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Finite Element Analysis for Deformation Studies in Natural Fiber (Human Hair) Composites

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ABSTRACT

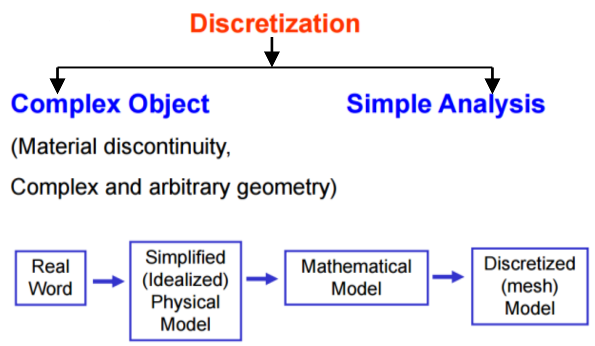
Transitions to modernization involve materials and profits from sophistications in materials modeling. Present trend in design and utility of advanced materials majorly concentrate on accuracy, predictive capabilities, preciseness, repeatability, realism and of tools for the theory its modeling and simulation. Simulation methods are typically deployed to hasten product development with reliable design, increase of efficiency, and enable fundamental learning and understanding. Integrating good analysis and experimentation facilitates materials modeling that drive progress by saving time, resource and effort. Results are realistic, swiftly available and project relevant. Composites are the favorable engineering materials of high demand in industrial sectors. This paper presents the exploitation of software package ANSYS based on the Finite Element Analysis (FEA) for forecasting stress distribution in a general natural fiber composite. Though this is not the exact model, it still provides a detailed insight into the behavior of composites and fine-tuning this model may benefit in extrapolating them for forecasting the characteristics of natural and synthesis fiber composites for static and dynamic loading conditions.

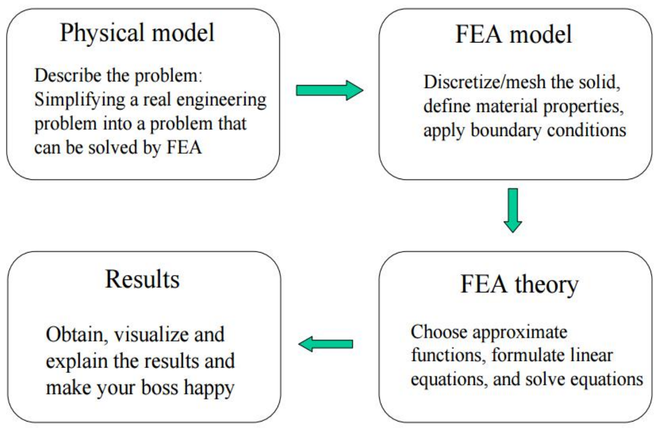
Keywords: Finite Element Analysis, Natural Fiber, Composite Material, Human Hair

INTRODUCTION

Finite element method is a numerical technique generally employed for solving complex engineering problems. It is mostly preferred during design and product development which involves complicated geometries, complex dynamic loadings and the corresponding material property changes that cannot be obtained analytically. In case of analytical solutions analysis is typically carried out using dramatic idealization and simplification. Design relies on the estimated results obtained from idealized structures and safety factors arrived out of experience. Design geometry being intricate and needing higher accuracy requirement, it is essential to adopt finite element analysis[1]. This demands a clear understanding of the complex objects physical behaviors that accounts for heat transfer capability, strength and fluid flow, etc. In order to forecast the performance and design behavior; to estimate the safety margin; and to determine the weakness of the design and optimize the design it is imperative to use finite element analysis. This numerical technique is extended for applications involving Mechanical and Aerospace parts. Besides, it is regularly employed for structural analysis in civil automotive applications. Added to this, FEA is also employed for Structural/Stress Analysis, Dynamic/ static analysis, Nonlinear and linear analysis.

Further, there are two major features which emphasizes that the numerical solution is an approximation to the exact solution [2]. The subinterval number and the approximation dictate the accuracy of the numerical result. Figure 2 clearly depicts the working of FEA to identify solutions for various loadings.





GEOMETRIC MODELLING

Initially to build the geometry of the model with simplicity, the coordinate systems is changed to cylindrical from default decart [3]. The thickness is defined and the model being 3D, the display is changed to isometric. Coordinate key points are defined and is shown in figure 3. A rectangular beam kind of natural fiber composite material structure is considered for the analysis.

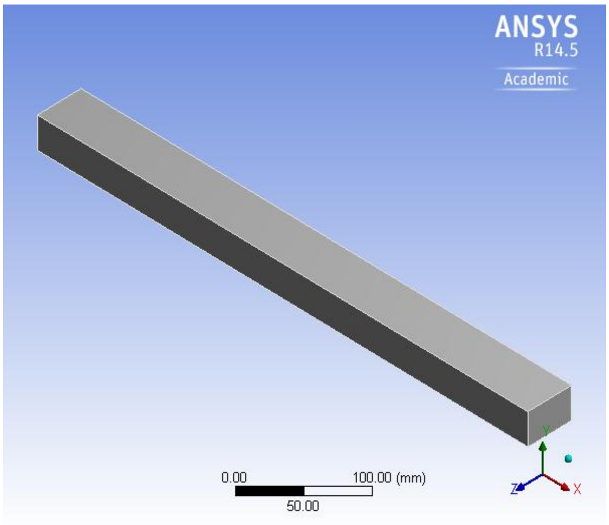


Figure 3. Natural fiber composite geometry used for FEA

For smooth and uniform meshing, all lines are divided into three elements exclusive of the division of two lengthier sides that are divided into eight finite elements [4]. After the choice of mesh size, system is allowed to perform meshing of all marked areas. The FE mesh is presented in Figure 4.

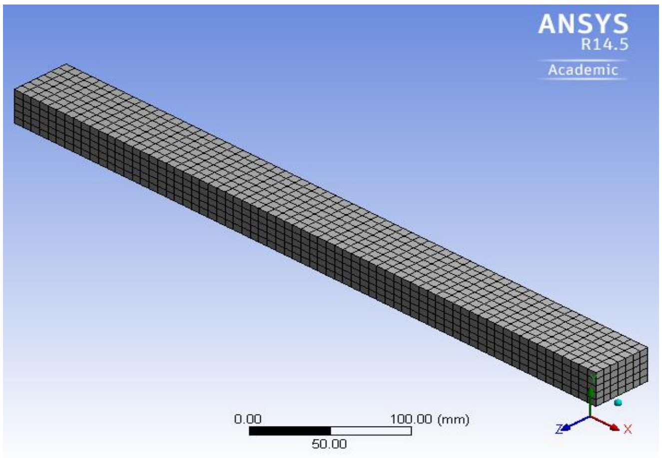


Figure 4. Meshing of the FE model

Concentrations of Zn, Cu, Se, Mn, Hg, Fe, Cr, Co, Sb, Sc and Au were determined in hair samples of considered for this study and these components were fed into the material properties in preprocessing analysis. The hair fiber cross section and the structures reconstructed tri-dimensionally and used for this FEA is shown in figure 5.

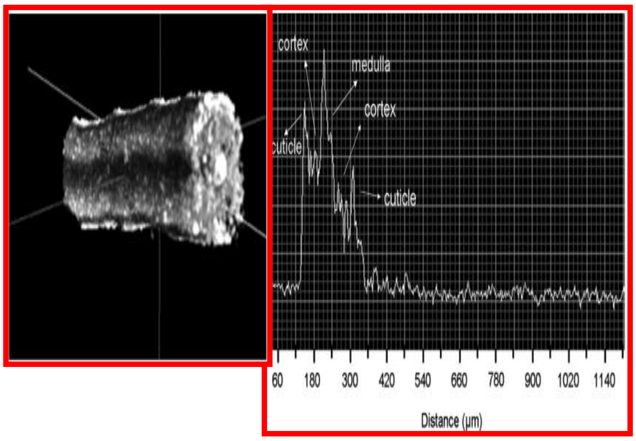


Figure 5. Human hair cross section and its structures

This is followed by static structural loading analysis. The parameters used for the analysis are shown on table 1 and figure 6 illustrates the corresponding loading of the model.

Table 1. Model Analysis settings

Object Name	*Static Structural (B5)*
State	Solved
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Solver Target	Mechanical APDL
Options	
Environment Temperature	22. °C
Generate Input Only	No

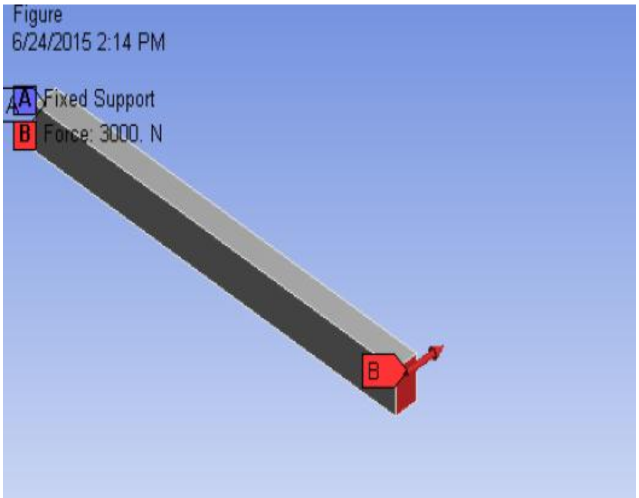


Figure 6. Mechanical loading for FEA analysis (static structural)

The overall stress distribution is apparently established with the help of the 3-D structure. FEM computations are employed to investigate displacement due to mechanical loading influenced by the thermal expansion. Generally, natural fiber composites are composed of a matrix and reinforcing particles. Available literatures [5],[6] illustrates that the arrangement of reinforcement material influences in changing of CTE also. Here a load of about 3000N force is being provided at node B with node A held strongly fixed and acts as a cantilever beam. As the model is symmetrical about the axis, only half part of the structure is modeled by considering it to be cantilever beam. Analysis has been carried out by using ANSYS by applying the boundary conditions and the load.

RESULTS AND DISCUSSION

The simulated deformation and stress distribution of the mechanical properties of the hair based natural fiber composite samples, under static loading conditions, was performed (Figure 7 and 8). The maximum stresses are averages of values of the elements center used in the FEA. The numerical results of the predicted stress data for these specimens are recorded. By comparing the simulated and actual results, it appears that the model is partially reflecting the results and still few fine tuning is necessary. Certain compositions containing complex protein components in hair could not be included due to lack of the provision in the software.

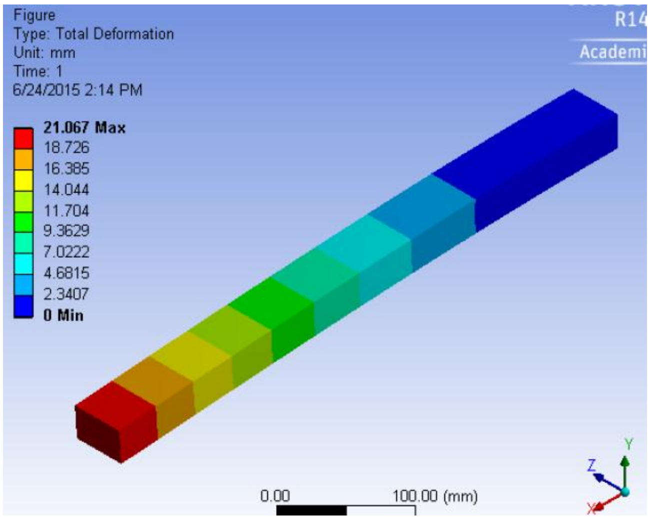


Figure 7. Total Deformation due to the applied load.

From the figure 7 it may be observed that the deformation is within acceptable limits and can be a suitable alternative for conventional engineering materials used for various structural applications[7],[8]. This further emphasizes that the matrix fibers and the reinforcement resins have been bonded strongly or exhibits good adhesive nature. The bending moment is generally governed by the Young's modulus and inertia. Deformation maximum is observed at the load edge with a value of about 21.067 mm which gradually tends to decrease while moving towards the fixed side. Uniform diffusion is another interpretation from these results. The density observed is 2.11e-009 tonne mm-^{3}.

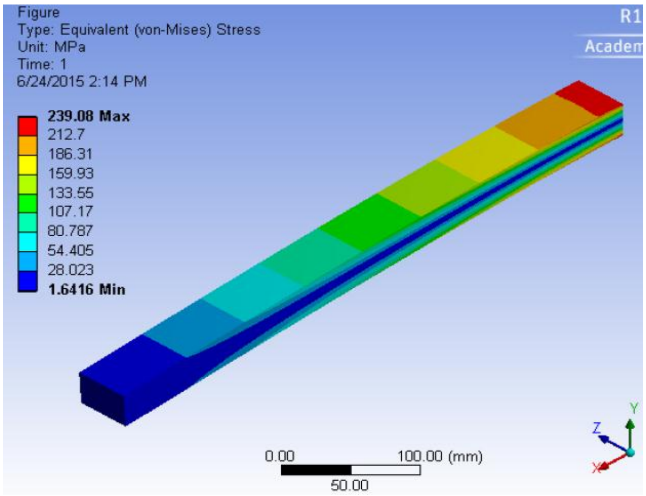


Figure 8. Stress Distribution Analysis

Figure 8 clearly illustrates the distribution of equivalent stress based on Von-Mises analysis. The stress appears maximum with a value of 239.08Mpa at the fixed edge. With the application of 3000 N force on the opposite edge there seems to be a bending stress at the fixed edge gradually propagating to the point of application of load. These are again governed by the material properties and the kinetic energy of the molecules with the application of indirect energy. The bonding nature between the matrix and the reinforcement also play a vital role in the stress distribution pattern [9], [10]. The final material data from this investigation is provided in table 2 showing young's modulus and poisons ratio.

Table 2. Material Data

Temperature C	Young's Modulus X direction MPa	Young's Modulus Y direction MPa	Young's Modulus Z direction MPa	Poisson's Ratio XY	Poisson's Ratio YZ	Poisson's Ratio XZ	Shear Modulus XY MPa	Shear Modulus YZ MPa	Shear Modulus XZ MPa
	60520	10370	10370	0.23	3.9e-002	3.9e-002	40100	40100	40100

CONCLUSIONS

Finite Element Analysis is employed for hair based natural fiber composites to examine and determine the materials response to static structural loading conditions. A known force is applied for the natural fiber in cantilever position and the corresponding material behaviors and property changes are observed. Total deformation and stress distribution is simulated for the developed 3D model which indicates that the responses are well within the acceptable range and also emphasizing a good and uniform bonding between the reinforcement and the matrix. The model developed provides an insight into the numerical aspects of the material while it is a preliminary model aimed at providing basic understanding. Since, some of the properties of proteins in hair cannot be fed into the material properties and the provision is lacking, the accuracy may not be high. Nevertheless, the procedures and software features can be enriched in future for fine tuning the model. With a successful implementation, the model may be extrapolated for other natural fiber based composites as well.

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