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Evaluation of CFRP Composite Laminates by Drilling Using Finite Element Approach

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ABSTRACT

Numerical modelling of material behavior & defect formation during machining was made possible by the years. Rapid expansion of the usage of carbon fiber composite materials, which are extensively employed in a variety of civilian industries, including aviation, aerospace, defense, automotive, electronic information, and high-speed machinery. Drilling is a vital final machining process for components made of composite laminates. Determining static structural, dynamic, or vibrational, and explicit dynamics is a crucial challenge in drilling CFRP.

In this work, the drilling behavior of CFRP composite laminate with five layers is analysed. Drilling behavior is examined using the finite element method while taking into account the precise geometrical considerations as well as the static, dynamic, and explicit factors involved in the operation in order to find the initial modes and corresponding natural frequency using Ansys workbench 19.2 and Catia V5 software used to modelling required 3d Geometry.

Keywords: Drilling, Finite Element Method, Ansys Workbench 19.2 and CFRP

I. INTRODUCTION

Carbon fiber reinforced plastic (CFRP) composites have become widely used as structural components in the aerospace, naval, automotive, and defense industries due to advancements in manufacturing technology. In order to create riveted and bolted joints for the assembly operation of composite laminates with other components, drilling procedures are widely used. To provide high joint strength and precision for riveted and bolted joints, damage-free and precise holes must be drilled in the components. However, the non-homogeneous, anisotropic, extremely abrasive, and strong reinforced fibers that are a part of composite laminates by nature make them challenging to machine. Drilling significantly reduces strength against fatigue due to a number of unfavorable effects (including delamination and fiber pull-out), which lowers the durability of composite laminates [1]. When drilling Carbon Fibre-Reinforced Plastic (CFRP) materials, achieving acceptable hole quality is challenging while balancing productivity and tool wear. Numerical models are important tools for the optimization of drilling CFRP materials in terms of material removal rate and hole quality. In this research, a macro-Finite Element (FE) model was developed to accurately predict the effect of drill tip geometry on hole entry and exit quality [2]. This study develops a 3D finite element (FE) model for drilling in CFRP composite laminate.

II. METHOD AND METHODOLOGY

First Stage is to model each part with exact Dimensions and second stage is to assemble the different parts together and next third stage is preparing the final assembled model and converting into STP/IGES File Format using Catia V5.
Selection Of Elements and next stage is finite element modelling which includes importing the file followed by mesh generation and applying the boundary conditions and solving the problem. This procedure is called Pre-Processing. Next extracting the required results and validating the answers. This procedure is called post-Processing. Flow Chart of Methodology is shown in Figure.1

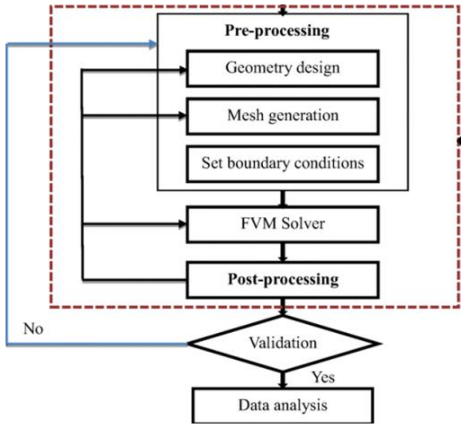

Fig.1. Flow Chart of Methodology

2.1. Geometrical Modelling

The FE analysis used a CFRP composite laminate with a stack sequence of [(90/-45/0/45)2]s. Modeling was done for a layered CFRP plate with overall measurements of 120 mm, 15 mm, and 7.2 mm. Additionally, the flute and shank lengths are 50mm and 50mm, respectively. To discretize the intricate drill geometry, a model with a diameter of Ø7.04 mm and a point angle of 120.04° and a helix angle of 30° was used. 5 layers are analyzed in which the first four layers are CFRP material and the last one is Aluminum 2024.Three-dimensional Geometric model which is imported in Ansys Workbench 19.2 is shown in Figure 2.

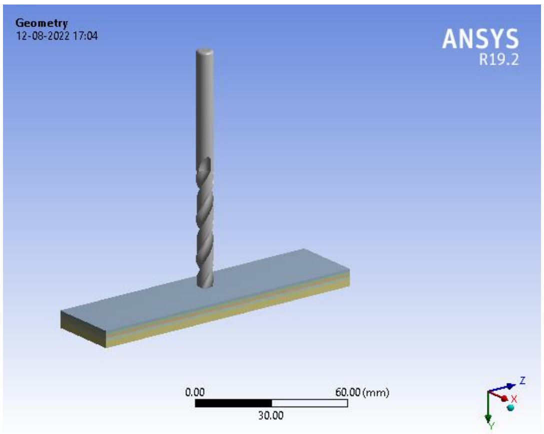

Fig 2. 3D Geometry Model Imported in Ansys Workbench 19.2

2.2 Meshed Model

The mesh used in the FE analysis was Hexahedral mesh. Effective meshing has been done for the Bladed Disc assembly geometry model. It is believed that the mesh, which consists of a mixture of triangular and quadrilateral pieces, is a good mesh. It efficiently absorbs the stress and strain caused by the load on the geometry model. When there are bodies that cannot be swept, choose this option. Tet and pyramid cells are mixed in the mesh, with the majority being hexagonal cells. Element count was decreased by hex dominating meshing. Number of nodes and elements was 4465 and 7557 respectively. Meshed Model for the corresponding FE setup is shown in Figure 4.

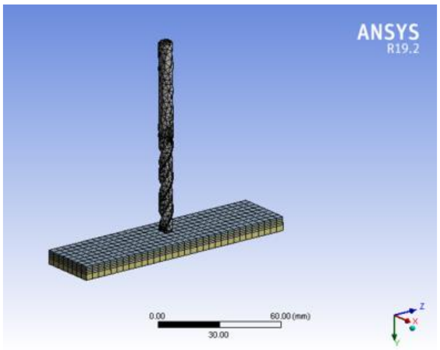

Fig.3. Meshed Model

2.3 Loads and boundary conditions

Displacement is constrained at X and Z co-ordinates and Y is left free. The load is in the form of compression and applied in Y-axis as in the form of steps which is varying from 1000-7000N. Displacement and Force applied is shown in Figure 4 and 5 respectively. Loads is applied in steps is shown in the Table 1.

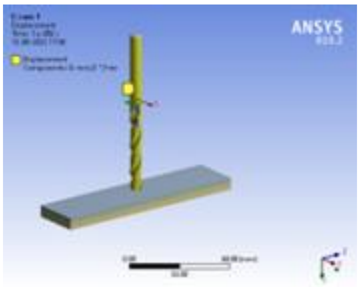

Fig.4 Displacement

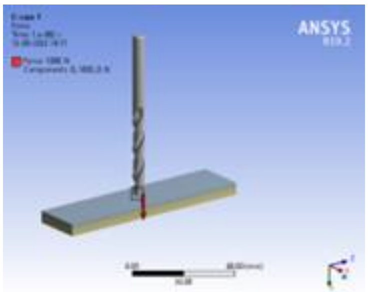

Fig.5 Force

Table.1. The Loads Applied in Steps

Tabular Data

	Steps	Time [s]	X [N]	Y [N]	Z [N]
1	1	0.	= 0.	= 1000.	= 0.
2	1	1.e-002	0.	1000.	0.
3	2	1.1e-002	= 0.	2000.	= 0.
4	3	1.2e-002	= 0.	3000.	= 0.
5	4	1.3e-002	= 0.	4000.	= 0.
6	5	1.4e-002	= 0.	5000.	= 0.
7	6	1.5e-002	= 0.	6000.	= 0.
8	7	1.6e-002	= 0.	7000.	= 0.
*					

III. RESULTS AND DISCUSSION

3.1. Results of Case I-Glass Fiber Reinforced Polymer

Equivalent Von -Mises Stress for the Analysis of Drilling in GFRP obtained is 158.81 MPa Illustration of Equivalent Von-Mises Stress is shown in Figure.6

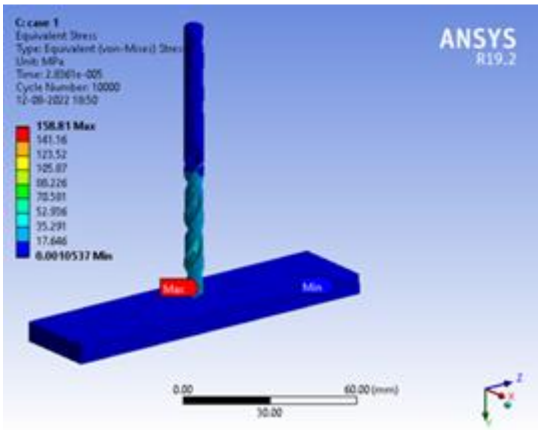

Fig.6. Equivalent Von-Mises Stress and for the Applied Load Condition of 1000 N.

3.2 Results of Case II-Carbon Fiber Reinforced Polymer

Equivalent Von-mises Stress for the Analysis of Drilling in CFRP obtained is 160.01 MPa. Illustration of Equivalent Von-mises Stress is shown in Figure.7

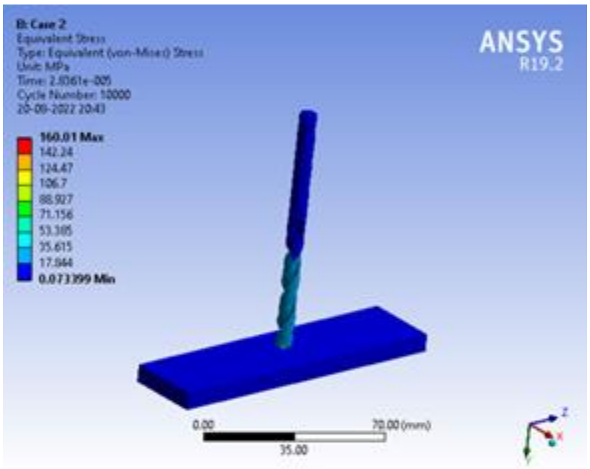

Fig.7. Equivalent Von-Mises Stress and for the Applied Load Condition of 1000 N.

3.3 Dynamic Analysis

Initial modes and corresponding natural frequencies are obtained in this analysis. Frequency obtained for this mode 1- 2023.2 Hz. Mode 1 Results are shown in Fig.8. Bar graph which indicates the frequency at each calculated mode is shown in Fig.9 and corresponding natural frequencies at each mode is shown in Table.2.

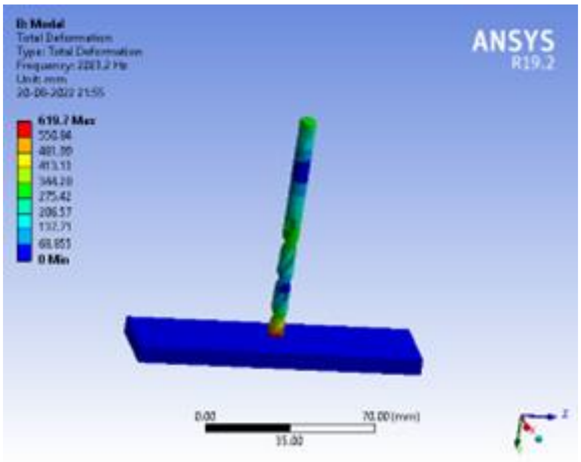

Fig.8. Initial modes and Corresponding Natural Frequency

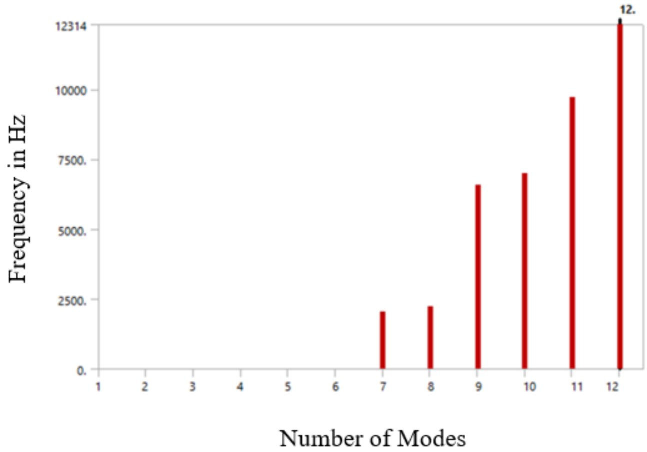

Fig. 9. Bar graph which Indicates the Frequency Calculated at Each Mode.

Table.2. Corresponding Frequencies at Each Mode

Sl. No	Mode	Frequency in Hz
1	7	2023.2
2	8	2215.4
3	9	6581.8
4	10	6990.6
5	11	9703.9
6	12	12314

IV.CONCLUSION

This research examines the drilling behavior of a composite laminate made of five-layer CFRP. The required 3D geometry is modelled using Ansys Workbench 19.2 and Catia V5, and drilling behavior is correctly determined using the finite element approach by accounting for the static, dynamic, and explicit aspects involved in the process as well as precise geometrical considerations. On Comparing CFRP and GFRP, the Equivalent von mises stress obtained for GFRP material is 158.81 MPa whereas the Equivalent von mises stress obtained for CFRP material is 160.0 MPa. Therefore, GFRP can be chosen as the best material for the analysis of drilling.

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