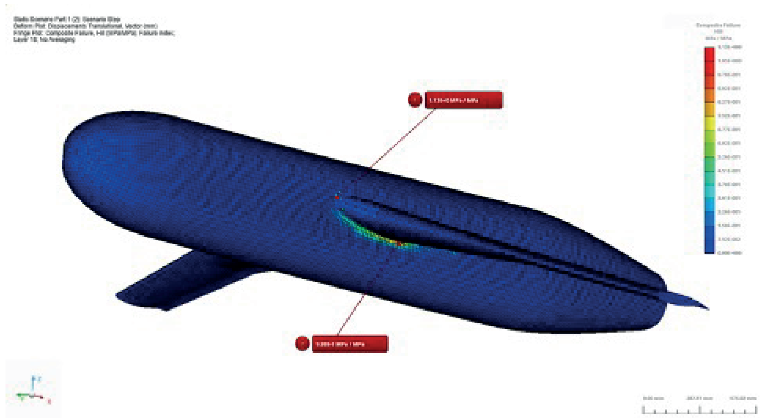
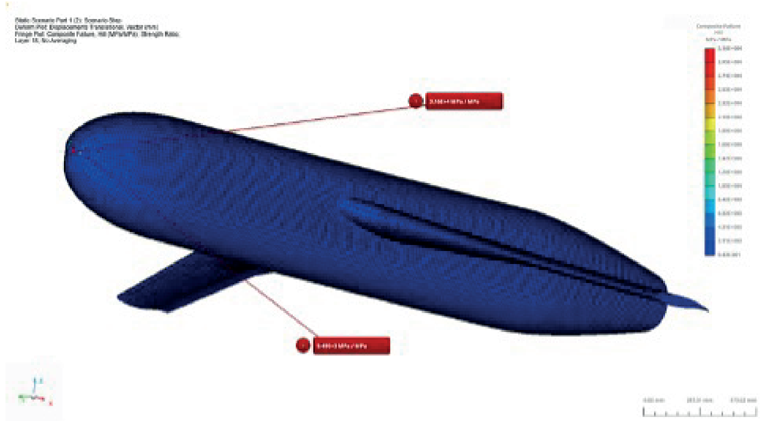
TECHNICAL DOCUMENT

MSC Apex

MSC Nastran

This technical document provides a detailed examination of how composite analysis and pressure mapping processes are carried out in MSC Apex.





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Composite Analysis and Pressure Mapping in MSC Apex

PREPARED BY
Betül ABLAY *CAE Structural Analysis Engineer*

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MSC Apex offers a powerful platform for engineering simulations, making it possible to analyze the performance of structures in detail. In particular, it offers a wide range of analyses for testing the strength and performance of structures. Composite analysis and pressure mapping are especially critical in material designs that require high strength and low weight. Analysis of composite materials aims to accurately model the behavior of the structure, taking into account the properties and orientations of the different layer. Pressure mapping allows engineers to assess the safety and efficiency of their designs by visualizing how the pressures applied on a structure are distributed. MSC Apex offers a wide range of solutions, from composite material analysis to pressure mapping analysis, allowing engineers to achieve accurate and reliable results. This article examines in detail how composite analysis and pressure mapping processes are performed in MSC Apex.

1. What is Composite Analysis?

Composite materials are formed by combining two or more different materials. Since these materials usually have different mechanical properties, the advantages of each component are utilized when used together. Composite analysis refers to the simulations performed to study the behavior of such materials under various loads. Composite materials are widely used for many industrial applications such as aircraft wings, automobile parts and wind turbines.

When analyzing composites in MSC Apex, it is very important to correctly define the material properties. The software performs structural analyses taking into account the material properties and orientations of each composite layer. It also simulates how the composite material will behave under different loading conditions and environmental factors.

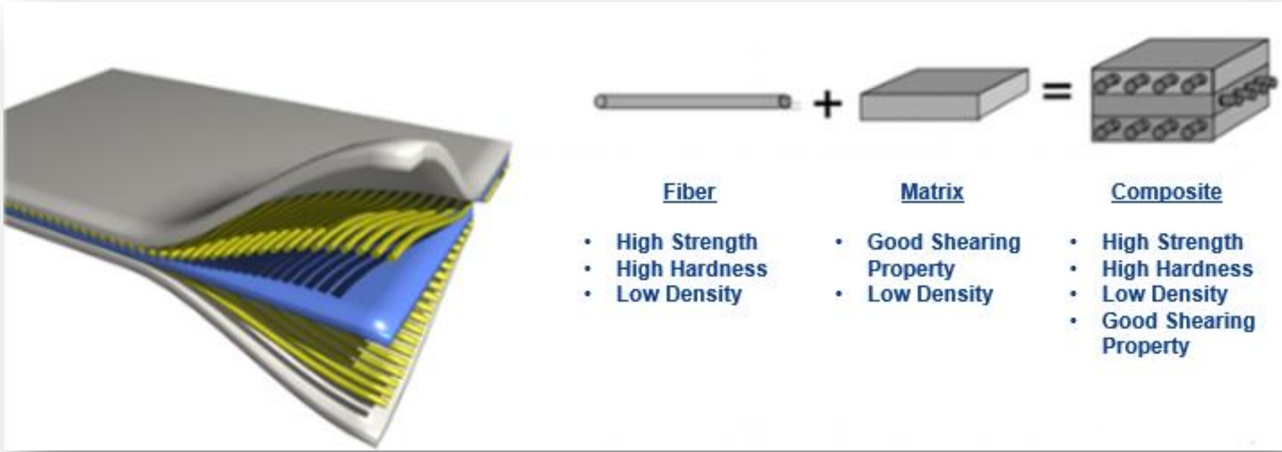

Figure 1: Composite Material Content

1.1. Composite Analysis in MSC Apex

MSC Apex is a simulation software that offers powerful tools for analyzing composite materials. Composite analyses aim to accurately simulate the behavior of structures by considering the properties of material layers (plies).

To achieve accurate and reliable results in composite analysis, several critical factors must be considered. Composite materials are heterogeneous materials consisting of multiple layers, each with distinct properties. Below, the details to be considered when performing a composite analysis of a two-dimensional wing-body connection model are outlined, along with the tools you can use within the MSC Apex interface.

1.1.1. Model Preparation

The model in ".bdf" (Bulk Data File) format or exported from a CAD software can be imported into MSC Apex for analysis. MSC Apex supports the ".bdf" format and allows modifications after import. Additionally, structural models can be created from scratch.

After importing the geometry, unnecessary or faulty parts can be cleaned within the MSC Apex interface. A finite element mesh is then generated. An excessively fine or irregular mesh may reduce solution accuracy. In composite material analysis, transition regions between layers and high deformation areas must be carefully considered. The mesh should accurately represent the thin structure of each ply.

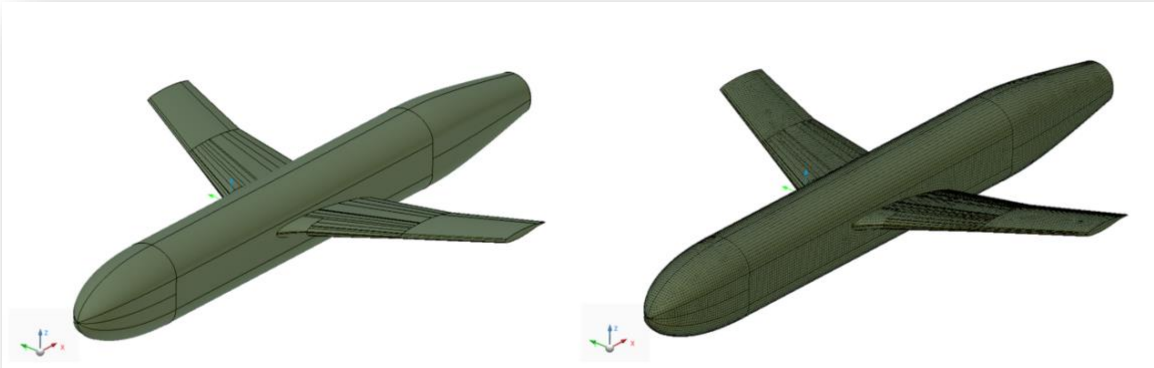

Figure 2: NASA Wing-Fuselage Junction Surface and Finite Element Model

1.1.2. Material Definition

MSC Apex includes various composite material models to simulate material behavior more accurately. Some of these models are:

- **Isotropic Materials:** It has the same mechanical properties in all directions.
- **Orthotropic Materials:** It has different mechanical properties in three perpendicular directions.
- **Anisotropic Materials:** It is modeled with completely different mechanical properties in each direction.

The properties of composite materials must be defined for each layer. In MSC Apex, elastic modules, Poisson's ratio, density and other physical properties can be defined in material cards.

The mechanical properties of the material can be created by defining the material model in the “Materials” section of the MSC Apex interface. Below are the orthotropic material properties defined during the composite analysis of the two-dimensional wing-fuselage connection model. If damage is to be analyzed, the “Failure” criterion can be defined (Attribution Tools --> Panel --> Advanced Properties --> Failure Criteria).

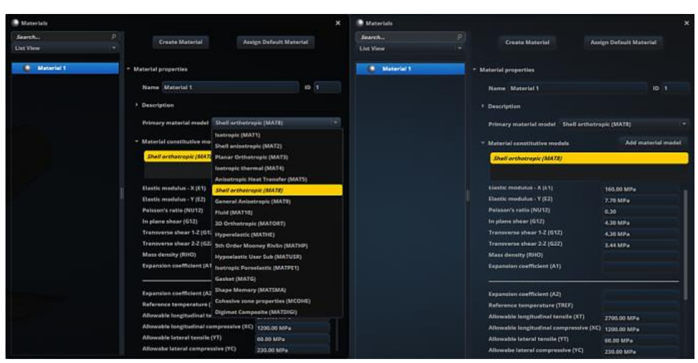

Figure 3: Orthotropic Material Model and Mechanical Properties in MSC Apex Interface

In our two-dimensional sample model, two-dimensional properties of the layers are created from “Panels- Ply Property” in the MSC Apex interface and assigned to the relevant regions. If desired, element properties can be created by entering material, fiber orientation and thickness values using the PCOMPG card from the “2D Element Properties” tab.

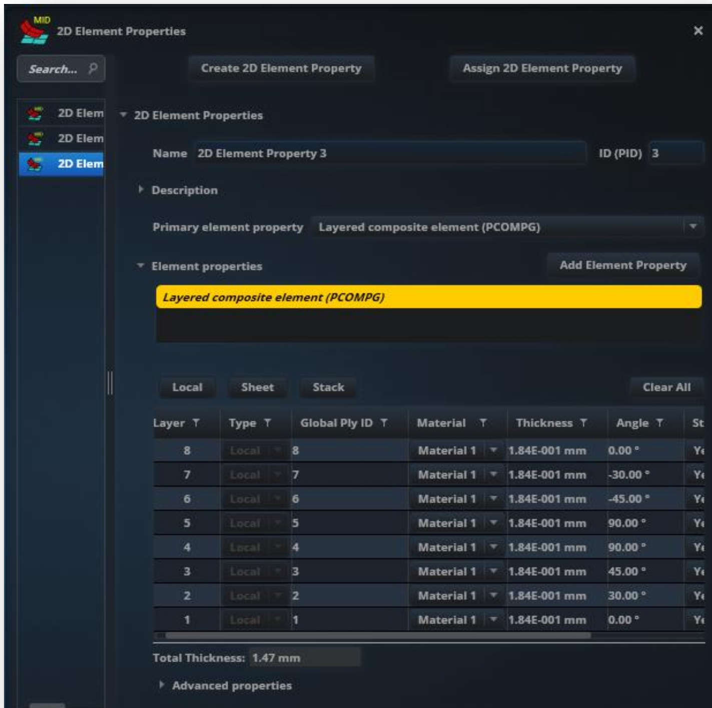

Figure 4: “2D Element Properties” Tab in MSC Apex Interface

Before defining a composite structure, you need to apply the material orientation directly to your model using the “Material Orientation Field” tool. In order to determine in which directions, the material will be aligned, it is necessary to specify the material orientation in coordinates and select the region to be aligned. In the MSC Apex interface, a coordinate can be assigned for the material orientation reference using the “Coordinate System” tool.

1.1.3. Composite Structure Definition

The analysis of composite materials considers the properties of each ply. These materials consist of layers arranged in different orientations, where each layer affects the overall behavior of the composite material. MSC Apex provides various features to model these layers.

Composite materials are typically made up of thin layers called "plies." Each ply may have different material properties and orientations. MSC Apex allows easy definition and modeling of these layers.

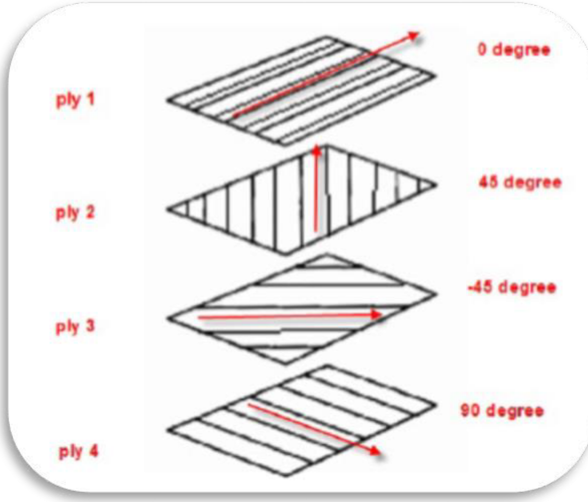

Figure 5: Laminar Model Consisting of Four Ply

Each ply is defined by material type (e.g. carbon fiber, glass fiber, etc.), thickness, orientation (e.g. 0°, 90°, ±45°) and other mechanical properties.

One of the most critical properties of composite materials is the orientation of the plies. The orientation of each ply significantly affects the mechanical behavior of the material. The orientation determines in which direction the loads to be carried by the composite material will be better resisted.

The strength in the fiber direction depends on the tensile/compression resistance of the fiber, while the strength in the perpendicular direction depends largely on the bearing capacity of the matrix. Therefore, the strength against loads in the fiber direction is high, while the strength against loads perpendicular to the fiber direction is low.

The placement and orientation of the layers directly affect the strength, stiffness and overall performance of the composite material.

The thickness of each layer also has a significant impact on the overall thickness and mechanical properties of the composite material. Usually, the thickness of each layer is determined homogeneously, but the material design can be customized by using different thickness values. Very thin layers can make the interlayer interaction more sensitive, while very thick layers can have different material properties.

The following steps are followed when adding a ply via the MSC Apex interface:

1. **Material Selection:** The material to be used (e.g. carbon fiber) is selected.
2. **Determining Thickness and Orientation:** Determine the thickness and orientation for each ply.
3. **Ply Stacking (Layup):** Plies are stacked on top of each other in the desired number and order.

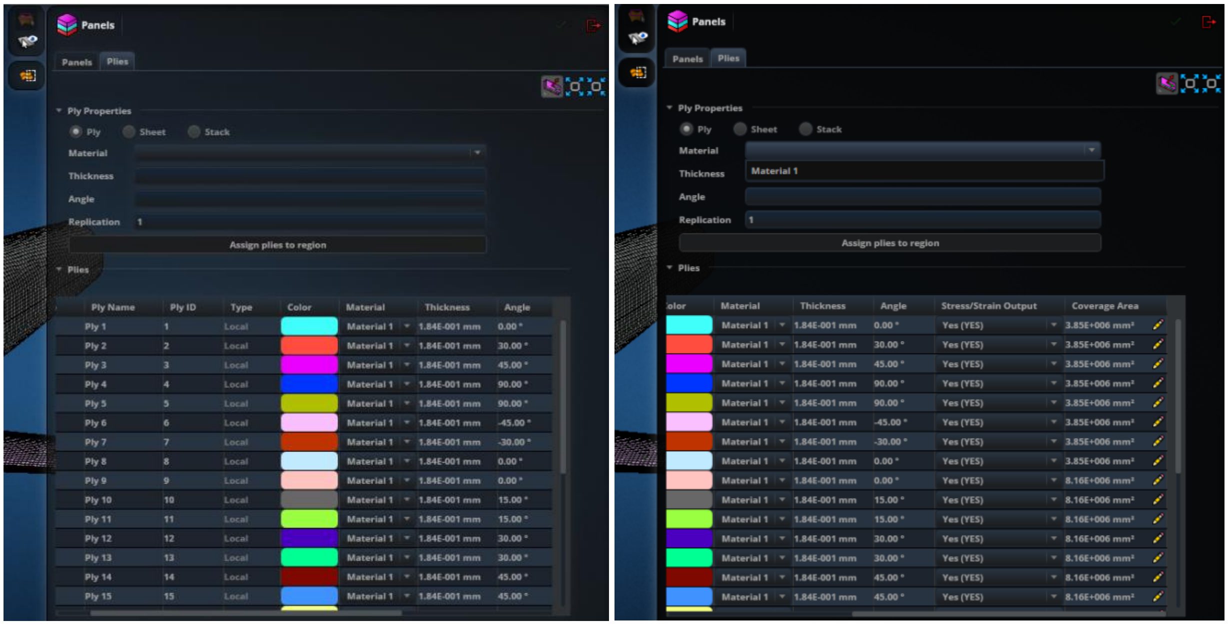

Figure 6: Display of Plies in the “Panel” Tab in the MSC Apex Interface

In addition, you can create plies in different regions of your model, stacked on top of each other in the desired number and order. In MSC Apex, the plies in the regions you have assigned in your model can be viewed from the “Zones” section.

“Zone” is a property that defines the ply structure of composite materials. Here, “zone” can be used as a ply region and is used to determine the position, orientation and material properties of each ply.

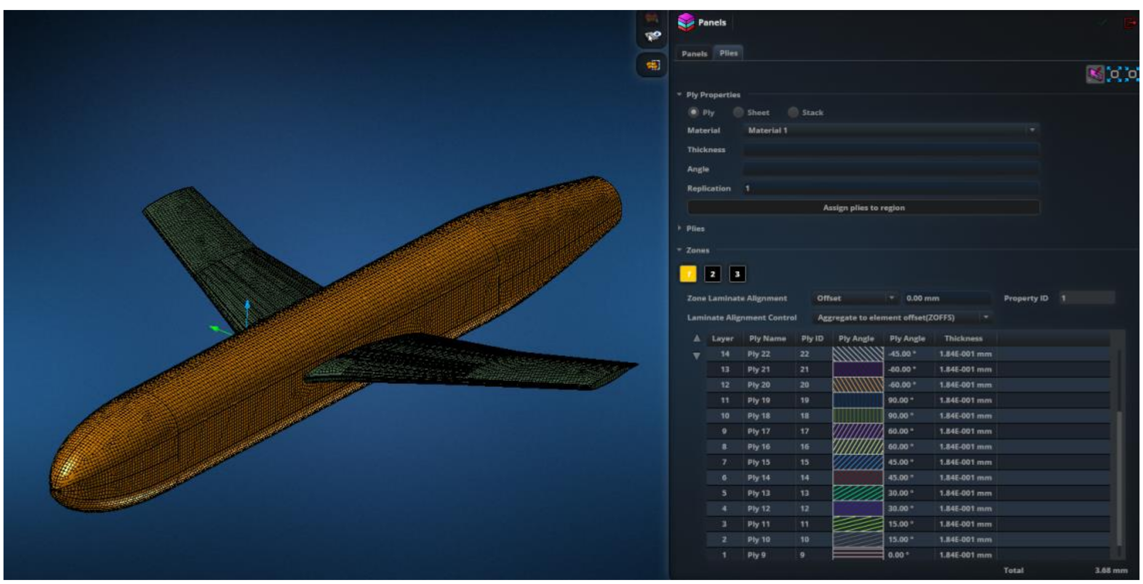

Figure 7: “Zones” in MSC Apex Interface

Layup is the process of placing plies on top of each other in an orderly manner, which is used in the production of composite structures. The "Core Sample" tool in MSC Apex can be used to examine the layup of composite materials in a model based on a surface or a two-dimensional mesh.

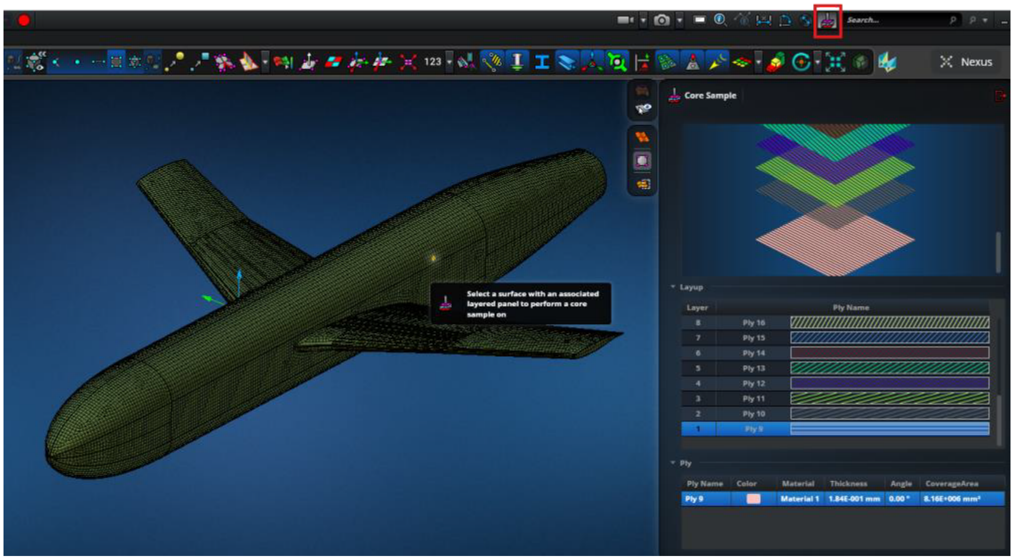

Figure 8: “Core Sample” Tool in MSC Apex Interface

1.1.4. Defining Loads and Boundary Conditions

The loads and boundary conditions applied during the analysis of composite materials must accurately reflect the behavior of the structure. The different types of loads (compression, tension, shear, bending) and boundary conditions (fixed points, free points) must be correctly defined. According to the loading conditions, the layers of the material can react differently, which affects the result of the analysis.

The rear surface of the two-dimensional wing-fuselage connection model is constrained in 6 directions. As a load, the pressure obtained in the CFD analysis is applied to the structure using the “Map Spatial Load” tool.

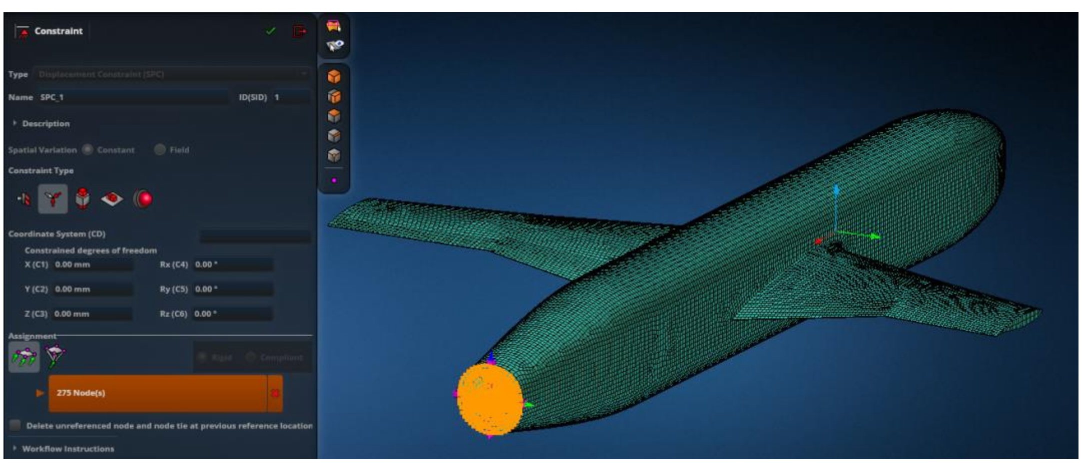

Figure 9: Boundary Conditions of Wing-Fuselage Connection Model

What is Pressure Mapping?

Pressure mapping is a technique that visualizes the effect of forces applied on a structure. This method is widely used, especially in aerodynamic designs, automotive engineering and the aerospace industry. MSC Apex has the ability to map pressure distributions to help users visually understand analysis results. Pressure mapping can be done with the "Map Spatial Load" tool.

When the "Map Spatial Load" tool is entered, the pressure ".xml" file from the CFD analysis must be defined. The pressure unit selected during mapping and the pressure unit obtained as a result of CFD analysis must be the same.

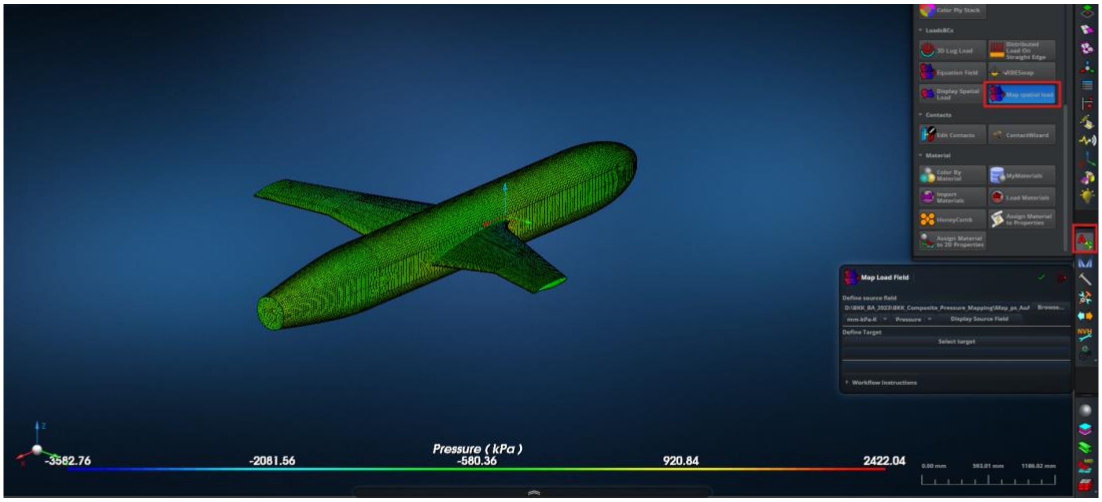

Figure 10: "Map Load Field" Tool in MSC Apex Interface

In MSC Apex, after transferring the unit and ".xml" pressure file in the "Map Load Field" tool, the load can be transferred to the model by clicking "Select Target".

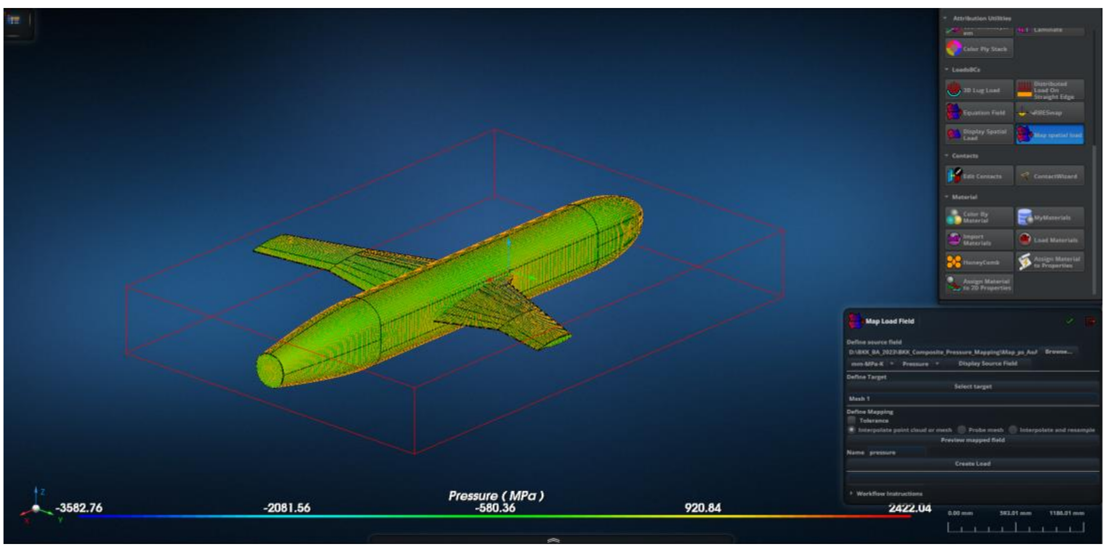

Figure 11: Preview of the Region to be Mapped in the "Map Load Field" Tool in MSC Apex Interface

1.1.5. Review of Analysis Results

The analysis results help evaluate the durability, safety, and performance of composite materials. If necessary, changes can be made to the layer placement, material properties or loading conditions in the model.

In addition, when performing safety assessment for composite laminates, the failure index of the material under various loading conditions is examined using failure criteria (Tsai-Wu, Tsai-Hill, Hoffman etc.). These criteria can be evaluated by combining parameters such as failure index and strength ratio. The MSC Apex program allows users to apply failure criteria.

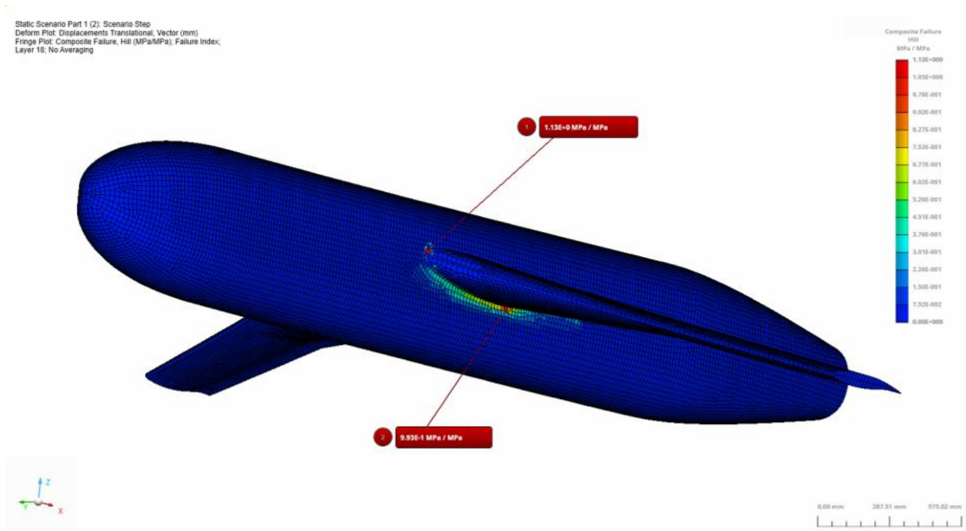

Figure 12: Failure Index (Hill) Results for a Sample Layer (18 Layer) in the Wing-Fuselage Connection Model

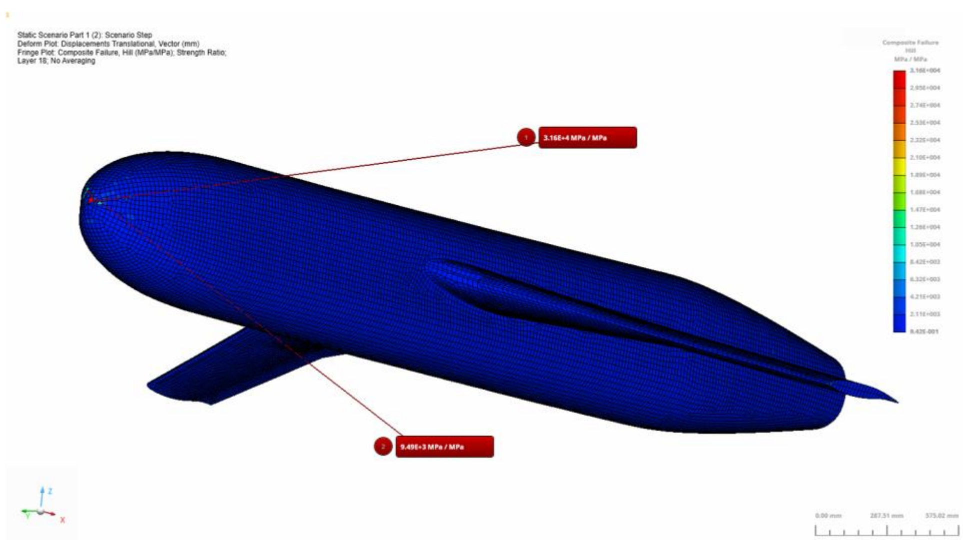

Figure 13: Strength Ratio (Hill) Results for a Sample Layer (18 Layer) in the Wing-Fuselage Connection Model

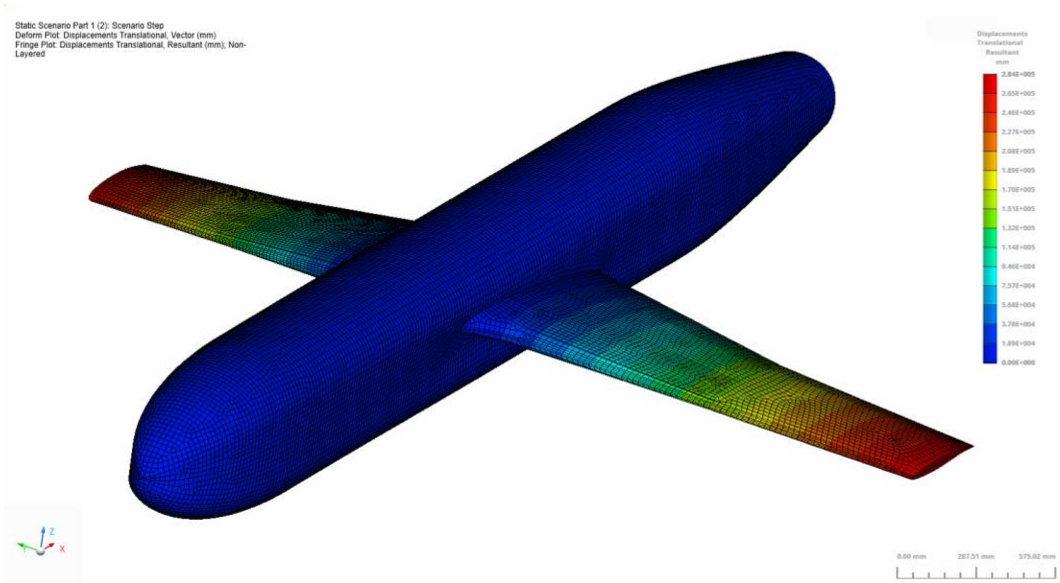

Figure 14: Translational Displacement Results of Wing-Fuselage Connection Model

2. REFERENCES

- MSC Nastran 2024.1 Quick Reference Guide
- Kegerise, M., Neuhart, D., & Rumsey, C. (2017). Turbulence Measurements on a Wing-Fuselage Junction Model for CFD Validation. NASA Langley Research Center