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STUDY ON THE PROPERTIES OF NATURAL FIBRE REINFORCED POLYMER MATRIX COMPOSITES MATERIAL

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ABSTRACT

Presently several ventures and industries need perishable or eco-accommodating materials to interchange with existing materials with no compromise on properties or performance execution variety. Fibre strengthened compound resin materials are economically or monetarily perishable and renewable sources. These properties generated widespread research and development in this area, and these new materials have received more and more attention in industrial applications. Properties of such material will further be changed by adding natural resins with synthetic resin, therefore an effort was created in an exploitation of these composite of artificial plant product with jute fibre as reinforcement. So an endeavor was created by utilizing the properties of jute fibre with the mixture blend of three artificial resins particularly general purpose resin, vinyl ester organic compound and isophthalic polyester and cardanol alkali treatment. The employment of such composites for low-temperature structures is usually hindered by inconsistency of fabric properties choice of composite materials for such applications is tough and inferable by their anisotropic thermal behavior and complicated surface characteristics whereas undergoing low-temperature drifts and therefore the eventfully massive variations in their properties. it's well-known that polymeric materials have low thermal conductivity (0.1-0.5 W/m/K) and hence thermal expansion. Thermally sensitive to conductivity and expansion, polymer composites have many benefits compared to conventionally used metals, like low density, corrosion resistance, and low processing price. The parameters like cardanol concentration, type of synthetic resin and number of layers (and fibre orientation) are varied in this project and with the aid of Taguchi's L9 array method, samples are prepared. The samples are tested for their coefficient of linear thermal expansion by Dilatometer. The variation of each parameter is studied and a regression equation is developed using ANOVA analysis for optimum thermal properties. The variation of every parameter is studied and an equation is developed for optimum thermal properties.

Keywords: general purpose resin, Isophthalic polyester, vinyl ester, jute fibre, composite material, thermal expansion.

1. INTRODUCTION

Environment pollution being caused by plastic waste has threatened the delicate atmosphere in several developing countries. However only a few countries have worked on such reasonably tricky issues of waste management and reducing environment pollution .Republic of India was troublesome in financing such amounts of cash and infrastructure over alternative solutions that are required. During this work an attempt is created for fabrication of such chemical compound composites like natural fibre reinforcing which is way favorable substitute. For such non-biodegradable plastics which are employed in reinforcing and creating composite largely ecofriendly. Additional demanding environmental laws are encouraging researchers to design composites with the smallest amount environmental footprint which might be used for the domestic and industrial purpose. Green, ecologically (environmentally) friendly, sustainable, renewable and perishable composites from plant derived fibre and derived plastics are among the foremost keenly needed materials of the 21st century. Biobased composites possess a large vary of end of life prospects like incineration, recovery/recycling and composting. Research on this field drew attention because of the following parameters of jute. Research on biodegradable polymer composites, containing lingo cellulosic fibres, generates attention due to the dwindling petroleum resources, low costs of lingo cellulosic reinforcements with a variety of properties and increasing ecological considerations. Fossil fuel-based polymers are non-degradable and non-renewable while renewable polymers are generally sensitive to moisture and do not provide effective gas barrier properties, hybrid filler filled composites have shown great potential to overcome some of these shortcomings. The interactions, between the filler and the epoxy matrix, are found to be improved by the chemical treatment of the filler. Cellulosic materials are abundant which can be used as reinforcements, for ecological and economic reasons, with high mechanical and thermal performance. The incorporation of these natural fibres in the polymer matrix has been found helpful in biodegradation of the composite materials. several industrial and additionally in engineering approaches this consideration [1] As composite of those polymers primarily based Composite fibres reinforcements show sensible strength and stiffness subsequently therefore are thought of in are used as thermosetting or thermoplastics as matrix besides natural fibres and their fillers. [2] Behaves as very soft matrixes material having sensible stiffness and powerful fibre reinforcement. [3] The necessities for eco-friendly materials are enhanced and researchers are encouraged in developing such composite materials. [4]As they're of low price, occurs naturally, partly capable of recycling and perishable presently

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researchers on polymer composites are specializing in the implementation of such natural fibre reinforcement in artificial and resin. Natural fibres like Jute are used as reinforcement in composite that yields needed properties when utilized in thermo sensitive application. Research on biodegradable polymer composites done previously are-[1] Jartiz *et al*. declared that "Composites have many functional material systems that offer characteristics not procurable from any distinct material. They're cohesive structures created by physically combining two or additional compatible materials, totally different in composition and characteristics and typical in kind. [2] Kelly *et al*. emphasis clearly that the composites mustn't be regarded straightforward as a mixture of two materials. Within the broader significance; the mixture has its own distinctive properties. In terms of strength to resistance to temperature or another fascinating quality, it's higher than either of the parts alone or radically totally different from either of them being considered. [3] Beghezan *et al*. defines as "The composites are compound materials which differ from alloys by the fact that the individual components retain their characteristics but are so incorporated into the composite as to take advantage only of their attributes and not of their short comings", in order to obtain improved materials.[4] Van Suchetclan *et al*. explains composite materials as heterogeneous materials consisting of two or additional solid phases, that are in intimate contact with one another on a microscopic scale. they will be additionally thought of as uniform materials on a microscopic scale within the sense that any portion of it'll have a similar property. [5] Li yan *et al*. conducted a look to check the mechanical properties, particularly surface performances of the composites supported natural fibres because of the poor surface bonding between the hydrophilic natural fibres and also the hydrophobic compound matrices. 2 varieties of fibre surface treatment strategies, particularly chemical bonding and chemical reaction were wont to improve the surface bonding properties of fibre bolstered compound composites. Surface properties were evaluated and analyzed by single fibre pull-out check and also the theoretical model. The surface shear strength (IFSS) was obtained by the applied math parameters. The results were compared with those obtained by ancient ways that. supported this study, Associate in Nursing improved technique that may a lot of accurately judge the surface properties between fibre and compound matrices was planned. [6] Joshi *et al*. compared life cycle environmental performance of natural fibre composites with glass fibre reinforced composites and found that natural fibre composites are environmentally superior in the specific applications studied. [7] BC Ray *et al*. used three point flexural take a look at to qualitatively assess such effects for fifty five, sixty and sixty five weight percentages of the glass fibres strengthened epoxy composites throughout refrigerant and once thawing conditions. The specimens were tested at a spread of 0.5 mm/min to 5.00 mm/min crosshead speed to judge the sensitivity of mechanical response throughout loading at close and sub-ambient (- 80 °C temperature). These shear strength values square measure compared with the testing information of as-cured samples.

Once reviewing the prevailing literature obtainable on fibre composites, notably natural fibres. composites are likely to be environmentally superior to glass fibre composites in most cases for the following reasons: [1] natural fibre production has lower environmental impacts compared to glass fibre production; [2] natural fibre composites have higher fibre content for equivalent performance, reducing more polluting base polymer content; [3] the lightweight natural fibre composites improve fuel efficiency and reduce emissions in the use phase of the component, especially in auto applications; and [4] end of life incineration of natural fibres results in recovered energy and carbon credits. Jute fibre is definitely obtainable in lots of abundance and being environment friendly and low fabrication value.

Chemical composition of jute truly brings attention towards them. Some of the natural fibres used for composite manufacturing are jute, flax, banana, coir and hemp. Currently, natural fibre composite materials are applied in automobile and packing industries used for low load carrying application. And kind of resin used in conjunction with cardanol additionally plays very important role to find the thermal properties of such material.

In preparation of such samples, three sorts of artificial resin specifically general purpose resin (GP), vinyl organic compound (VE) and isophthalic polyester (IP) with 10%, 20%, and 30% cardanol resin have been used. The thermal properties namely Coefficient of linear thermal expansion are evaluated using dilatometer respectively .Some of the natural fibres used for composite manufacturing are jute, flax, banana, coir and hemp. Currently, natural fibre composite materials are applied in automobile and packing industries used for low load carrying applications. The applications of natural fabric reinforced hybrid polymer matrix composites can be found in many sectors like Storage devices, Electric devices, automobile, aerospace, refractory products, packaging materials, insulators etc.

2. DESIGN APPROACH

It is clear that the individual parameters of level three factors with further division of three subvarying parameter chosen here can produce a combination of twenty seven samples all together so, to have a design constraint for optimal combinations the consideration of design of approach is encouraged in producing the required samples. The design of the experiment is carried out with the help of Taguchi L9 array method. The total numbers of parameters to be varied are, Cardanol percentage (10, 20 and 30 %), Type of Synthetic resin (GP, IP and VE), orientation (0, 30, and 45). So, it is clear that with the help of design of experiments L9 (DOE), can channelize the vision to a very specific and limited combination and produced a required specific combination

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as on Table-1 thus the application of DOE has made reduction of sample quantity to only nine out of 27samples, saving time and money.

2.1. Design of experiments (doe) for preparation of samples

Design of experiments (DOE) is powerful, as used in different fields such as new product developments, process optimizations and better quality controlling. Taguchi's approach is mainly to the quality losing function. Quality can be achieved only by minimizing the effect of deviation of a target. So the products designed in uncontrollable environmental causing factors should have very small impact on their product performance or its characteristics.

Design of experiment (DOE) procedure according to Taguchi is as follows for finding no of samples:

a) Define the Product / Process objective.

b) Determination of the design parameters affecting the product characteristics.

c) Selection of response variables & control parameters and their levels

d) Selection of the orthogonal array.

e) Conducting the matrix experiments.

f) Analysis of the data and prediction of optimum level. Considering the above merits the Table-1, is the resultant L9 array required.

So, considering the parameters Cardanol percentage (10, 20 and 30 %), Type of Synthetic resin (GP, IP and VE), orientation (0, 30 and 45).the resultant is generated Table-1.

Table-1. Number of samples prepared by using taguchi L9 array method.

Serial No.	Cardanol %	Synthetic resin*	Orientation
1	10	VE=1	0
2	10	IP=2	30
3	10	GP=3	45
4	20	VE=1	30
5	20	IP=2	45
6	20	GP=3	0
7	30	VE=1	45
8	30	IP=2	0
9	30	GP=3	30

3. SPECIMEN PREPARATION

According to the above Taguchi's L9 orthogonal array which was used along with design of experiments for the parameters provided an optimal path provided for a specific number of samples as shown in Table-1. The varying cardanol %, type of synthetic resign and fibre orientation have brought the realistic constraints as per suggested by the design of experiments. The CNSL provides the enhancement of biodegrading property and recycling of composite specimen. The composite specimens are prepared by using hand layout technique according to the Table 1. Fibre used as reinforcement which are taken in long continuous forms are cut according to the required dimensions and placed in moulds in straight manner before getting in contact with their resign which is to be prepared in the combinations which are suggested by the orthogonal array. Then the mixture of cardanol concentration varying in addition to synthetic resign are mixed and then applied to the fibre of different orientations in required layers following the sequences of Table-1. Once the samples are prepared accordingly, they are carefully prevented from the ambient particles from contaminating, as they also may offer excess resistance during the experiment. Thus the prepared samples are carefully allowed to cure in hot air oven. As the polymer matrix is the combination of GP, IP and VE (synthetic resin) and cardanol(natural resign)in different portions it may take different time for cure. After providing an appropriate time to cure for all the samples is given they will be ready for testing. The addition of methyl ethyl ketone peroxide is used as catalyst which helps in speeding up the process of solidification during curing period and cobalt naphthenate is used as hardener for above specimen being prepared. Generally specimens are allowed to cure in normal atmospheric conditions for 5-8 days to get completely cured. The Figure-1 shows the completely cured composites taken out from the mould row-wise .Later the composites are trimmed to get the required size and dimensions as per ASTM D696 standards for the test for COTE.

Figure-1. Samples prepared.

3.1. Test specimen for thermal expansion

The specimens to be tested are laminated and are made free from contain any metal layers. This specimen whose value for COTE is to be determined should be of 2-

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4 inches long with ¼ inches wide and a minimum thickness of 1/8 inches is to be maintained, at the end surfaces of the specimen are maintained to be in parallel with each other. Any change from the nominal should be known before such as thermal gradient of temperature chamber and temperature lag of the specimen and any distortion of the specimen.

4. SET UP DESCRIPTION AND PROCEDURE

4.1. Apparatus: Coefficient of thermal expansion by the vitreous silica (Quartz) dilatometer method

Vitreous silica dilatometer of either the tube or push rod type to determine the change in length of a solid material as a function of temperature. The temperature is controlled at a constant heating or cooling rate. The linear thermal expansion and the coefficients of linear thermal expansion (COTE) are calculated from the recorded data. The sole purpose of the device is to find out the differences and thermal expansion between the required test specimen and virteous silica of the setup. Specimen holder (tube) and probe shall be made of vitreous silica. The probe contact shall be flat or be rounded to approximately a 10 mm radius. Chamber for uniformly heating and cooling the specimen. The specimen temperature change rate shall be con-trolled. The temperature gradient in the specimen shall not exceed 0.5°C/cm. Transducer, for measuring the difference in length between the specimen and the specimen holder with an accuracy of at least ± 0.5µm. The transducer shall be protected or mounted so that temperature changes will not affect the readings by more than 1.0µm. Micrometer, for measuring the reference length, Lo, of the specimen with an accuracy of at least ± 25µm. Thermocouple, types E, K, or T, for measurement of the specimen temperature. (Type E is NiCr versus constantan, type K is NiCr versus NiAl and Type T is Cu versus constantan)Recorder or data logger for collecting temperatures and lengths.

4.2. Test procedure for cote

Specimens are measured using micrometer to find the initial length in inches. This specimen is taken care for avoiding any presence of foreign particles before being placed in the dilatometer which is in Figure-2, as it may result in wrong conclusion of values. Specimens of thickness 0.125 inches are taken care by supporting with side plates in order to have a good placement of the specimen against the bottom of the tube and the push rod. At the mid length of the specimen thermocouple sensor being available is made to have an intimate contact. A proper mounting of the transducer in the set up must be done so as to have a stable contact with the probe available. The precaution to avoid a larger loading force during sample installation should be taken for a optimum and proper contact between the rod and the specimen, and the bottom of the tube and the specimen .setting of nominal initial reading of the transducer is to be done, now the entire assembly set up of dilatometer is to be placed into a chamber which will allow the specimen to reach an equilibrium state. The initial temperature readings of the thermo couples as well as the initial reading of the transducer are to be recorded before conducting the experiment. The rate of cooling or heating during the experiment must be always at a constant rate and the preferred rate of heat change can be to a range of 2-3 °C/min. the corresponding change in length is noted as function of temperature. The same procedure is repeated by removing the specimen for the fixture.

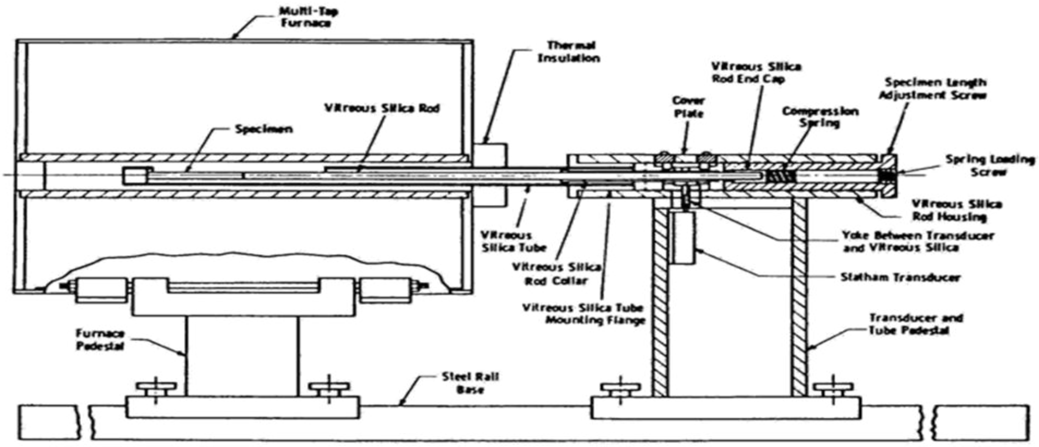

Figure-2. Cutaway view of vitreous silica tube dilatometer.

5. RESULT AND ANALYSIS FOR COEFFICIENT OF THERMAL EXPANSION

Coefficient of linear thermal expansion is the measure of thermal sensitivity of a material in terms of its size. In the dilatometer apparatus, the standard specimen size is inserted in a silica vitreous tube, which is attached to a dial gauge. When the specimen is heated using a heat source, the specimen starts increasing in size which can be noted in the dial gauge. This way coefficient of thermal expansion of all the 9 samples was calculated accordingly suggested by Table-2.

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The experiment has been conducted to the standards of ASTM D696 standards for the test for COTE

Table-2. Coefficient of thermal expansion (cote) of all the samples.

S. No.	Coefficient of thermal expansion ($\times 10^{-4}$) /K	Initial temperature (Celsius)	Final temperature (Celsius)
1.	1.903	30	110
2.	1.2547	30	110
3.	0.3817	30	110
4.	0.9375	30	110
5.	2.3	30	130
6.	1.375	30	130
7.	0.0625	30	130
8.	1.25	30	130
9.	2.00	30	130

5.1. Main effect plot for thermal expansion (cote)

The main effects plot, shown in Figure 3 presents the influence of the parameters such as cardanol %, synthetic resin and fibre orientation on COTE. From the main effects plot COTE is least when the percentage of cardanol is 10% and it slightly increases when it is 20% and again it decreases when cardanol goes to 30%. When it comes to the role of synthetic resin vinyl ester has the least COTE and Isophthalic polyester has highest COTE. Fibre orientation has also has a major role to play as 0/0 orientation has the highest COTE and 45 /45 has the least*)*

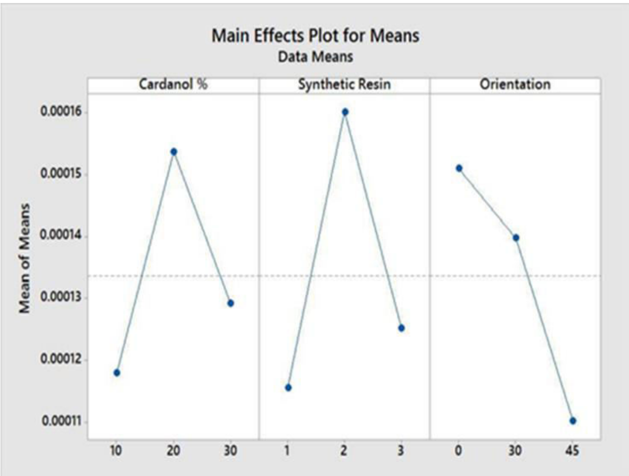

Figure-3. Main effect plot of COTE vs cardanol%, synthetic resin, orientation.

5.2. Contour plots for thermal expansion

In the Figure-4 contour plot of orientation vs caradanol is presented with COTE as the response factor. From the contour plot COTE is lowest at 10% cardanol and 45/45 orientation. From this we can infer that COTE increases with percentage of cardanol and is highest when the fibres of jute fabric are in the direction of heat flow.

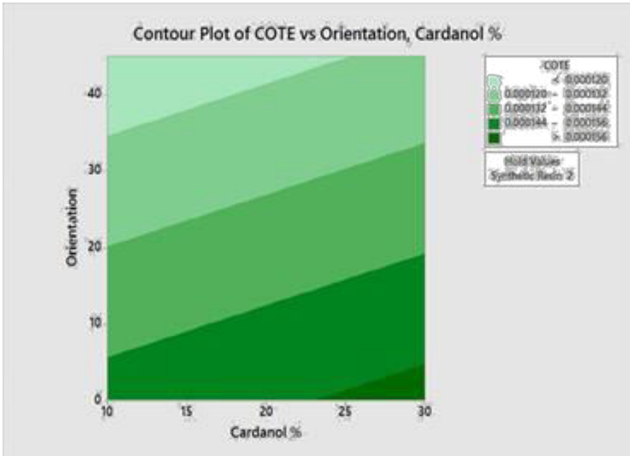

Figure-4. Contour plot of COTE vs orientation, cardanol%.

In the Figure-5 contour plot of orientation vs synthetic resin is depicted with COTE as the response factor. The contour plot depicts that COTE is highest when general purpose resin is combined with 0/0 oriented jute fibres. It can also be seen that it is least at 45/45 orientation and vinyl ester combination.

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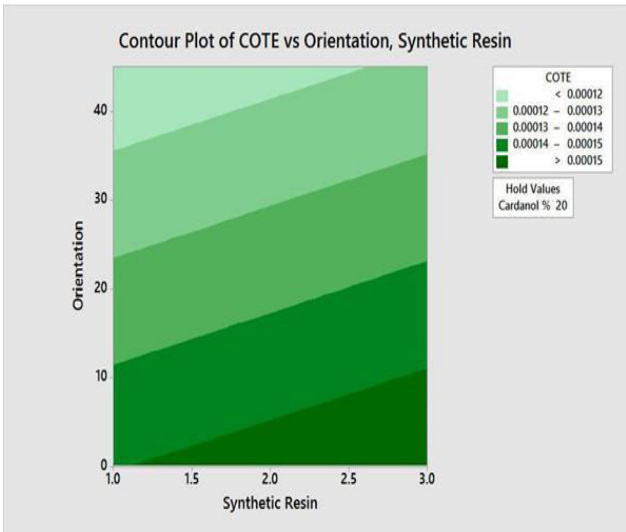

Figure-5. Contour plot of COTE vs orientation, synthetic resin.

In the Figure-6 the contour plot is for synthetic resin vs cardanol% with COTE as the response factor. It can be seen that COTE is highest at 30% cardanol and general purpose resin combination and COTE also decreases with the percentage of cardanol when the resin is kept constant.

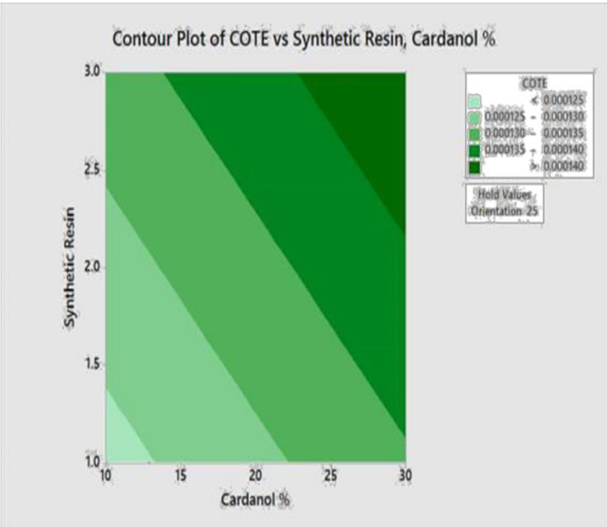

Figure-6. Contour plot of COTE vs synthetic resin, cardanol%.

5.3. Regression equation for cote

In order to know the combined effect of the individual varying parameters such as (percentage of cardanol, synthetic resin% and orientation) on the dependent property i.e. COTE, a linear equation has been generated, which shows the dependency rate of each individual independent parameter together on the required dependent property. The equation thus satisfying the requirements to find the COTE as depending property on chosen parameters is obtained using MINITAB software. The regression equation obtained for thermal equation COTE

COTE = 1.361 - 0.00377 Cardanol % + 0.1422833 Synthetic Resin - 0.118598 Orientation

The regression equation here depicts that orientation is inversely proportional to the COTE and the value of COTE for any of the combination can be calculated from the given regression equation. By looking at the coefficients of all the variables it can be concluded that type of synthetic resin plays a very important role when it comes to calculating the COTE of a composite.

6. CONCLUSIONS

Our aim for studying the thermal property of PMC materials have been successfully accomplished, to that of the selected and considered varying independent parameters and their responses such as thermal expansion have been obtained and studied. Our successful approach in studying the thermal property for various combinations has lead us to know the influence of each independent variables being considered, apart from that of the combined effect on the result and the following conclusions are drawn from the ANOVA analysis for Thermal expansion results. The following conclusions are drawn from the ANOVA analysis for Thermal conductivity results.

a) The increase in cardanol % causes increase in COTE for same type of resin.

b) VE gives the lowest COTE when combined with 10% cardanol and Jute Fibre as reinforcement compared to any other combination.

c) The increase in fiber volume decreases the COTE.

d) In order to have an increase in the cote value for the orientation the percentage of cardanol in the blend should be also increases correspondingly.

e) The value of cote for increasing in the orientation is also a linear dependent on the amount of synthetic resin. So the resin either synthetic or cardanol have an incremental property on cote.

f) To have a linear increasing of cote value for the resin, they should be blended with cardanol percentage in increasing manner. It is optimum when cardinal percentage is added from 10 to 20% (the value of cote gradually decreases in further additional of cardinal for 20 to 30% with a steep slope). Out of the synthetic resin being used IP, gives a higher cote value.

g) Increase in the angle of fabricated fibers shows decrease in cote value.

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So, considering the above discussed conclusions which are drawn from the analysis, the requirement polymer composite properties can be obtained by carefully selecting the combination of materials as per the purpose required.

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