlar:

Kevlar has many applications, ranging from bicycle tires and racing sails to bulletproof vests, because of its high tensile strength-to-weight ratio; by this measure it is five times stronger than steel. It is also used to make modern marching drumheads that withstand high impact. When used as a woven material, it is suitable for underwater applications. Kevlar is resistant to almost all types of chemicals and it withstands temperatures as high as 450°C and as low as -196°C.

Basalt:

Basalt is an alternative raw material for fiber forming because of its relatively homogeneous chemical structure, its large- scale availability throughout the world. Basalt fiber offers prospect of completely new range of composite materials and product. Low-cost high-performance fibers offer potential to solve the largest problem in the cement and concrete industry, cracking and structural failure of concrete.

Epoxy:

Epoxy resins are the most commonly used resins. They are low molecular weight organic liquids containing epoxide groups. They have high strength, low viscosity and low flow rates, which allow good wetting of fibers and prevent misalignment of fibres during processing.

Design and Fabrication:

In the present work, epoxy composites reinforced with alternate layers of Kevlar and basalt fibers of varying orientations. The composite beams are prepared by hand layup technique. The combined weight of the fibers is 43.7% and that of epoxy is 56.2% of the total weight of the sample. The layers of Kevlar and basalt are placed at different orientations, outer most layers are made by Kevlar and inner layers are prepared by basalt. The resultant Composite plates are of the following layer patterns and fiber orientations: $(0^0/0^0/0^0/0^0/0^0/0^0)$, $(0^0/-30^0/+30^0/-30^0/+30^0/0^0)$, $(0^0/-45^0/+45^0/-45^0/+45/0^0)$, $(0^0/60^0/+60^0/60^0/+60^0/0^0)$. The processed wet composites are dried for 24hrs, and after drying the composite, the composite plate is cut into samples. The samples for tensile test, flexural test and vibration test are cut into required dimension as per ASTM standards.

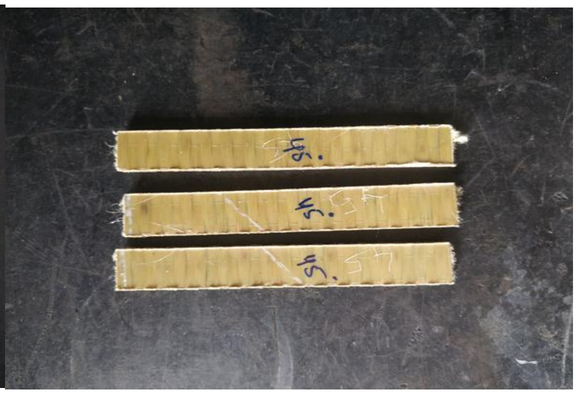


Fig no:1 Specimen for tensile test Fig no:2 specimen for flexural test

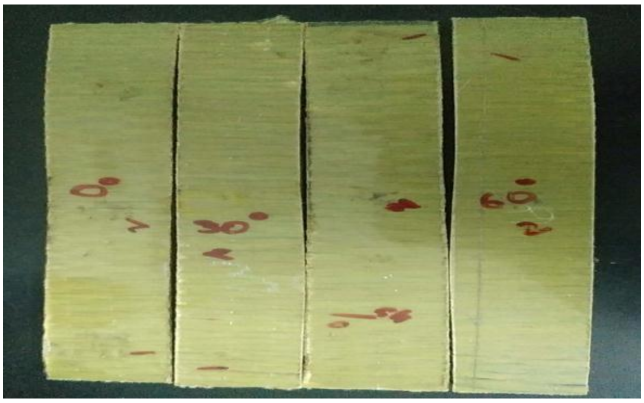


Fig no:3 Specimens for FRF test

Tensile Test:

In the present work, Kevlar & basalt reinforced epoxy hybrid composite material tensile properties are determined using Universal Testing Machine (UTM). ASTM Standard D638-03 is used to prepare specimen for tensile test. The specimens under tensile test are shown in fig no: 1and 4.

Flexural Test:

The prepared specimens are tested for flexural strength as per ASTM standard D256. This test is conducted on the same UTM which is used for tensile testing. The beam is placed on the two grips and the point load is applied on the composite beam. The sample fails after the maximum load. The specimens under flexural testing are shown in fig no: 2 and 5.

Fig no: 4 specimen of tensile test after load

Fig no: 5 specimen of flexural test after load

Vibration Test:

The CoCo-80 (Coco) is a handheld data recorder, dynamic signal analyzer, and vibration data collector that is ideal for a wide range of industries including automotive, aviation, aerospace, electronics, and military applications that demand easy, quick, and accurate data recording and real-time processing in the field**.** The Coco hardware platform supports two different software working modes: Dynamic Signal Analyzer (**DSA**) and Vibration Data Collector (**VDC**). Each working mode has its own user interface and operation navigation structure. The test specimens for FRF test and equipment are shown in fig no: 3 and 6.

Fig no: 6 FRF vibration test setup.

Results

Tensile Test: Table 1 shows the tensile strength of Kevlar & Basalt fibers at various orientations. The tensile strength of the composite is increased by changing the orientation of fibers. The higher mean tensile strength value is noticed at (0°/-45°/45°/-45°/45°/0°) orientation.

S. No	Type of orientation	Average Load (KN)	Tensile Strength (N/mm^2)	Young's Modulus (E) (N/mm^2)
1	(0°/0°/0°/0°/0°/0°)	0.550	13.814	650.074
2	(0°/-30°/30°/-30°/30°/0°)	0.725	17.452	460.776
3	(0°/-45°/45°/-45°/45°/0°)	1.250	31.232	715.919
4	(0°/-60°/60°/-60°/60°/0°)	0.610	16.542	648.700

Table 1: Tensile Strength Vs Type of Orientation

Flexural test: Table 2 shows the flexural strength of Kevlar and basalt fibres. The flexural strength of the fibre at different orientations.

S. No	Type of orientation	Flexural strength (N/mm^2)	Flexural modulus (N/mm^2)
1	(0°/0°/0°/0°/0°/0°)	64.415	3390.26
2	(0°/-30°/30°/-30°/30°/0°)	119.70	1940.03
3	(0°/-45°/45°/-45°/45°/0°)	220.74	3396.00
4	(0°/-60°/60°/-60°/60°/0°)	94.087	1908.40

Table 2: Flexural Strength Vs Type of Orientation

Vibration Test: The natural frequency of the composite beams at different orientations are analysed by using the FRF analyser. The natural frequency of the composite beam at different orientations and different supporting condition (cantilever) by H function &COH function graphs obtained from FRF analyser. The ASTM standards used are D175. The test results are represented in graphical form from fig no: 7 to 14 and corresponding H and COH function values in the table no: 3 to 10.

SIG1771_H (ch2, ch1) at 0° on cantilever beam.

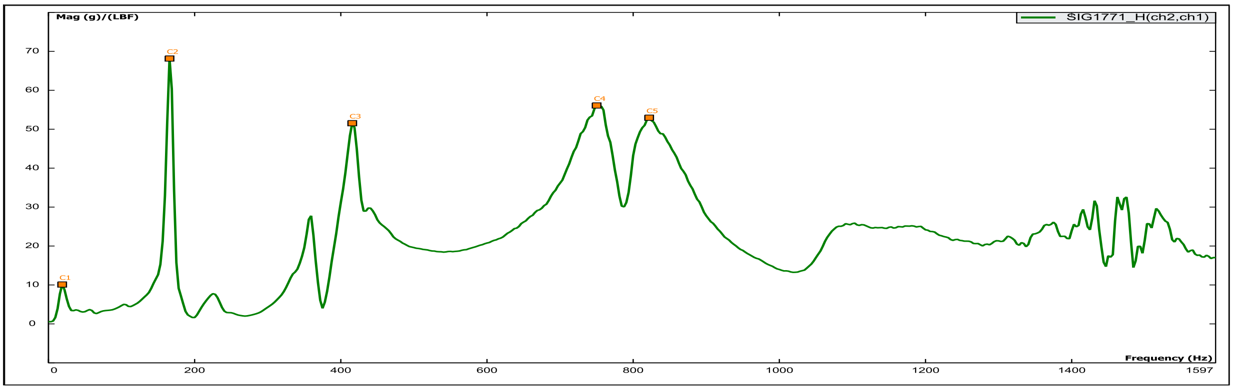
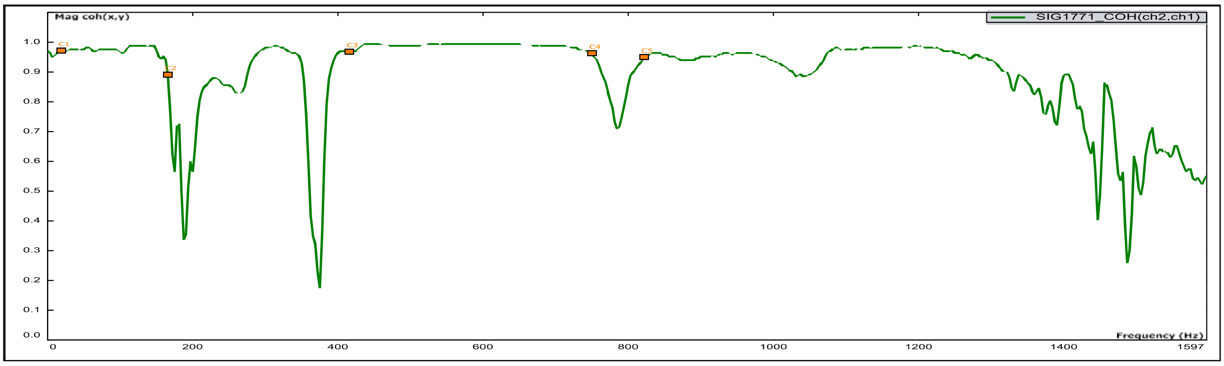


Fig no:7 Magnitude Vs Frequency In Cantilever Condition

H (ch2, ch1)	X Frequency (Hz)	Y Mag (g)/(LBF)
C1	**18.7500**	**10.1075**
C2	**165.6250**	**68.1499**
C3	**415.6250**	**51.5388**

Table: 3 H Function Values.

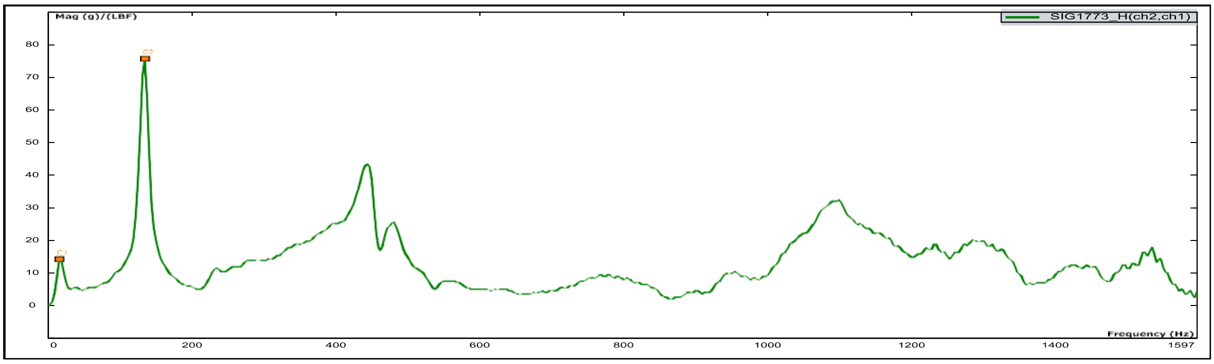


SIG1771_COH (ch2, ch1) at 0° on cantilever beam (coherence values)

Fig No: 8 Magnitude Vs Frequency In Cantilever Condition

COH (ch2, ch1)	X Frequency (Hz)	Y Mag coh(x,y)
C1	18.7500	0.9718
C2	165.6250	0.8907
C3	415.6250	0.9679

Table: 4 COH Function Values

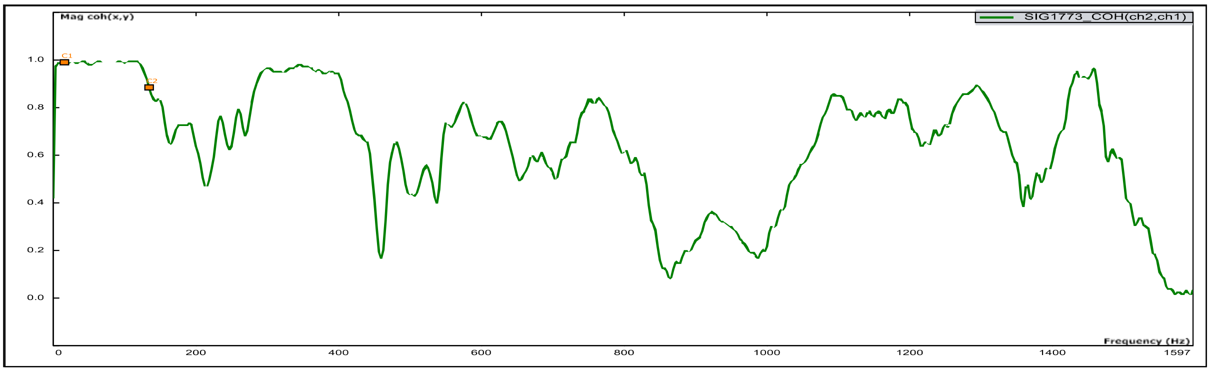


SIG1773_H (ch2, ch1) at 30° on cantilever beam.

Fig No: 9 Magnitude Vs Frequency In Cantilever Condition

H (ch2, ch1)	X Frequency (Hz)	Y Mag (g)/(LBF)
C1	**15.6250**	**14.3670**
C2	**134.3750**	**75.8103**

Table: 5 H Function Values



SIG1773_COH (ch2, ch1) at 30° on cantilever beam (coherence values).

Fig no: 10 magnitude vs frequency in cantilever condition

COH (ch2, ch1)	X Frequency (Hz)	Y Mag coh(x,y)
C1	**15.6250**	**0.9900**
C2	**134.3750**	**0.8845**

Table: 6 COH Function Values

SIG1775_H (ch2, ch1) at 45° on cantilever beam.

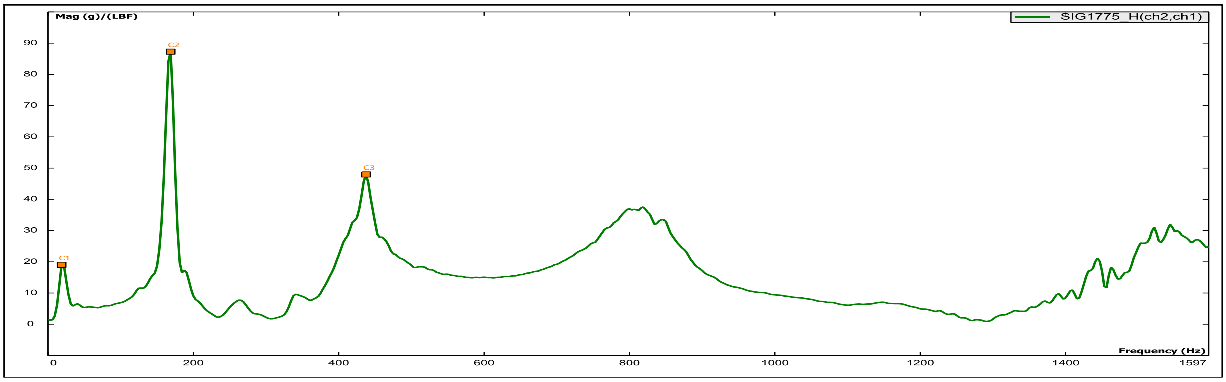


Fig no: 11 magnitude vs frequency in cantilever condition

H(ch2,ch1)	X Frequency (Hz)	Y Mag (g)/(LBF)
C1	18.7500	19.0454
C2	168.7500	87.2888
C3	437.5000	47.9690

Table: 7 H Function Values

SIG1775_COH (ch2, ch1) at 45° on cantilever beam (coherence values).

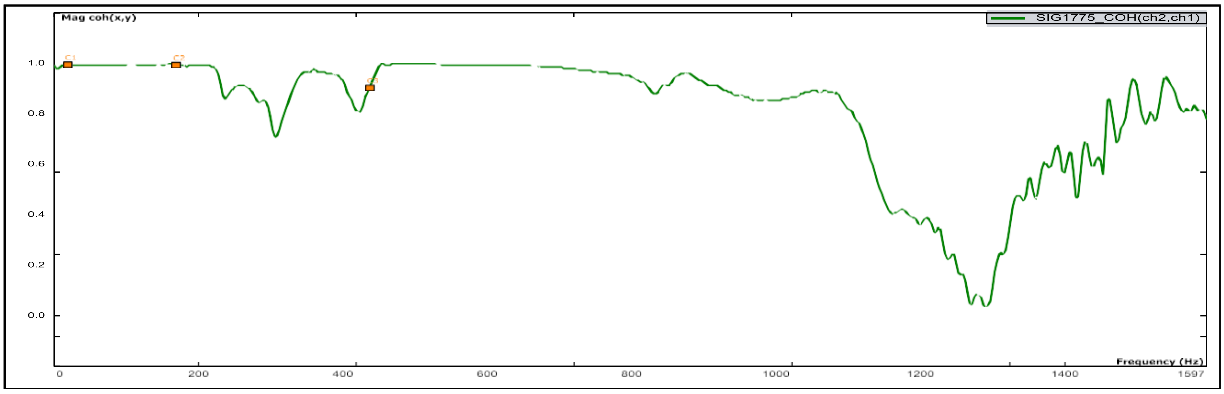
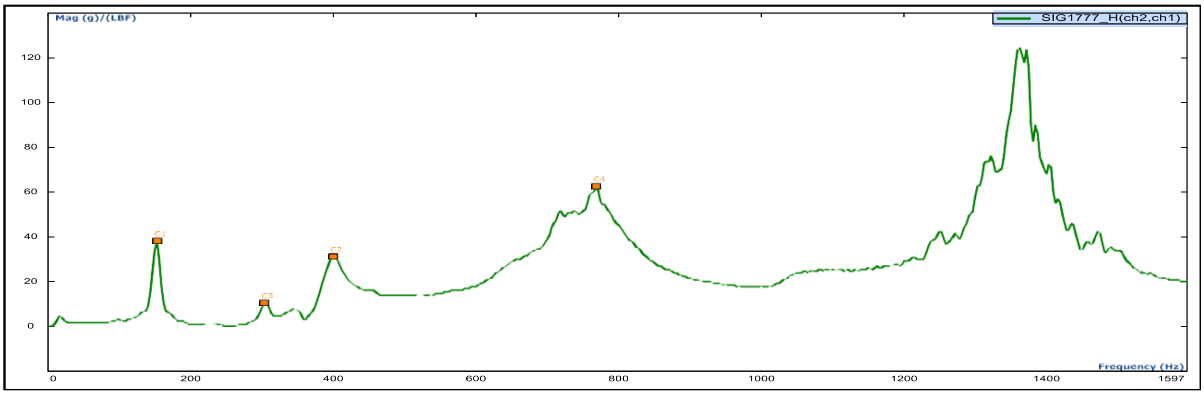


Fig no: 12 magnitude vs frequency in cantilever condition

COH (ch2, ch1)	X Frequency (Hz)	Y Mag coh (x, y)
C1	18.7500	0.9968
C2	168.7500	0.9945
C3	437.5000	0.9032

Table: 8 COH Function Values

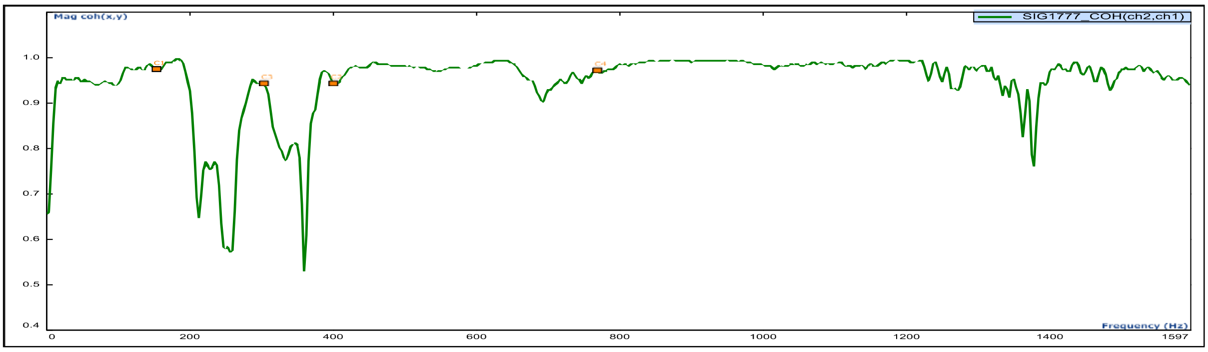


SIG1777_H (ch2, ch1) at 60° on cantilever beam.

Fig no 13 magnitude vs frequency in cantilever condition

H (ch2, ch1)	X Frequency (Hz)	Y Mag (g)/(LBF)
C1	153.1250	38.3890
C2	400.0000	31.2688
C3	303.1250	10.6375

Table: 9 H Function Values



SIG1777_COH (ch2, ch1) at 60° on cantilever beam (coherence values)

Fig no 14-magnitude vs frequency in cantilever condition

COH (ch2, ch1)	X Frequency (Hz)	Y Mag coh (x, y)
C1	153.1250	0.9747
C2	400.0000	0.9440
C3	303.1250	0.9437

Table: 10 COH Function Values

Conclusion:

The present work experimentally evaluated the mechanical and vibrational properties of fabricated epoxy polymer reinforced with Kevlar and basalt fibers at different orientations. The tensile test, flexural test & vibration test are carried out at different orientations. It is observed that the orientation (0°/-45°/45°/-45°/45°/0°) has highest values of tensile strength, flexural strength, and natural frequencies. The lowest values are obtained at orientation of (0°/-30°/30°/-30°/30°/0°).

References:

[1]. Fasil Mohi UD Din. Experimental investigation on mechanical properties of Kevlar fibre. International journal of engineering and technology2017; 4:3466-3473.

[2]. M.C. Lin, C. W. Lou, J.Y. Lin, T. A. Lin, and J.H. Lin, Mechanical property evaluations of flexible laminated composites reinforced by high performance Kevlar: tensile strength, peel load, and static puncture resistance compos. Part B Eng., vol. 166, no. April2018, pp. 139-147.

[3]. shaari, N., Jumahat, A., Yahya, K.H and Suleiman, M.F. 2014. Impact resistance of woven fibre reinforced polymer composites. environ.biol.8(8): 2662-2668.

[4]. Articles aramid fibres -an overview M Jassal & S Ghosh., Indian journal of fibre &Textile research vol.27, (2002), pp. 290-306.

[5]. Y. K Sahu "Study on the effective thermal conductivity of fibre reinforced epoxy composites," 2014.

[6[Mohanty AK, Misra M, Hinrichsen G, Biofibres, biodegradable polymers and bio composites: An overview, Macromolecular Materials and Engineering 276-277 (1), 2000, 1–24.

[7] Fowler PA, Hughes JM, Elias RM, Bio composites: technology, environmental credentials and market forces, Journal of the Science of Food and Agriculture 86 (12), 2006, 1781-1789.

[8] Wambui P, Iven's J, Verpoest I, Natural fibres: can they replace glass in fibre reinforced plastics Composites Science and Technology 63 (9), 2003, 1259–1264.

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