AUTODESK UNIVERSITY

MP21673-L

Hands-on Training: Advanced Fiber Placement and Tape Laying

Matt Thorn
Autodesk

Learning Objectives

- Learn how to import composite designs
- Learn how to create manufacturing strategies
- Learn how to analyze material defects
- Learn how to create Fiber Paths

Description

This session is a follow up to “Intro to Composite Manufacturing Platform.” This hands-on course will follow the entire manufacturing process of composite and carbon fiber parts using automated fiber placement and tape laying. We will cover the following topics: we will compare and analyze manufacturing strategies to determine the best manufacturing method for the part shape in question using TruPlan software; once we select the correct manufacturing technique for each layer of material, we will select a machine to lay the material automatically; we will define the automated fiber placement (AFP) machine using TruFiber software; and, finally, we will generate each toolpath to create the part for the AFP machine using TruFiber software. This session features TruPlan and TruFiber.

Your AU Expert(s)

Matt Thorn is a Product Release Manager at Autodesk. Matt received his BS in Mechanical Engineering and Mathematics from Rutgers University and Stockton University respectively after completing a five year Dual Degree program. He began his expertise in Advanced Manufacturing with Magestic Systems Inc. which was then acquired by Autodesk in July 2014. Matt has been teaching and advising companies around the world on how to optimize their nesting, laser projection, and fiber placement manufacturing processes for over 3 years.

matt.thorn@autodesk.com

Introduction to Composite Manufacturing

Composite manufacturing combines conventional manufacturing techniques with advanced workflows in order to produce high quality parts. Composite manufacturing methods include forming, hand laying, injection molding, automated tape laying and more. Due to the high variability in the end product, the industry is moving toward design methods that incorporate downstream manufacturing techniques to determine feasibility. TruPlan and TruFiber allow the user iterate through different manufacturing scenarios of each part without costly attempts at determining the ideal manufacturing process.

What are Composites?

Composite materials are defined as a material with two or more constituents with significantly different properties. These constituents can be defined as identifiable materials within the homogenized material. For the purpose of this discussion, our “constituents” are fibers and a polymer matrix. Composite materials are traditionally manufacturing by placing multiple layers, called lamina, together in a specific sequence of orientations to make up the laminate.

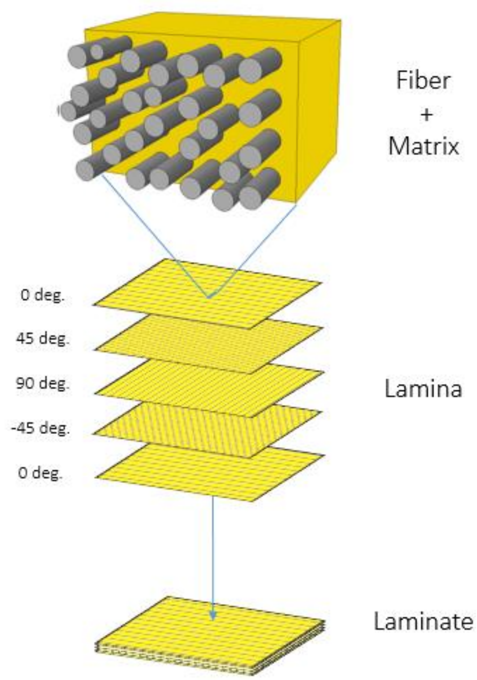

FIGURE 1: DIAGRAM DESCRIBING A STANDARD COMPOSITE LAYUP

Why Composites?

Composite materials allow designers and manufacturers to tailor the properties of the material to their needs. You can tune the material properties to meet engineering requirements for thermal expansion, high strength to weight ratios, stiffness, environmental response, and more. The fibers in the composite material provide the strength, stiffness, and other mechanical properties while the matrix provides the shape, protection from the environment, and transverses the loads the material may experience. Since we have the ability to design the lamina, we can narrowly design the material for our needs.

FIGURE 2: EXAMPLE OF A COMPOSITE MATERIALS

Composite Workflows

Much like traditional parts, composite parts start off with a conceptual design. The conceptual design envisions the geometry, mechanical properties, factor of safety, etc. targeted for the part specifications. Once the constraints for the part are envisioned, ply design and structural simulation are next. The ply design consists of the rosette definition, boundaries, orientations, and materials used to construct the composite laminate. The composite laminate definition greatly influences the structural simulation of the part and causes an iterative process to form between the two components until the composite laminate design has been finalized. Next in the composite workflow is the design for process step. TruPlan incorporates the finalized composite laminate design and provides detailed analytics for the potential manufacturing techniques that can be used for production. Depending on the manufacturing techniques available, users can go through the hand laying manufacturing workflow or one of the automated material laying workflows available. In this course, we will be focusing on the automated material laying workflow that includes analyzing material defects, fiber path generation, and machine simulation.

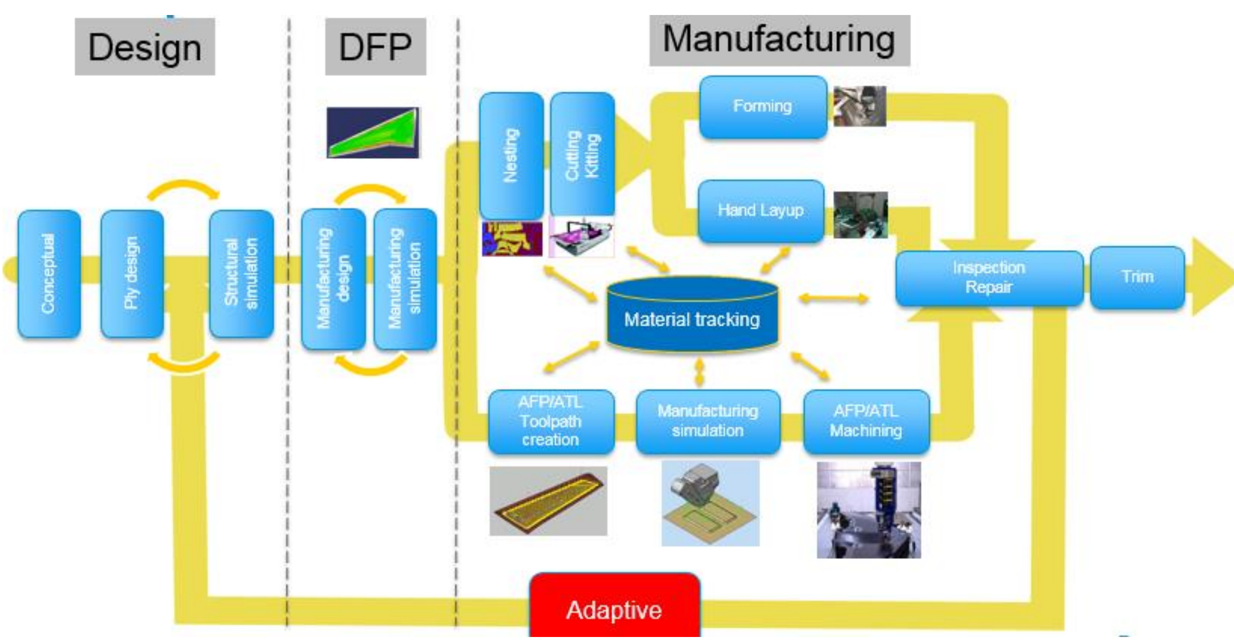

FIGURE 3: COMPOSITE WORKFLOW

TruPlan: Design for Process

Importing the Composite Design

As part of the "any CAD" mentality, TruPlan supports the major composites design packages available on the market. These packages have an export utility that creates an output containing all the necessary composite design information that TruPlan will need. Alternatively, you can import the model directly and create a link between the design and manufacturing models. This link creates one source of the truth and any updates to that design are then populated directly into the manufacturing model.

Manufacturing Preparation

TruPlan requires some prerequisites to be completed prior to running any analysis of the manufacturing strategy. This preparation is necessary to define how each ply's manufacturing intent. The first step is defining the composite material(s).

Composite Library

Importing the composite design creates entries in the TruPlan composite library for every material used in the design. The composite library stores important material properties like cured and uncured thickness values and warning and limit deformation angles of the material. The user must now decide the material packaging for each. Material defines the size of the material purchased from the material supplier as well as the manufacturing intent of either hand layup, fiber placement, or tape laying.

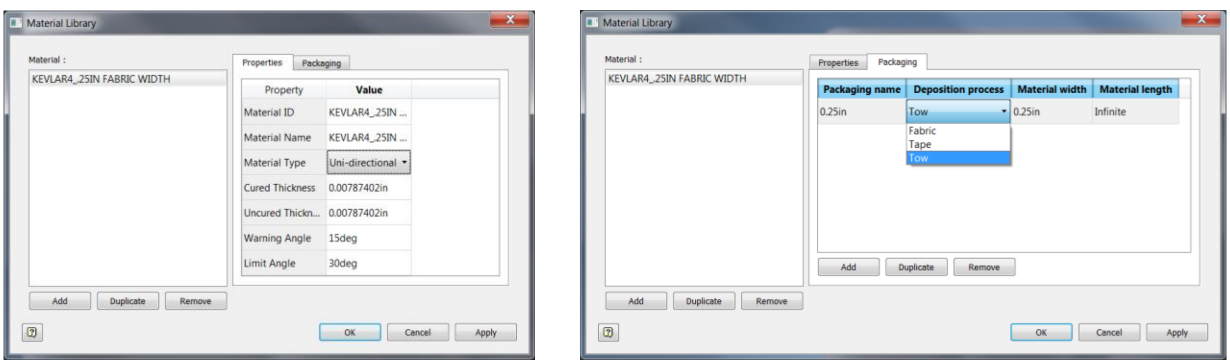

FIGURE 4: TRUPLAN COMPOSITE LIBRARY

Manufacturing Start Point

The manufacturing start point, or seed point, is pivotal in determining how a ply is to be manufactured. The seed point defines where are the manufacturability analysis propagates from and changing it may generate drastically different results. A projection of the seed point is necessary in order to guarantee it lies on the manufacturing surface.

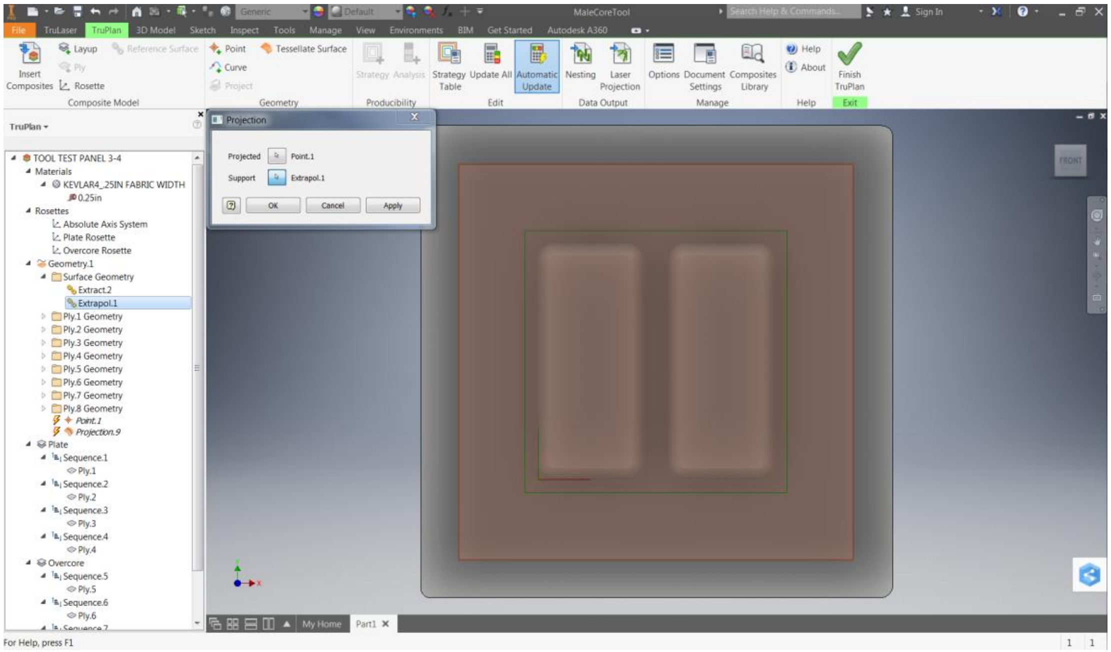

FIGURE 5: SEED POINT PROJECTION

Creating Manufacturing Strategies

Manufacturing strategies define all of the process characteristics required to provide an analysis of the manufacturability of the ply. Multiple strategies can be added for each ply to test all available scenarios.

General Tab

Inside of the General Tab, a user can define the name of the strategy, the material packaging that is desired, the number of tows available on the fiber placement machine, and the surface offset that needs to be applied. Selecting a different material packing here switching between the available manufacturing methods defined in the composite library for that material. If Deposition Process is set to tow or tape, the number of tows or tapes can be defined to create the maximum width of the fiber path.

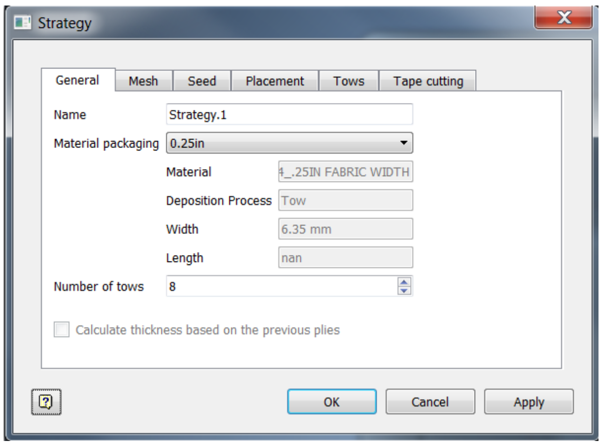

FIGURE 6: STRATEGY DIALOG GENERAL TAB

Mesh Tab

Inside of the Mesh Tab, the user can define the size of the material mesh that is calculated for the manufacturing analysis. The warp is the longitudinal direction (length) and the weft is the latitudinal direction (width) based on the orientation of the ply as described by the ply and the layup rosette definitions. The cell width option allows the user to specify whether the width should follow the value defined in the weft or the width value defined in the material packaging. If the cell width is defined by the material packaging, the user can enable boundary and course trimming to bring further detail to the analysis.

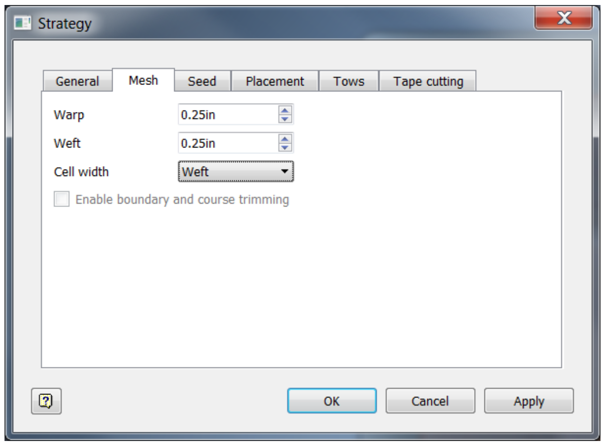

FIGURE 7: STRATEGY DIALOG MESH TAB

Seed Tab

Inside of the Seed Tab, the seed point and seed curve (optional) are defined. The seed point must be on the manufacturing surface within the boundary of the ply. When defining a seed curve, the seed curve must also be on the manufacturing surface and the seed point in this case must be located on the seed curve within the boundary of the ply. Defining a seed curve enables additional fiber path propagation modes.

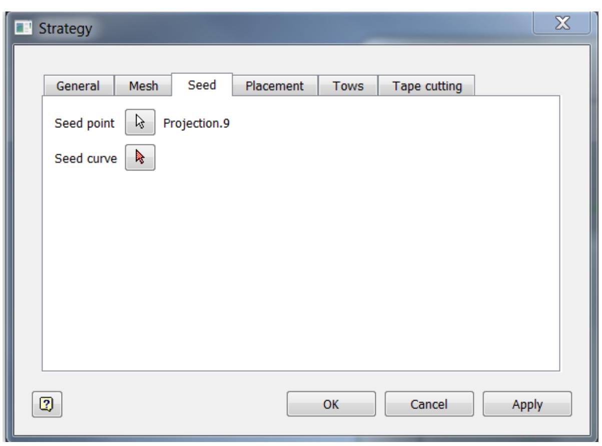

FIGURE 8: STRATEGY DIALOG SEED TAB

Placement Tab

Inside of the Placement Tab, multiple fiber path placement parameters are defined along with some fiber path optimization routines. Propagation mode defines how the fiber path propagates over the manufacturing surface. Available methods include a constant angle, guide curve, natural path, constant steering, and winding. Additional optimization is achieved on the fiber paths to minimize gap and overlap scenarios on converging/diverging surfaces based on the allowable tolerances for manufacturing. Course offset and initial course offset can enforce strategic gaps and overlaps in the layup as well as applying a shift in the start point from layer to layer for better part quality.

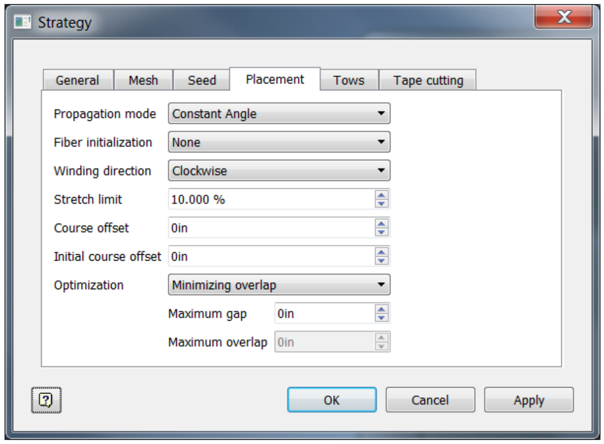

FIGURE 9: STRATEGY DIALOG PLACEMENT TAB

Tows Tab

Inside of the Tows Tab, a user can define the percentage of material that is allowed to overlap the boundary of the ply as well as adjacent courses. This controls the placement of cuts and adds of material which can greatly affect the quality of the layup.

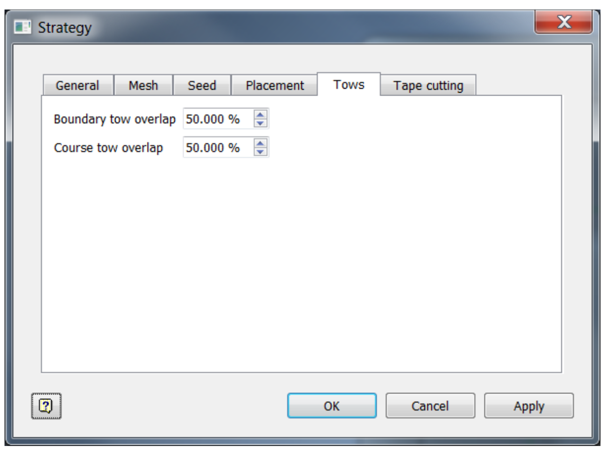

FIGURE 10: STRATEGY DIALOG TOWS TAB

Tape Cutting Tab

The parameters inside of this tab further define the type of tape laying machine available. Strategy defines the cutting capabilities on the tape laying machine. The supported types are perpendicular (straight) cut, angled cut, and contoured cut. The maximum cut angle limits the cut angle so it does not exceed this value.

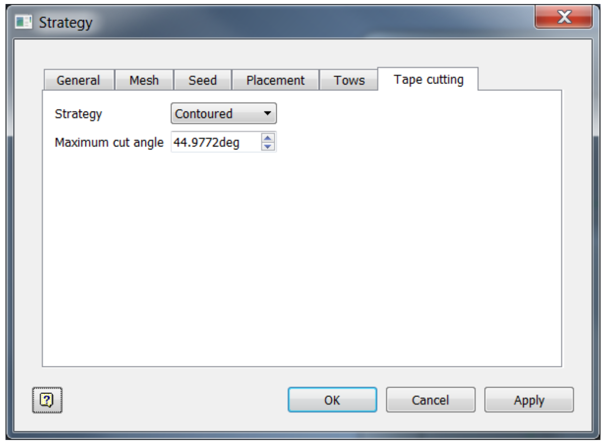

FIGURE 11: STRATEGY DIALOG TAPE CUTTING TAB

Analyzing Material Defects

After all the manufacturing preparations, material properties, and composite design have been completed, TruPlan begins to show what manufacturing processes are feasible through the supported analyses. These analyses include angle deviation, gap and overlap, wrinkling, steering, compaction, and tow length. In the fiber placement manufacturing scenario, the fiber path that is calculated based on the strategy parameters set determines the position of the material as well as the associated material behavior on the surface.

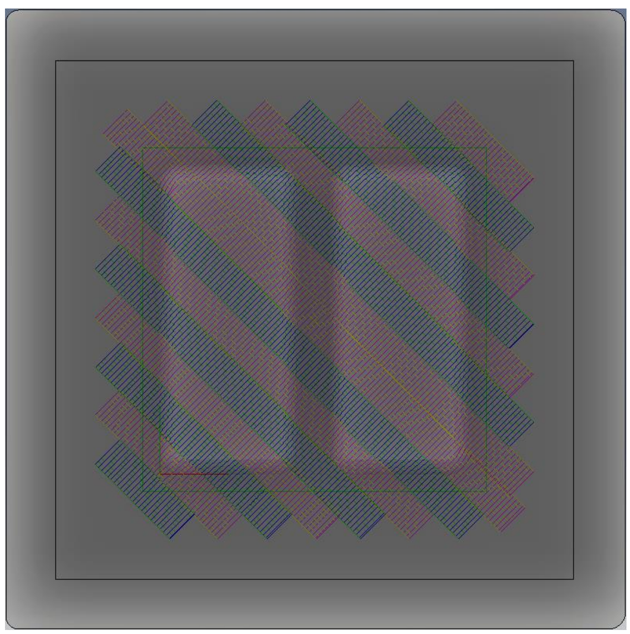

FIGURE 12: FIBER PATH CALCULATION OF PLY AT -45 DEGREES

Angle Deviation

Angle deviation analysis has a warning and limit tolerance for the deviation in fiber angle from the defined rosette orientation for the ply. The warning angles are shown in yellow and the limit angles are shown in red. For a constant angle propagation method, the results angle deviation should be minimal when compared to other propagation methods.

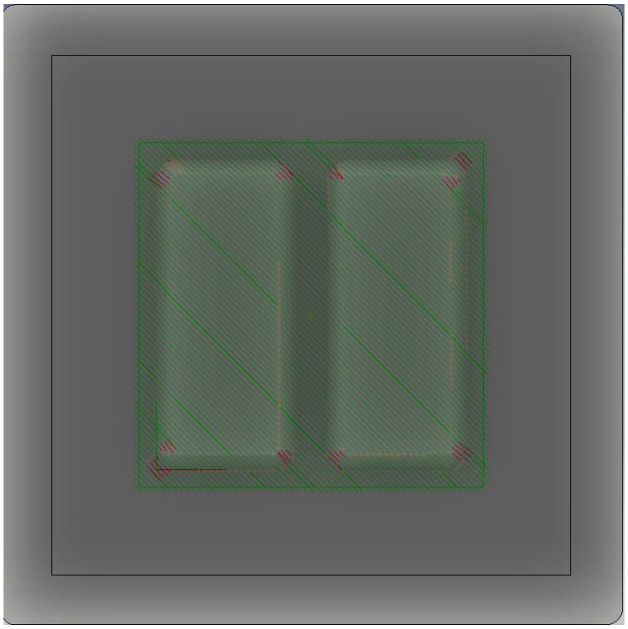

FIGURE 13: ANGLE ANALYSIS OF CONSTANT ANGLE PLY AT -45 DEGREES

Gap and Overlap

Gap analysis shows the gaps and overlaps between successive courses. There are warning and limit tolerances for both gap and overlap scenarios. In fiber placement, it is typical to only have overlap scenarios, which are shown in figure 14.

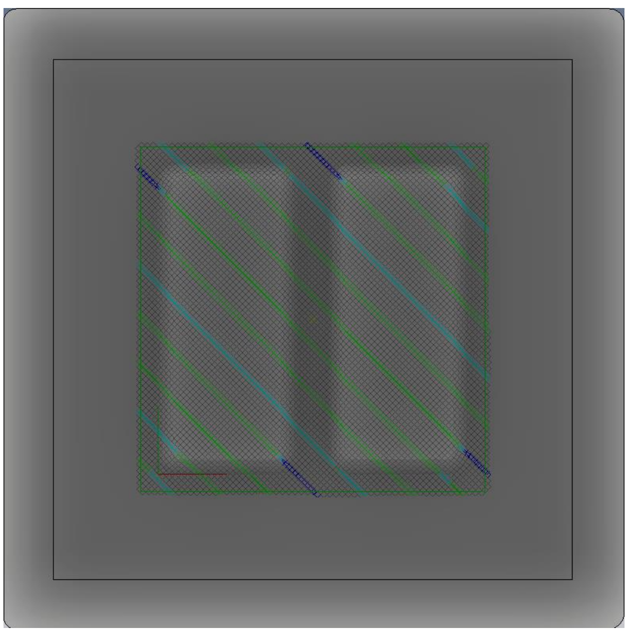

FIGURE 14: GAP ANALYSIS OF CONSTANT ANGLE PLY AT -45 DEGREES

Wrinkling

Wrinkling analysis shows where the material will wrinkling during the manufacturing process. Shearing and spreading of the material from its relaxed state are displayed by this analysis. Situations where both shearing and spreading are occurring is indicated by the red color.

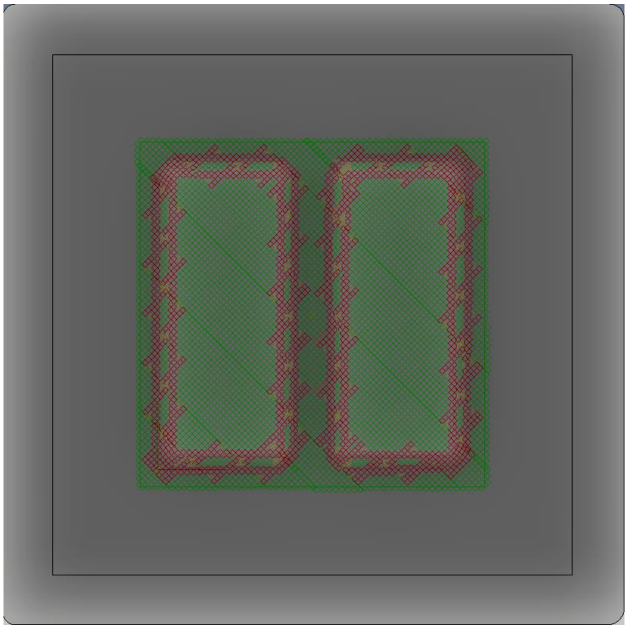

FIGURE 15: WRINKLING ANALYSIS OF CONSTANT ANGLE PLY AT -45 DEGREES

Steering

Steering analysis shows the user where the material is stretching due to the radius it is being driven on. Composite materials have a limit value for the maximum radius it can be steered by. TruPlan shows this value in red and a warning value in yellow. This maximum steering radius is a parameter known by most material manufacturers.

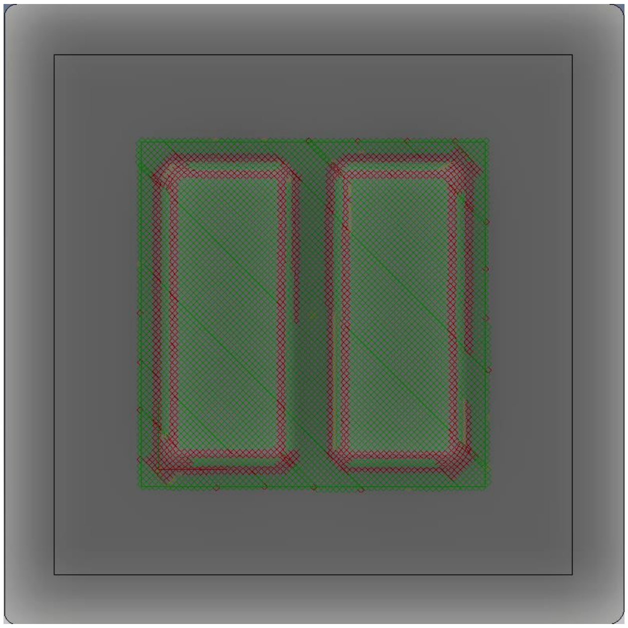

FIGURE 16: STEERING ANALYSIS OF CONSTANT ANGLE PLY AT -45 DEGREES

Compaction

Compaction analysis shows how well your material will be applied to the surface. This illustration of a compaction analysis shows areas where a roller would not be able to fit and maintain enough pressure (compaction) on the material to properly apply it to the surface. Red areas indicate no compaction, while yellow indicates a potential lack of compaction.

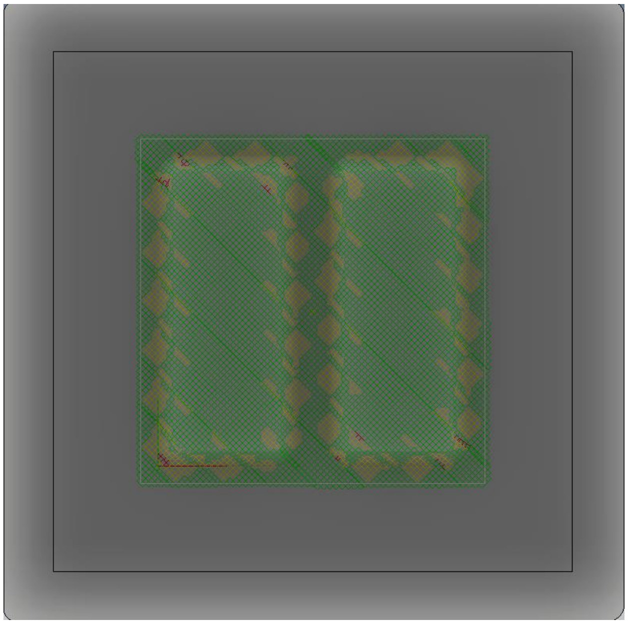

FIGURE 17: COMPACTION ANALYSIS OF CONSTANT ANGLE PLY AT -45 DEGREES

Tow Length

Tow length analysis determines if tow lengths are long enough for your manufacturing solution. This illustration of a tow length analysis shows two corners where tow lengths are too short and cannot be manufactured. One solution to combat this issue might be to build out the ply in the corners to make room for tows of acceptable length.

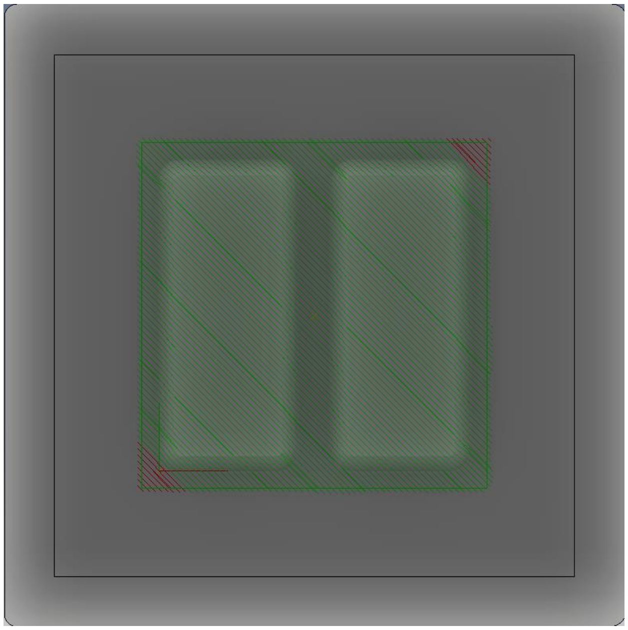

FIGURE 18: MINIMUM TAPE ANALYSIS OF CONSTANT ANGLE PLY AT -45 DEGREES

TruFiber: Programming and Simulation

Fiber Path Programming

After the design for process loop has been completed in the composite manufacturing workflow, TruFiber is used to program the fiber placement machine. Using all the manufacturing parameters generated for each ply in TruPlan, TruFiber calculates the same scenarios with additional information for the tool path. This includes collision avoidance, off-part motion, course to course linking, material overfeed, and compaction compensation based on the surface geometry. The fiber paths calculated are fully editable and allow the user to have complete control over the machine. This package also allows the user to fully define the machine and kinematics of the machine in order to generate a machine specific post processed NC file or a generic APT output. Once the output is generated, the NC file can be read in to the simulation software in order to have a final check of machine motion, collisions, machine bounds, and material deposition.

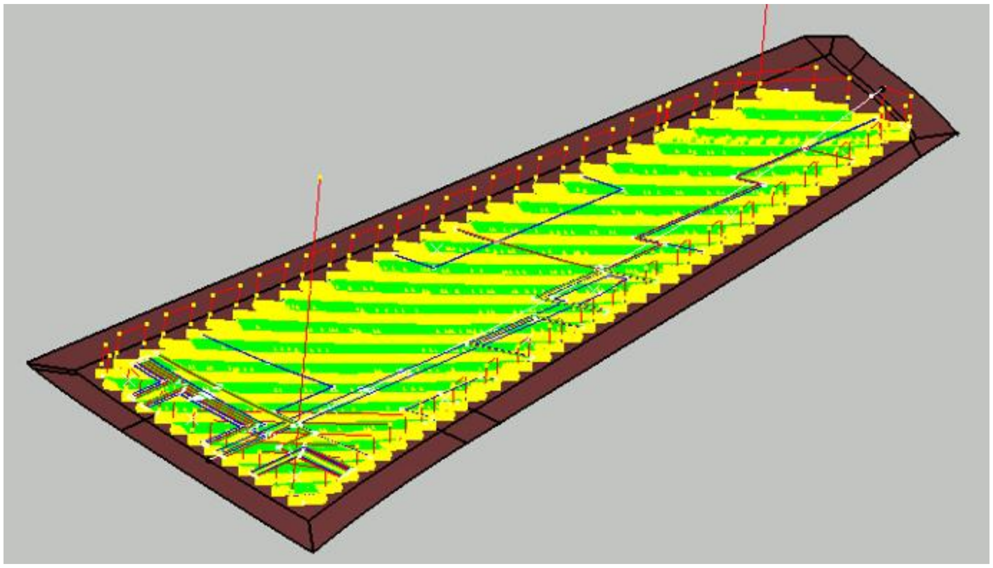

FIGURE 19: TOOL PATH CALCULATION FOR VERTICAL STABILIZER

Fiber Path Simulation

The simulation of the fiber path provides the user with a full machine simulation of the NC code generated for the machine. Simulation provides the user with a play by play of each NC point to make sure the fiber paths that are generated were placed correctly, have no collisions, and are an appropriate solution for the motion of all the axes on the machine.

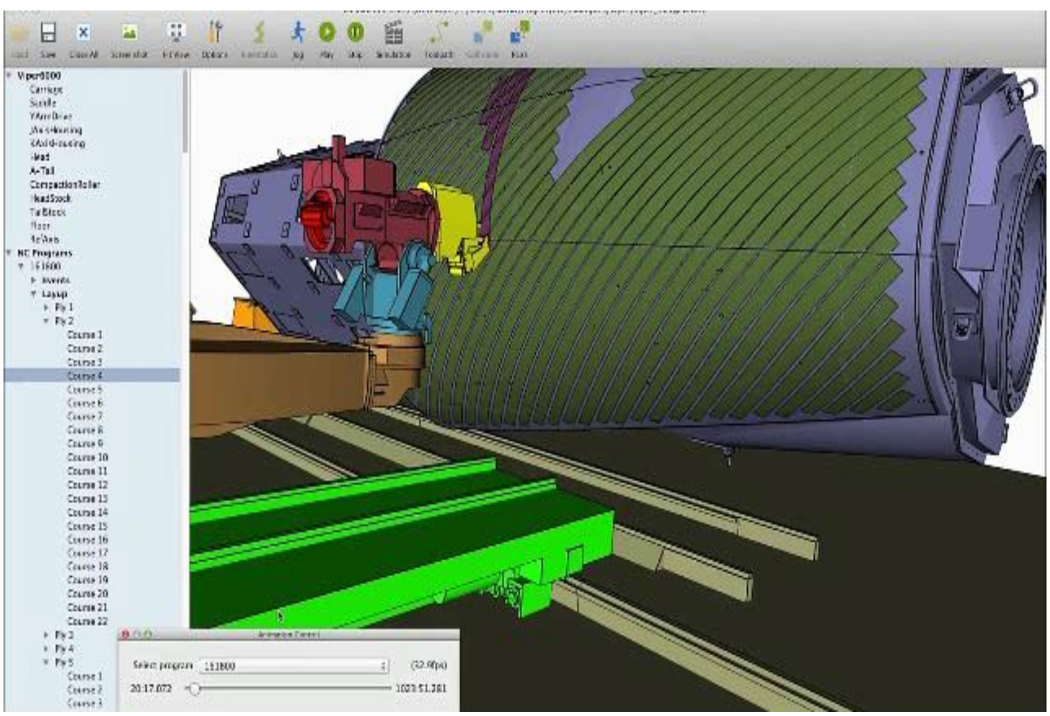

FIGURE 20: SIMULATION OF FIBER PATH PROGRAMMING