

RTM-Worx MSC/Laminate Modeller interface

1. INTRODUCTION

The capability to read Layup files, generated by the MSC/Laminate Modeller allows RTM-Worx users to analyse the effect that deformation of fabric - because it is draped over a doubly curved surface - has on resin flow in the (Vacuum Assisted) Resin Transfer Molding and Vacuum Infusion processes. However, not all the data needed to do an RTM Simulation is included in the Layup file. Therefore, an additional file is defined, with the extension XData, which contains the data needed to translate the output from draping simulations in the MSC/Laminate Modeller to local permeabilities and fiber/volume fractions. This document describes how the interface with MSC/LM works (chapter 2), the XData file format (chapter 3), and the theory used to translate fabric deformation into fiber/volume fractions and permeabilities (chapter 4).

2. IMPORTING LAYUP FILES IN RTM-WORX

2.1. Overview

Importing a model from a Layup file is like importing any other file, with an important difference: RTM-Worx also looks for a file with the same name and in the same directory, but with the extension '.XData' instead of '.Layup'. This file is used to specify fiber/volume fraction and permeability for each material. If this file is not present, RTM-Worx uses default values. When the model has been read from the Layup file, RTM-Worx always overwrites the XData file, or creates one if it did not exist yet. You can use this file as a template. The XData file generated by RTM-Worx will always contain all the materials from the Layup file.

2.2. Recommended procedure

The easiest way to work with the MSC/LM interface is given by the following steps:

1. Use the Project/New command to start a new project.
2. Import the Layup file (Project/Import menu).
3. Add injection- and venting ports, runners if you need them, specify the viscosity and do a test run.
4. Edit the XData file. Specify correct fiber/volume fraction and permeabilities in all '599' records.
5. Import the Layup file again (Project/Import). Now, the fiber/volume fraction and permeabilities you specified in the XData file will be used to calculate local properties.

If you change the mesh in Patran, you will need to delete your current model. You might consider to save runners and injection/venting ports to copy their properties quickly to the new model. Even better, if ports and runners are defined on nodes that will not change (or that are not part of the geometry imported from the Layup file) they will be merged with the model automatically.

2.3. Translation of Layup file data

Importing a model from a Layup file is done in two passes. In the first pass, the XData file and Layup file are read (in that order), and all the data is stored. Only keypoints are directly generated from the nodes in the first pass. In the second pass, the geometry is generated (surfaces from the elements, with properties calculated from layup data from the Layup file in combination with fiber/volume fraction and permeabilities from the XData file). Curves are generated automatically along the element edges.

For all entities - nodes, curves and surfaces - a check is done to see whether the object already exists. Properties of existing surfaces are always updated.

2.3.1. Header

RTM-Worx only reads the version number (006 VERSION_LAYUP_FILE0, but it is not used in the current implementation.

2.3.2. Nodes

RTM-Worx reads the user node identification number (UNID) from record 101 and the x-y-z coordinates from record 102. Nodes are translated to RTM-Worx keypoints.

2.3.3. Elements

The User element id (UEID) from record 201 is used to identify the element. From record 202, the geometry type (GMTP) is used to interpret the element shape (linear/quadratic triangle/quad). In the translation to surfaces, linear elements will have straight edges (curves connecting the vertices) and quadratic elements are translated to surfaces with spline curves as boundary edges that interpolate the vertices and the midpoint. The number of nodes specified in record 203 (NNOD) is used in combination with record 204 (UNIDs) to read in the node numbers. Records 205, 206 and 207 are ignored. Record 210 (in first draft entire calculation relied on its presence) is now ignored too.

2.3.4. Layers

RTM-Worx reads layer type (record 301 – LYRTP), layer id (302 – LYRID), material id (305 – MTRLID) and pattern id (306 – PTTRNID).

The data is used to link each layer to the material and pattern.

2.3.5. Patterns

Pattern data is used to define the plies on each element. RTM-Worx reads records 401 (LYRTP) and 402 (PTTRNID) and stores the layer type and pattern id for later use. The sequence of 430 records is partly read: only the UEID (user element id), WPANG (warp angle) and WTANG (weft angle) values are used: the orientation of the fabric on the element (ORIENT in record 210 – which is now skipped) is taken as WPANG, the angle between warp and weft is calculated as WTANG – WPANG (and reduced to an angle in between $-\pi$ and π if necessary).

2.3.6. Materials

From the material data, the material identification number (MTRLID) is read from record 502, the material name (MTRLNM) is read from record 503 and the nominal thickness (MTRLTHCK) from record 504. All this data is dumped to the XData file (note that MTRLNM and MTRLTHCK always override values from the XData file). The nominal thickness is used in lay-up properties (not the value defined on elements - in RTM-Worx the volume change is incorporated in the local fiber/volume fraction, see chapter 4)

2.3.7. Global Layup

Global layup data is partly read; all records except record 601 are skipped; only LYRTP, LYRID are stored to be able to apply the sequence of predefined layers.

2.3.8. Offset Definition

Offset Definition data (records 700-730) is not used by RTM-Worx.

2.3.9. Tolerance Definition

Tolerance Definition data (records 800-830) is not used by RTM-Worx.

3. XDATA FILE FORMAT

3.1. Comments

Any line which does not begin with three digits is a comment and is ignored. Readability is improved if these lines begin with a double asterisk.

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** COMMENT

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3.2. Header

Header lines begin with the number 0. The header data includes the name of the original file (as it was constructed from the name of a Layup file), a code for its creator (typically says the file is generated by RTM-Worx, including date and time), and the version of the XData file format.

000 HEADER

001 ORIGFILENAME

003 CREATOR

006 VERSION_XDATA_FILE

007 BNODRAPE **

008 BDUMPSURFS **

009 FGEOMSCALE **

010 BPURGEGM **

(** records added in specification 04)

The 'bNoDrape' flag (record 007) can be used to turn off all corrections of permeability and fiber/volume fraction as a function of fabric deformation angles. When a non-zero value is supplied, RTM-Worx simply uses the rule of mixtures for all plies, using nominal fiber/volume fraction and nominal permeability (as specified in 5xx records).

If a non-zero value is given for 'bDumpSurfs' (record 008), a file with the 'XDump' extension will be generated. This file contains detailed information about the plies and surfaces imported. For each ply, it lists name, orientation, angle between warp and weft (wpwtang, 90 degrees for undeformed plies), thickness (h), fiber/volume fraction after correction (vf) and the correction factor applied to permeabilities (kc, equal to 1.0 for undeformed plies).

The 'fGeomScale' (record 009) can be used to automatically scale the geometry, if dimensions and coordinates in the Layup file are not in meters.

Finally, the 'bPurgeGm' flag (record 010) can be set to automatically delete orphan points and lines with no properties. This is similar to the same commands in the geometry editor.

3.3. Material data

Material lines begin with the number 5. Each material is identified by its identification number (MTRLID), which is used to link the material data to the model read from the Layup file. The name (MTRLNM) and nominal thickness (MTRLTHCK) are optional, and always overridden by data specified in the Layup file. The main reason they are included is to make manual editing of the file somewhat easier.

To make it possible to override the thickness for materials in the Xdata file, record 594 has been provided. A thickness specified in this record will be used instead of the ply thickness read from the Layup file.

The bNoDrape flag (record 597) can be used to turn off draping calculations for this material. When a non-zero value is specified, the nominal fiber/volume fraction and permeabilities as specified in record 599 will be used directly for the ply. You can use this if draping does not apply to a layer, like a glue or gelcoat.

Finally, the data needed for the flow simulation is included in (the newly defined) record 599: fiber/volume fraction in undeformed state (NOMVF) e.g. when the angle between weft and warp is 90 degrees, the permeability in warp direction (K1WARP) and the permeability in weft direction (K2WEFT). Note that permeabilities depend on fiber/volume fraction and fiber/volume fraction on thickness.

500 MATERIAL

502 MTRLID

503 MTRLNM

504 MTRLTHCK

594 XDTATHCK **

597 BNODRAPE **

599 NOMVF K1WARP K2WEFT

(** Records added with specification version 4)

IMPORTANT NOTE: The current release ignores all materials in calculation of RTM-Worx surface properties when the fiber/volume fraction (NOMVF) is not in the range [0..1]. You might want to exclude the gel-coat for example. While it could be included correctly with NOMVF=1 and K1WARP=K2WEFT=0, it makes it more difficult to interpret average fiber/volume fraction and permeability.

3.4 The default material

When RTM-Worx writes the file, the specification of a default material (MTRLID = -1) is always added. Those values are used for materials with ID's from the Layup file which are not explicitly defined in the XData file. If the default material is not specified, RTM-Worx uses it's internal definition (which is what is written to the XData file before it is modified by the user).

4. CALCULATION OF LOCAL PROPERTIES

4.1. Fiber/volume fraction

When a fabric shears, the area A of a square with side lengths b becomes

$$A = b^2 \cdot \sin(\theta) \quad (4.1)$$

where θ is the ply-angle, e.g. the angle between warp and weft directions. When the fiber/volume fraction in the undeformed state ($\theta = 90$ degrees) V_{f0} is known, the fiber/volume fraction can be calculated as a function of the shear angle with:

$$V_f = \frac{V_{f0}}{\sin(\theta)} \quad (4.2)$$

Note that the fiber/volume fraction should never be larger than one! Actually, equation (4.2) can be used to define a maximum shearing angle - a theoretical one which is probably larger than the maximum allowed in practice:

$$\theta_{\max} = \arcsin(V_{f0}) \quad (4.3)$$

In the current implementation, the fiber/volume fraction is simply limited to a maximum of 1.0. Shearing angles that exceed the maximum defined by (4.3) result in zero permeability (see next paragraph).

4.2. Dependency of permeability on fiber/volume fraction

The permeability is influenced strongly by variations in fiber/volume fraction. In RTM-Worx, the Kozeny-Carman equation is used:

$$K(V_f) = C \cdot \frac{(1 - V_f)^3}{V_f^2} \quad (4.4)$$

The constant C can be calculated from a known permeability value K_0 in the undeformed state where the fiber/volume fraction is V_{f0} :

$$C = \frac{K_0 \cdot V_{f0}^2}{(1 - V_{f0})^3} \quad (4.5)$$

Note that the permeability will be zero when the fiber/volume fraction equals one. The fabric will be impermeable, but on the other hand, no resin is needed because it can not be impregnated.

4.3. Permeability as a function of shearing angle

The model used to calculate the permeability tensor for various shearing angles is based on the assumption that the permeability can be decomposed along the warp and weft directions. The separate contributions are combined in the effective permeability tensor by a simple addition rule. Shearing defines the rotation of the permeability tensors for weft and warp directions. Physically this model most closely resembles non-crimp fabrics which are composed out of layers of UD reinforcement that have a transverse permeability that is negligible in comparison with the axial value. Generally, the effect of shearing on permeability will be exaggerated by this model, especially for woven fabrics. Because the fiber/volume fraction change has a much larger effect on permeability, this model will suffice in most cases.

The in-plane permeability tensor for each ply is calculated in a local coordinate system with:

$$\bar{K} = \bar{K}_{Warp} + \bar{K}_{Weft} \quad (4.6)$$

$$\bar{K}_{Warp} = \begin{bmatrix} k_{11} \cos^2(\alpha) & k_{11} \sin(\alpha) \cos(\alpha) \\ k_{11} \sin(\alpha) \cos(\alpha) & k_{11} \sin^2(\alpha) \end{bmatrix} \quad (4.7)$$

$$\bar{K}_{Weft} = \begin{bmatrix} k_{22} \cos^2(\alpha + \theta) & k_{22} \sin(\alpha + \theta) \cos(\alpha + \theta) \\ k_{22} \sin(\alpha + \theta) \cos(\alpha + \theta) & k_{22} \sin^2(\alpha + \theta) \end{bmatrix} \quad (4.8)$$

where α defines the warp direction (counterclockwise rotation angle relative to the local x-axis), k_{11} is the permeability in warp direction, and k_{22} the permeability in weft direction. Both k_{11} and k_{22} can be calculated as a function of fibre/volume fraction using equations (4.4) and (4.5).

4.4. Averaging properties from several plies

RTM-Worx calculates with properties locally averaged over the thickness, which are constant on an element. The contributions of all plies defined by Laminate Modeller are calculated according to the previous paragraphs and averaged using a simple rule of mixtures:

$$\bar{V}_f = \frac{1}{H} \sum_i h_i \cdot V_{f,i} \quad (4.9)$$

$$\bar{K} = \begin{bmatrix} k_{xx} & k_{xy} \\ k_{yx} & k_{yy} \end{bmatrix} = \frac{1}{H} \sum_i h_i \cdot \bar{K}_i \quad (4.10)$$

where the index i indicates the ply number, h_i is the thickness of each ply and H is the total thickness. For the permeability tensor, all components can be averaged individually if each tensor is defined relative to the same coordinate system. For application in RTM-Worx, the averaged permeability tensor needs to be decomposed into major and minor permeability, and the direction of the major permeability where the latter is defined by a reference direction, the vector $[x_r, y_r, z_r]^T$, and a rotation angle: φ . If the reference direction is taken equal to the local x-axis (already used to calculate the average permeability tensor), φ can be calculated from:

$$\tan(2\varphi) = \frac{2 \cdot k_{xy}}{k_{xx} - k_{yy}} \quad (4.11)$$

Rotation of the permeability tensor by this angle will lead to a permeability matrix that has non-zero values on the diagonal only. The major and minor permeability are given by:

$$k_{major} = k_{xx} \cdot \cos^2(\varphi) + k_{xy} \sin(2\varphi) + k_{yy} \cdot \sin^2(\varphi) \quad (4.12)$$

$$k_{minor} = k_{xx} \cdot \sin^2(\varphi) - k_{xy} \sin(2\varphi) + k_{yy} \cdot \cos^2(\varphi) \quad (4.13)$$