HyperSizer FEM Coupling:
FEM Imported and Exported Data Including NASTRAN PCOMP Laminates

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Hampton, VA

THE AP1 TRAINING FEM

(Refer to the HyperSizer Pro™ User Manual for more information)

The Complete FEM Input File

```
INIT MASTER(S)
ID S:\Hyper,MSC.v
SOL SESTATICS
TIME 10000
CEND
SUBCASE 101
  SUBTITLE = Wing Pressure
  FORCE = ALL
  SPC   = 100
  LOAD = 101
SUBCASE 102
  SUBTITLE = Internal Tank
Pressure
  FORCE = ALL
  SPC   = 100
  LOAD = 102
SUBCASE 103
  SUBTITLE = Fuselage Bending
  FORCE = ALL
  SPC   = 100
  LOAD = 103
SUBCASE 201
  SUBTITLE = Aero Heating
  FORCE = ALL
  SPC   = 100
  TEMP(LOAD) = 201
BEGIN BULK
$
PARAM,POST,-1
PARAM,OGEOM,NO
PARAM,AUTOSPC,YES
PARAM,MAXRATIO,1.E+8
PARAM,GRDPNT,0
```

```
$ Include applied load PLOAD4 and FORCE data
INCLUDE 'Ap1.LOAD'
$ Include applied thermal TEMPP and TEMPRB data
INCLUDE 'Ap1.TEMP'
$ Include boundary condition SPC data
INCLUDE 'Ap1.SPCS'
$ Include model Grids
INCLUDE 'Ap1.GRID'
$ Include model CQUAD4 and CTRIA3 elements
INCLUDE 'Ap1.SHEL'
$ Include Patran generated Property Name PSET data
$    Read by HyperSizer to assign character strings to Component IDs
INCLUDE 'Ap1.PSET'
$ Include HyperSizer generated property and material data to represent
$    panel thermoelastic stiffness changes that occur during sizing
$    iterations.Provides the updated PSHELL, PBAR, MAT2, and MAT1 data.
$    * 00=starting point properties, *.01=first sizing iteration
INCLUDE 'Ap1_00.PM1'
$ Include HyperSizer generated CBAR beam element data
$    Provides beam offset vectors to represent neutral axis shifts that
$    occur during sizing iterations.
$    *._00=starting point properties, *.01=first sizing iteration
INCLUDE 'Ap1_00.CL1'
ENDDATA
```

FEM Case Control

```
INIT MASTER(S)
ID S:\Hyper,MSC.v
SOL SESTATICS
TIME 10000
CEND
SUBCASE 101
  SUBTITLE = Wing Pressure
  FORCE = ALL
  SPC   = 100
  LOAD = 101
SUBCASE 102
SUBTITLE = Internal Tank Pressure
  FORCE = ALL
  SPC   = 100
  LOAD = 102
SUBCASE 103
  SUBTITLE = Fuselage Bending
  FORCE = ALL
  SPC   = 100
  LOAD = 103
SUBCASE 201
  SUBTITLE = Aero Heating
  FORCE = ALL
  SPC   = 100
  TEMP(LOAD) = 201
BEGIN BULK
```

Note: Must generate element forces in the *.F06 File.

Three Mechanical Load Sets imported.

One Thermal Load Set Imported.

FEM Bulk Data

```
$ Applied load PLOAD4 and FORCE data
INCLUDE 'Ap1.LOAD'
```

PLOAD4 pressure data is imported.

```
$ Applied thermal TEMPP and TEMPRB data
INCLUDE 'Ap1.TEMP'
```

TEMPP & TEMPRB temperature data is imported.

```
$ Boundary condition SPC data
INCLUDE 'Ap1.SPCS'

$ model Grids
INCLUDE 'Ap1.GRID'
```

GRID data is imported.

```
$ Include model CQUAD4 and CTRIA3 elements
INCLUDE 'Ap1.SHEL'
```

Element Shell data is imported.

```
$ Patran generated Property Name PSET data
$ Read by HyperSizer to assign character strings to
$ Component IDs
INCLUDE 'Ap1.PSET'
```

PATRAN PSET data is imported.

```
$ HyperSizer generated property and material data to
$ represent panel thermoelastic stiffness changes that
$ occur during sizing iterations. Provides the updated
$ PSHELL, PBAR, MAT2, and MAT1 data.
$ *_00=starting point properties, *.01=first sizing
$ iteration properties, etc.
INCLUDE 'Ap1_00.PM1'
```

Properties and Materials Created by HyperSizer

```
$ HyperSizer generated CBAR beam element data
$ Provides beam offset vectors to represent neutral axis
$ shifts that occur during sizing iterations.
$ *._00=starting point properties, *.01=first sizing
$ iteration properties, etc.
INCLUDE 'Ap1_00.CL1'
```

Beam – Element Offset Vectors Created by HyperSizer

```
ENDDATA
```

NASTRAN FEM ID Links

This is a part of file Ap1.SHEL

```
CQUAD4    5   48   1300      5   18   19 66.3244
CQUAD4    6   48      7   1300   19   20 66.3244
CQUAD4    7   47   1292      7   20   21 66.3244
CQUAD4    8   47   1288   1292   21   22 66.3244
CQUAD4    9   47     10   1288   22   23 66.3244
CQUAD4   10   47     11     10   23   24 66.3244
CQUAD4   11   46     12     11   24   25 66.3244
CQUAD4   12   46     13     12   25   26 66.3244
CQUAD4   13   49     15     14   27   28 66.3244
CQUAD4   14   49     16     15   28   29 66.3244
```

This is a part of file Ap1. PSET

```
$ Pset: "Wing skin, forward top" will be imported as: "pshell.46"
$ Pset: "Wing skin, midforward top" will be imported as: "pshell.47"
$ Pset: "Wing skin, mid aft top" will be imported as: "pshell.48"
$ Pset: "Wing skin, aft top" will be imported as: "pshell.49"
$ Pset: "Longerons, aft" will be imported as: "pbar.11"
$ Pset: "Spar caps bot, carry thru" will be imported as: "pbar.12"
$ Pset: "Spar caps top, carry thru" will be imported as: "pbar.13"
```

This is a part of file Ap1_00.CL1

```
CBAR   3400 11   1030   1031 -.004 -.707 -.707
           .0000   .0000 .0000 .0000 .0000 .0000
CBAR   3401 11   1031    818 -.009 -.707 -.706
           .0000 .0000  .0000 .0000 .0000 .0000
CBAR   2955 12    731    744   .000   .000 1.000
           .0000 .0000  .0000 .0000 .0000 .0000
CBAR   2956 12    744    757   .000   .000 1.000
           .0000 .0000  .0000 .0000 .0000 .0000
CBAR   3086 12    778    481   .000   .000 1.000
           .0000 .0000  .0000 .0000 .0000 .0000
CBAR   2923 13   2926   2929   .000   .000 -1.000
           .0000 .0000  .0000 .0000 .0000 .0000

CBAR   2924 13   2929   2932   .000   .000 -1.000
```

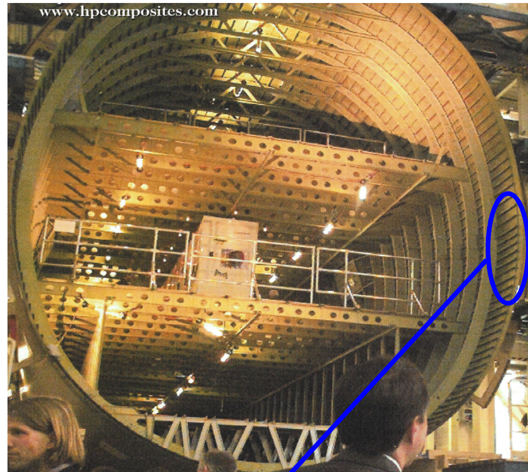
```
$ Structural Component ID = 46 material properties = COMPRESSION
PSHELL*                   46            460              1.0             459
*                       12.0                                 .6316581969E-04*
*                                                    457
MAT2*                    460  .261573575E+07  .367710635E+06  .000000000E+00*
*             .118616335E+07  .000000000E+00  .504585981E+06                *
*             .490000000E-05  .490000000E-05  .000000000E+00  .700000000E+02
MAT2*                    459  .168329979E+07  .166437165E+03  .000000000E+00*
*             .536894086E+03  .000000000E+00  .115175138E+04                *
*             .490000000E-05  .490000000E-05  .000000000E+00  .700000000E+02
MAT2*                    457  .117617021E+07  .647584319E+03  .000000000E+00*
*             .208898170E+04  .000000000E+00  .103210769E+05                *
*             .490000000E-05  .490000000E-05  .000000000E+00  .700000000E+02
$ - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
$ Structural Component ID = 12 material properties = TENSION
PBAR*                     12            120   .55500000E+00   .31866250E+00
*              .25478125E-01   .38488500E-02   .22981366E-03
*                     .0E+00          .0E+00          .0E+00          .0E+00
*                     .0E+00          .0E+00          .0E+00          .0E+00
*                                             .00000000E+00
MAT1*                    120  .162000000E+08  .620000000E+07
*             .000000000E+00  .490000000E-05  .700000000E+02
$
```

This is a part of file Ap1_00.PM1

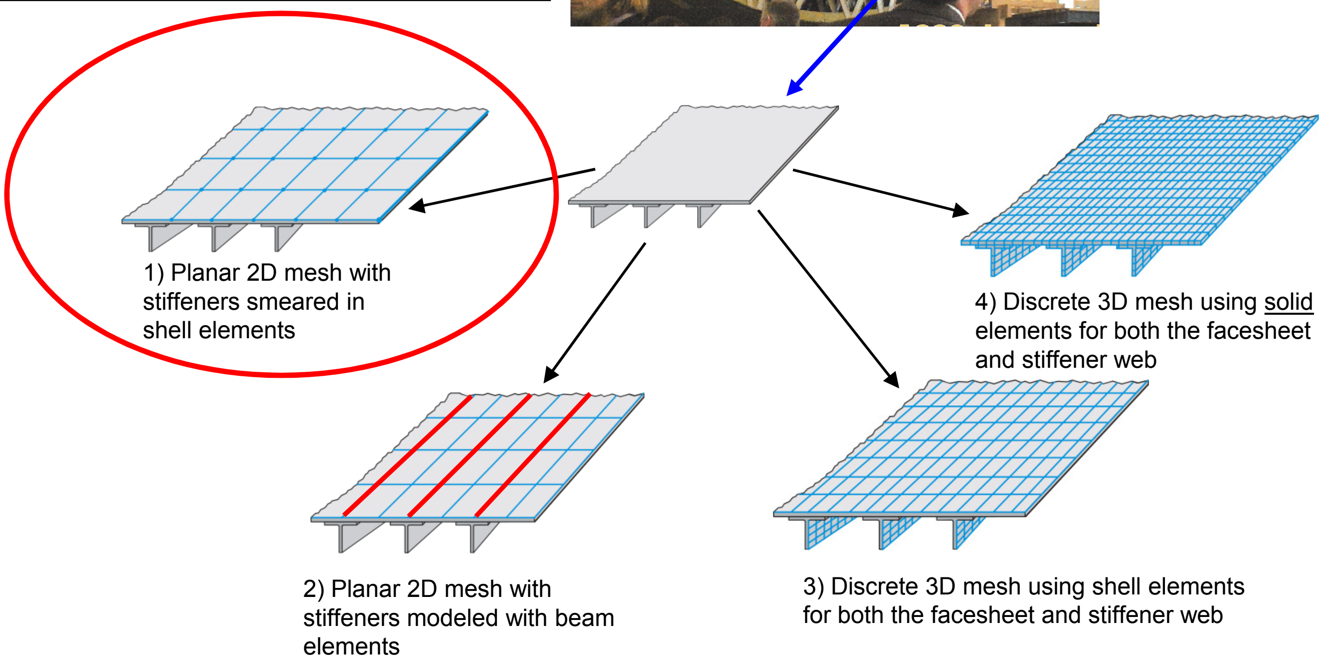
 FEM Imported and Exported Data

Four ways to model stiffened panels

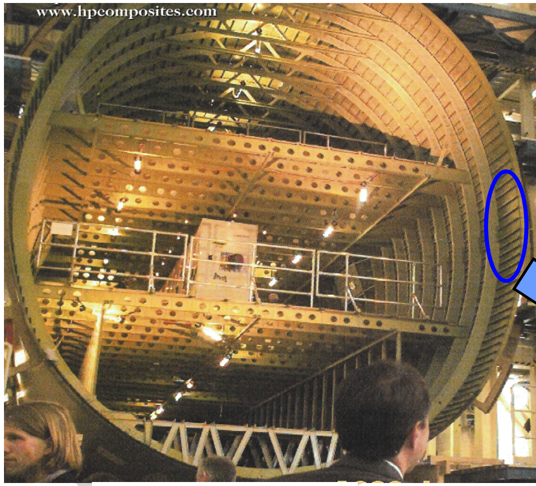
Approach 1 is the preferred approach for a HyperSizer analysis/sizing which allows users to swap out any panel concepts on the fly to be accurately represented in a FEM

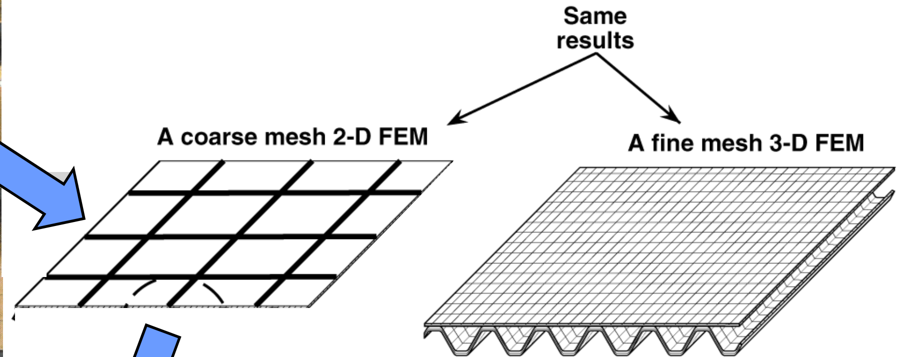


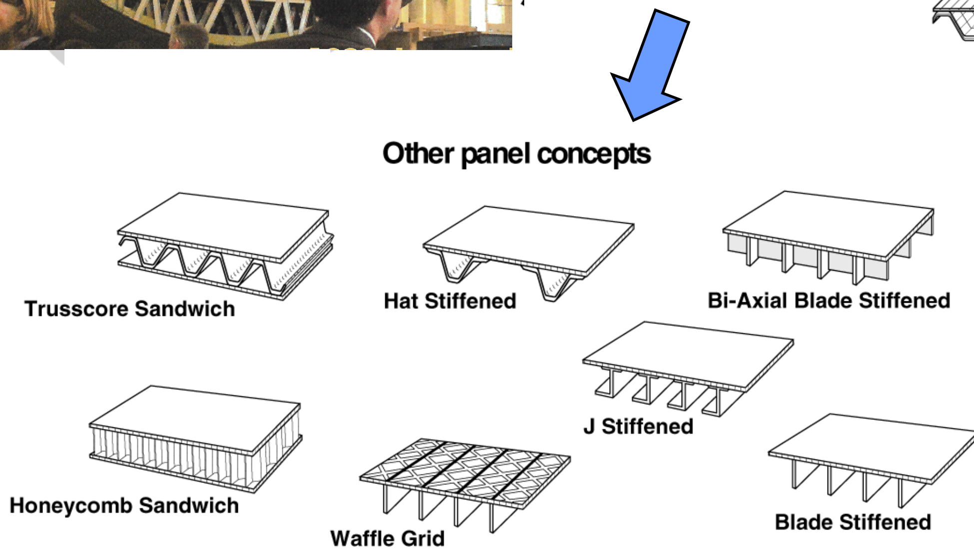
Airframe Fuselage Panel



HyperSizer's Panel Formulations Accurately Couple with Planar FEM Meshes







With a single plane of shell elements, HyperSizer is able to get accurate mechanical and thermal stress/strain fields throughout the panel depth for general FEM loading environments

This permits quick evaluation of other panel concepts without the need of changing the FEM mesh

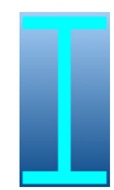
HyperSizer Generates FEM PSHELL & MAT2 Data for any Panel Concept

After sizing, HyperSizer creates FEM materials and properties to represent any panel concept with a single plane of shell CQUAD4 and/or CTRI3 elements and any beam concept with a line of CBAR elements

```
$ Structural Component ID = 46 material properties = COMPRESSION
PSHELL*                  46              460                1.0             459
*                      12.0                            .6316581969E-04*
*                                                      457
MAT2*                   460  .261573575E+07  .367710635E+06  .000000000E+00*
*            .118616335E+07  .000000000E+00  .504585981E+06                 *
*            .490000000E-05  .490000000E-05  .000000000E+00  .700000000E+02
MAT2*                   459  .168329979E+07  .166437165E+03  .000000000E+00*
*            .536894086E+03  .000000000E+00  .115175138E+04                 *
*            .490000000E-05  .490000000E-05  .000000000E+00  .700000000E+02
MAT2*                   457  .117617021E+07  .647584319E+03  .000000000E+00*
*            .208898170E+04  .000000000E+00  .103210769E+05                 *
*            .490000000E-05  .490000000E-05  .000000000E+00  .700000000E+02
```

Each MAT2 represents a 3x3 stiffness matrix:
MAT ID 460 = Aij (membrane)
459 = Dij (bending)
457 = Bij (coupling)
(sandwich concepts also include the 2x2 transverse shear terms)

```
$ Structural Component ID = 12 material properties = TENSION
PBAR*                    12              120   .55500000E+00   .31866250E+00
*             .25478125E-01   .38488500E-02   .22981366E-03
*                    .0E+00          .0E+00          .0E+00          .0E+00
*                    .0E+00          .0E+00          .0E+00          .0E+00
*                                              .00000000E+00
MAT1*                   120  .162000000E+08  .620000000E+07
*            .000000000E+00  .490000000E-05  .700000000E+02
$
```

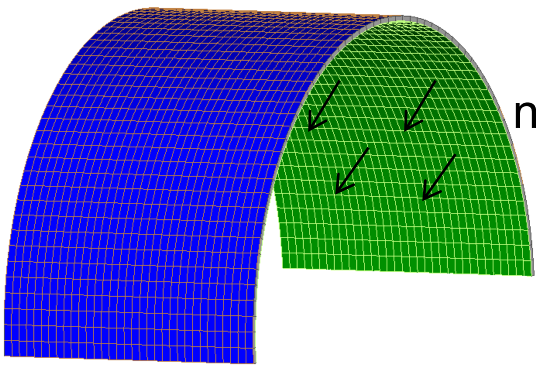


The PBAR lists the beam properties such as area, moments of inertia, etc.

HyperSizer can also import and export FEM PCOMP/MAT8 materials

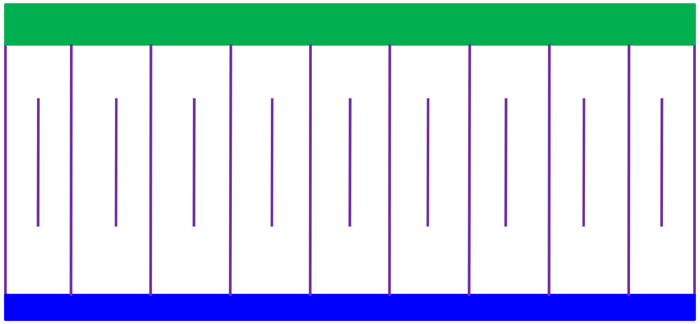
A typical FEM of a composite structure may have hundreds of individual NASTRAN PCOMPs defining the laminates.

In this fuselage barrel example, the honeycomb structure is modeled as a single plane of shell elements with a PCOMP. The honeycomb core is included as a layer in the PCOMP.



Although this sandwich panel is unsymmetric, both the FEA and HyperSizer consistently default to the midplane of the panel rather than the neutral axis or midplane of the core.

If the FEM PCOMP includes an offset, it will be imported into HyperSizer. This capability is described later.



HyperSizer will Import PCOMP/MAT8 Nastran Data for Solid Laminate and Sandwich Panels

Outer Facesheet

Inner Facesheet

Core

```
$ MSC.visualNastran for Windows Property 4 : Inner Facesheet
PCOMP          4                0.                        70.                +
+             54  0.0052       45.       YES       54  0.0052      -45.      YES+
+             54  0.0052       90.       YES       54  0.0052        0.      YES+
+             54  0.0052       90.       YES       54  0.0052        0.      YES+
+             54  0.0052       90.       YES       54  0.0052      -45.      YES+
+             54  0.0052       45.       YES      560  1.0000       0.0     YES+
+             54  0.0104      19.2       YES       54  0.0104     -19.2      YES+
+             54  0.0052     30.08       YES       54  0.0052    -30.08      YES+
+             54  0.0052     40.97       YES       54  0.0052    -40.97      YES+
+             54  0.0052     51.86       YES       54  0.0052    -51.86      YES+
+             54  0.0052     62.74       YES       54  0.0052    -62.74      YES+
+             54  0.0052     73.73       YES       54  0.0052    -73.63      YES+
+             54  0.0052     87.26       YES       54  0.0052    -87.26      YES
```

2D Orthotropic Material Property

```
$ MSC.visualNastran for Windows Material 54 : 2D Orthotropic Material
MAT8*                      54         22000000.         1900000.              0.3
*                    1190000.          1190000.          500000.            0.057*
*                       -2.E-7         0.000012              70.
```

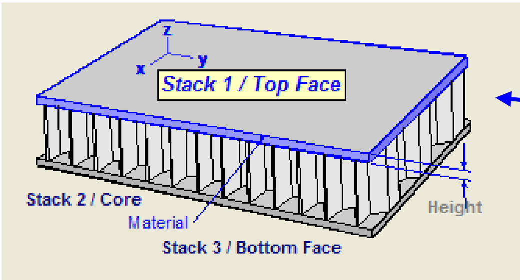
Honeycomb Core Material Property

```
MAT8*                     560  .100000000E-03  .100000000E-03  .333330000E+00
*           .100000000E-03  .111000000E+05  .134000000E+05  .449275362E-05
*           .000000000E+00  .000000000E+00  .720000000E+02
*
```


PCOMP Loaded into HyperSizer as a Honeycomb Sandwich Component

The PCOMP is imported into HyperSizer and automatically loaded into the Sizing Form as a honeycomb sandwich component.

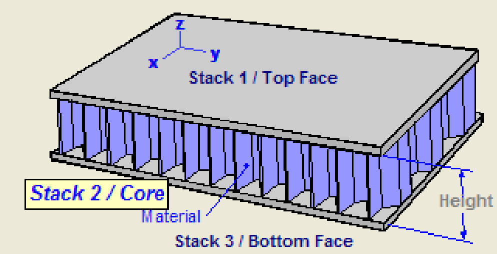
Inner Facesheet



Ply Sequence (in order from laminate top to

1	Ply	Angle	Thickness
	1	+19.2°	0.0104
	2	-19.2°	0.0104
	3	+30.1°	0.0052
	4	-30.1°	0.0052
	5	+41°	0.0052
	6	-41°	0.0052
	7	+51.9°	0.0052
	8	-51.9°	0.0052
	9	+62.7°	0.0052
	10	-62.7°	0.0052
	11	+73.7°	0.0052
	12	-73.6°	0.0052
	13	+87.3°	0.0052
	14	-87.3°	0.0052

Core



Core - Thickness (All materials except Hyper-Laminate

Group Variable Bounds

Minimum	Maximum	Permutations
1	1	1

Advanced Group Optimization

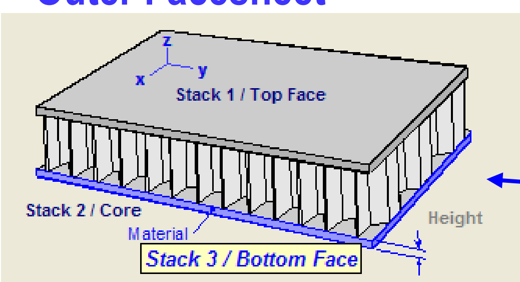
Minimum	Maximum	Permutations

Statistical Optimization Link All Variables

Material

Honeycomb "Hexcel 5052 4.1pcf KMAT8%560", Density 0.002378, Dry

Outer Facesheet



Ply Sequence (in order from laminate top to

1	Ply	Angle	Thickness
	1	+45°	0.0052
	2	-45°	0.0052
	3	+90°	0.0052
	4	0°	0.0052
	5	+90°	0.0052
	6	0°	0.0052
	7	+90°	0.0052
	8	-45°	0.0052
	9	+45°	0.0052

 FEM Imported and Exported Data

HyperSizer®

HyperSizer Automatically Generates PCOMP/MAT8 Nastran Data Based on Optimized Design

2D Orthotropic Material Property

Honeycomb Core

Outer Facesheet

Core

Inner Facesheet

```
$
$ Structural Component ID =        4           material properties = TENSION
MAT8*                    54 .217500000E+08 .190000000E+07 .300000000E+00
*          .119000000E+07 .119000000E+07 .119000000E+07 .147515528E-03
*         -.300000000E-06 .754000000E-05 .720000000E+02 .105600000E+06
*          .795500000E+05 .912000000E+04 .703000000E+04 .158000000E+05
MAT8*                   560 .100000000E-03 .100000000E-03 .333330000E+00
*          .100000000E-03 .111000000E+05 .134000000E+05 .449275362E-05
*          .000000000E+00 .000000000E+00 .720000000E+02
*
PCOMP          4 -1.0832          .136E+03    HOFF    72.0
+             54  0.0052      45.      YES      54  0.0052    -45.       YES+
+             54  0.0052      90.      YES      54  0.0052      0.       YES+
+             54  0.0052      90.      YES      54  0.0052      0.       YES+
+             54  0.0052      90.      YES      54  0.0052    -45.       YES+
+             54  0.0052      45.      YES     560  1.0000     0.0       YES+
+             54  0.0104     19.2      YES      54  0.0104   -19.2       YES+
+             54  0.0052    30.08      YES      54  0.0052  -30.08       YES+
+             54  0.0052    40.97      YES      54  0.0052  -40.97       YES+
+             54  0.0052    51.86      YES      54  0.0052  -51.86       YES+
+             54  0.0052    62.74      YES      54  0.0052  -62.74       YES+
+             54  0.0052    73.73      YES      54  0.0052  -73.63       YES+
+             54  0.0052    87.26      YES      54  0.0052  -87.26       YES
```

IMPORT PROCESS FOR PCOMP LAMINATES AND MAT8 MATERIALS FROM THE FEM

Automatic Importing of PCOMPs to create Laminates and Honeycomb Sandwiches

- PCOMP properties in a finite element model can be automatically imported into HyperSizer as layup and laminate materials.
- For honeycomb or laminate components, PCOMPs will be used to define sizing groups and set up all sizing parameters (materials, dimensions, etc.)
- If a honeycomb core layer is found, HyperSizer will import the PCOMP as a Honeycomb sandwich component.
- If a material exists in the HyperSizer database that corresponds to a MAT8 or MAT1 card, it will be associated with that material in the FEM.
- Offsets defined on PCOMP cards will automatically be imported and included as a Reference Plane offset on the Sizing Form.

Summary Steps: Importing PCOMPs with MAT1 or MAT8 into HyperSizer

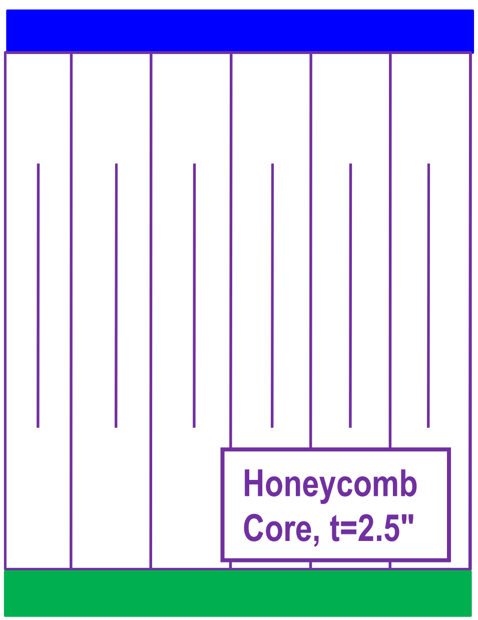
1. Create Materials in the HyperSizer Database corresponding to MAT1 and MAT8 cards in the FEM
2. Select the PCOMP Import Option on the Project Setup Form
3. Import the FEM
4. Open the Laminate Editor to view the generated composite laminates and material ply assignments
5. Open the Sizing form to analyze the components and obtain margins-of-safety

Each step will be discussed in detail on the following slides

Example problem to illustrate PCOMP import process

Shown here is a different sandwich design than the previous example. It is a honeycomb with composite fabric facesheets. The PCOMP has 18 layers representing the bottom facesheet (green outline), 18 for the top facesheet (blue outline) and one ply representing the core (purple outline).

Top Facesheet (tape)
[45/-45/0/90/0/90/45/-45/0]s



Bottom Facesheet (tape)
[45/-45/0/90/0/90/45/-45/0]s

```
MAT8*                450   .233502500E+08   .165047100E+07   .320000000E+00
*         .749818700E+06   .749818700E+06   .629441600E+06   .148550725E-03
*        -.100000000E-06   .150000000E-04   .720000000E+02
*
```

```
MAT8*                560   .100000000E-03   .100000000E-03   .333330000E+00
*         .100000000E-03   .170000000E+05   .430000000E+05   .615424431E-05
*         .000000000E+00   .000000000E+00   .720000000E+02
*
```

```
PCOMP         39                    .149E+03     HOFF     72.0
+            450     .0050   45.000               450     .0050  -45.000
+            450     .0050     .000               450     .0050   90.000
+            450     .0050     .000               450     .0050   90.000
+            450     .0050   45.000               450     .0050  -45.000
+            450     .0050     .000               450     .0050     .000
+            450     .0050  -45.000               450     .0050   45.000
+            450     .0050   90.000               450     .0050     .000
+            450     .0050   90.000               450     .0050     .000
+            450     .0050  -45.000               450     .0050   45.000
+            560    2.5000     .000               450     .0050   45.000
+            450     .0050  -45.000               450     .0050     .000
+            450     .0050   90.000               450     .0050     .000
+            450     .0050   90.000               450     .0050   45.000
+            450     .0050  -45.000               450     .0050     .000
+            450     .0050     .000               450     .0050  -45.000
+            450     .0050   45.000               450     .0050   90.000
+            450     .0050     .000               450     .0050   90.000
+            450     .0050     .000               450     .0050  -45.000
+            450     .0050   45.000
```

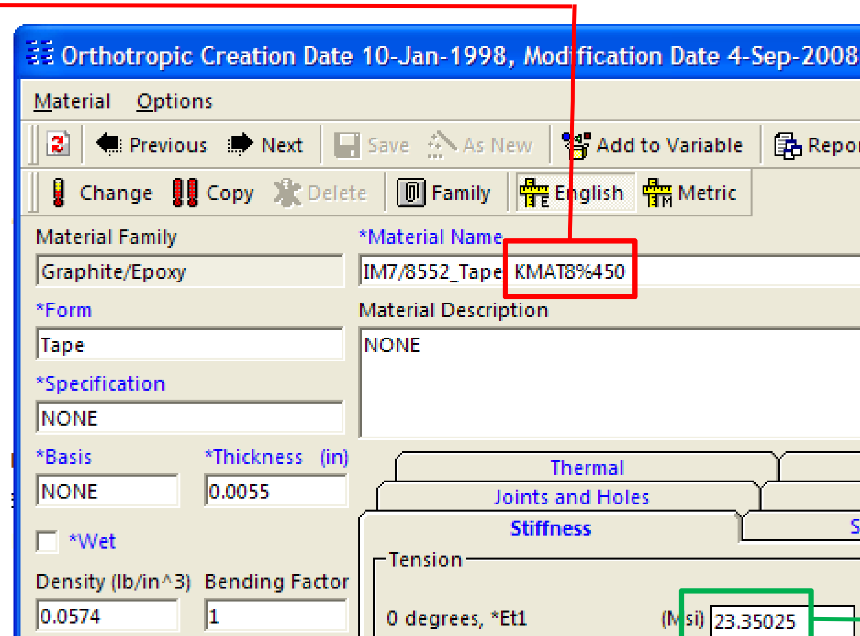
Step 1a: Create Materials in the HyperSizer Database corresponding to FEM MAT1 and MAT8 cards in the FEM

For every MAT1 and MAT8 card in the FEM, create a material in the HyperSizer database and at the END of the material name, append the string KMAT8%<MATID>

For example, the following MAT8 card has MATID=450,

```
MAT8*                     450  .233502500E+08  .165047100E+07  .320000000E+00
*             .749818700E+06  .749818700E+06  .629441600E+06  .148550725E-03
*            -.100000000E-06  .150000000E-04  .720000000E+02
*
```

Create a material in the HyperSizer database. The material name is arbitrary, but it must end with “KMAT8%450” in order to establish the association between the HyperSizer material and the NASTRAN material.



Note that this material is not created automatically. It must be created using processes described in the Material Manager User Manual.

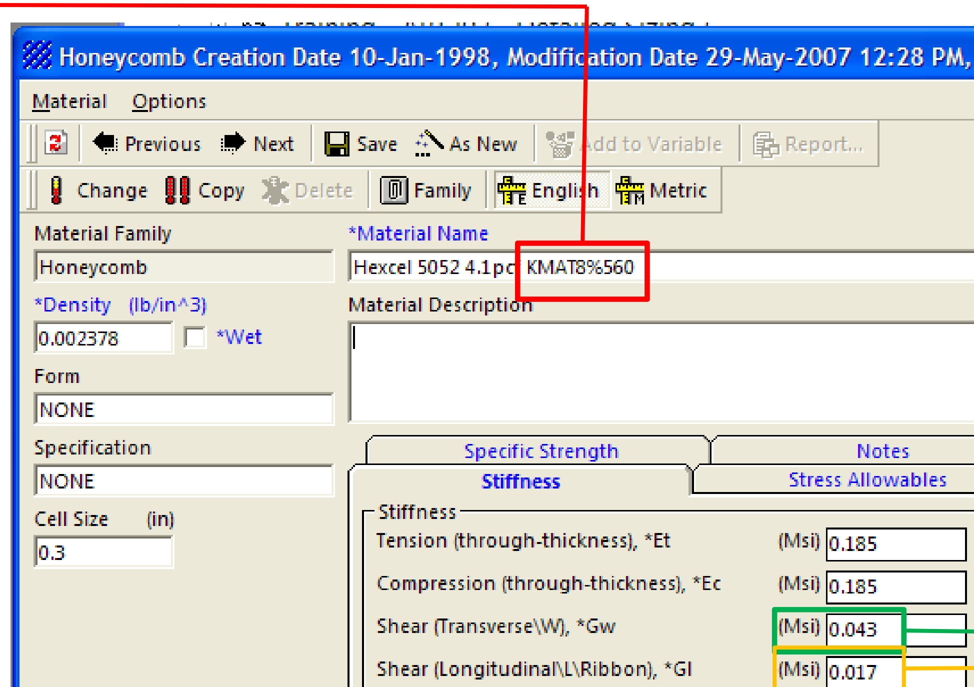
Step 1b: Create Materials in the HyperSizer Database corresponding to FEM MAT1 and MAT8 cards in the FEM

If the material represents a honeycomb core, then create a honeycomb material following the same pattern. The following MAT8 with MATID = 560 is created in the HyperSizer database as a honeycomb material where the name ends with KMAT8%560.

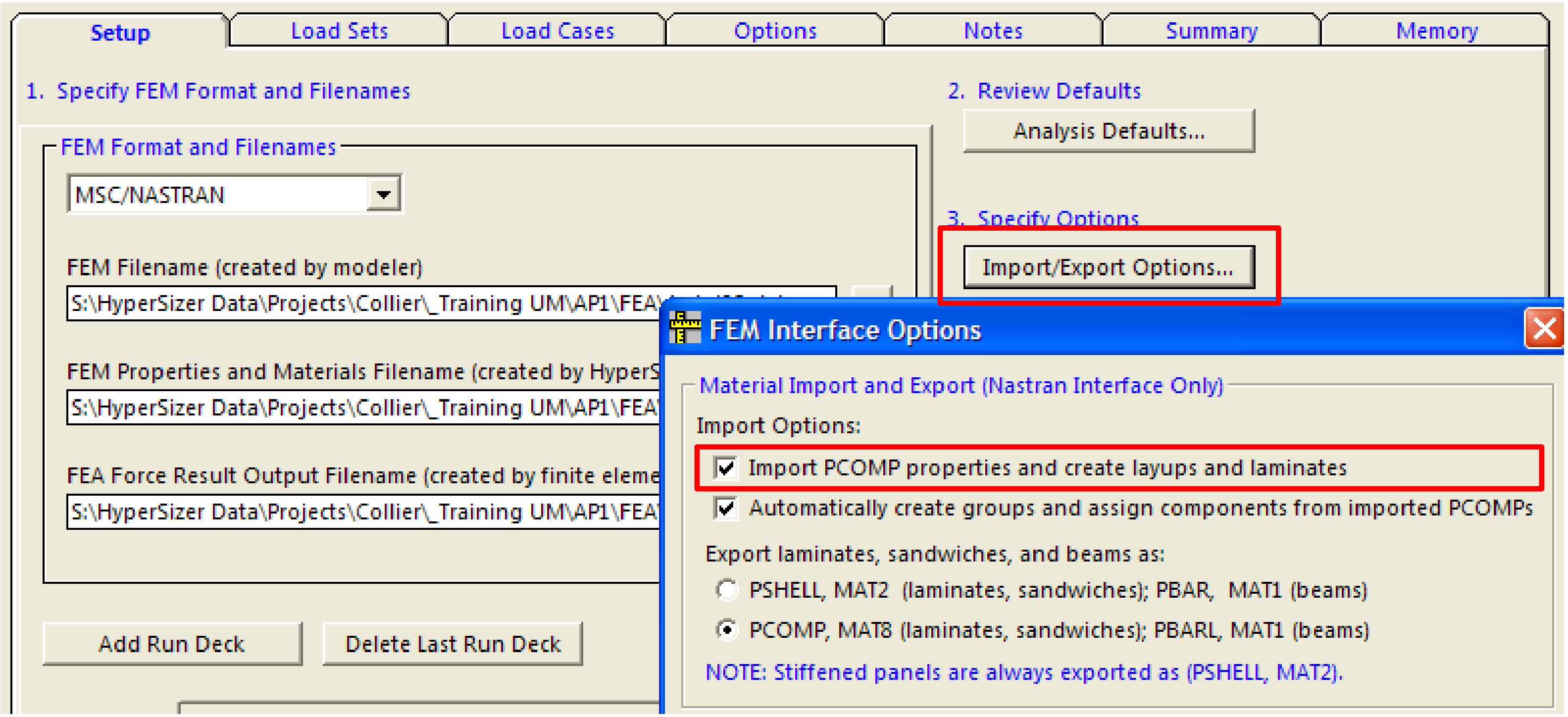
```
MAT8*                    560  .100000000E-03  .100000000E-03  .333330000E+00
*          .100000000E-03  .170000000E+05  .430000000E+05  .615424431E-05
*          .000000000E+00  .000000000E+00  .720000000E+02
*
```

The in-plane properties (E1, E2, G12) are assumed to be very small, entered here as 0.0001 psi. These FEM properties have no corresponding properties in the HyperSizer Material.

On the other hand, the HyperSizer honeycomb through-thickness tension and compression properties(Et, Ec) have no corresponding properties in the FEM because the MAT8 card does not support through thickness tension or compression.

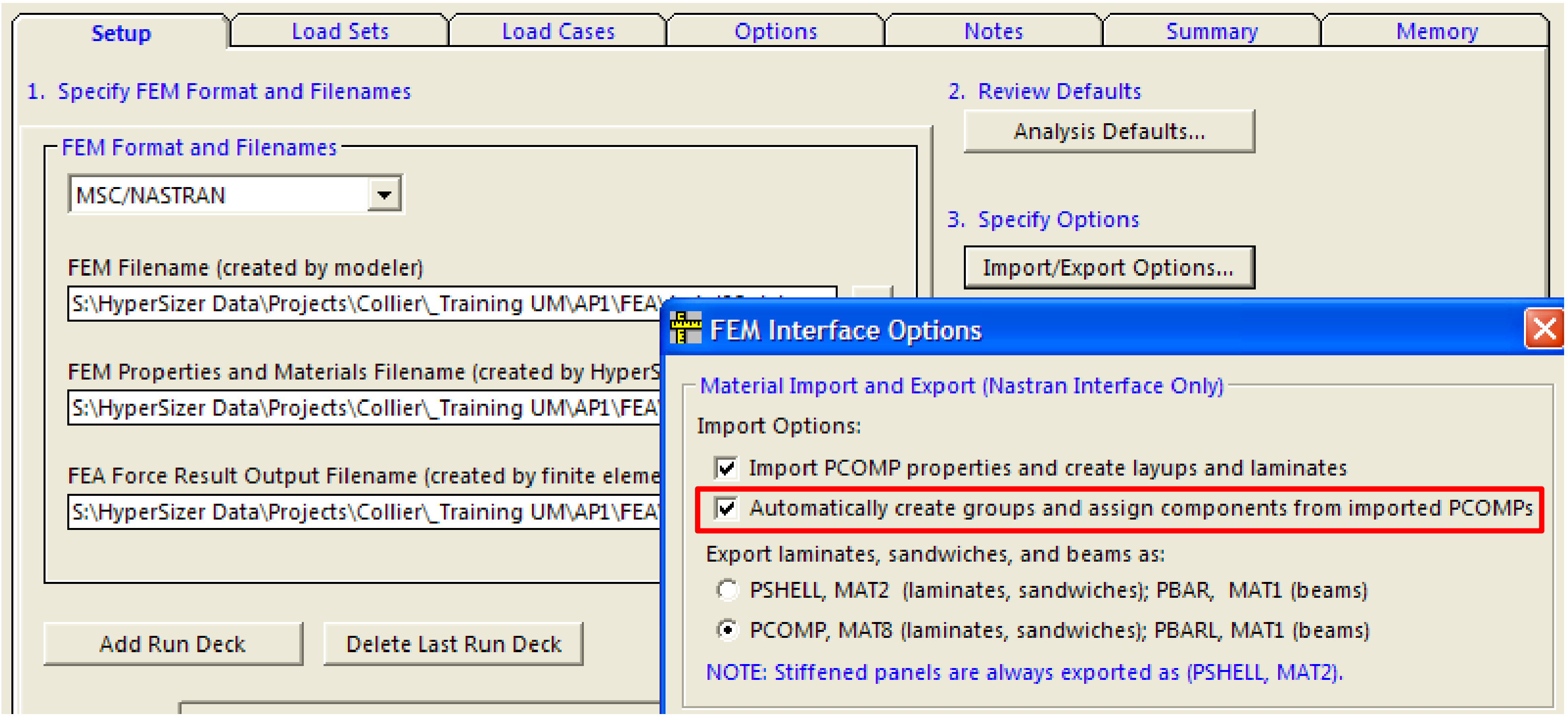


Step 2a: Select the PCOMP Import Option on the Project Setup Form



- The first flag to turn on is “Import PCOMP properties and create layups and laminates”. This flag tells HyperSizer to read the PCOMPs from the FEM and create layup and laminate materials in the database.

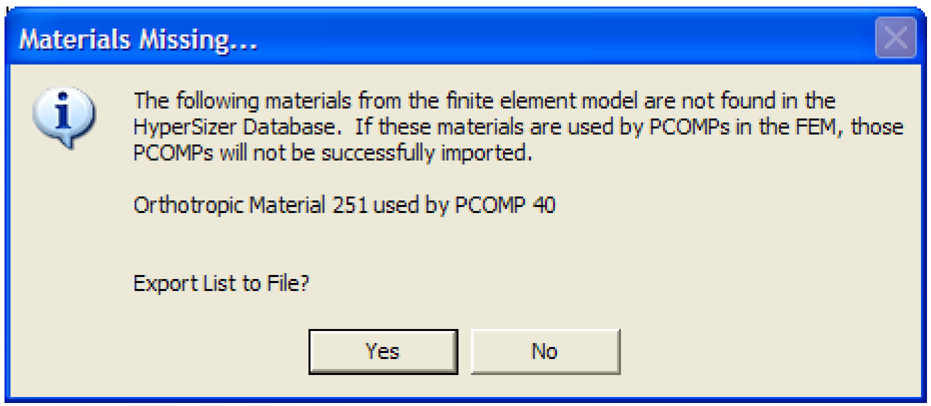
Step 2b: Select the PCOMP Import Option on the Project Setup Form



- **The second flag to activate, “Automatically create groups and assign components from imported PCOMPs”, tells HyperSizer that for every PCOMP imported from the FEM, create a Sizing Group and assign the Component corresponding to the imported PCOMP into that group. Every group created in this way will have exactly one component.**

Step 3: Import the FEM

- HyperSizer will read PCOMPs and create appropriate laminates and layups based on the PCOMP definition.
- If materials are in the FEM that do not have corresponding materials in HyperSizer, the following message will be displayed



- In this example, no material with ID = KMAT8%251 exists in the HyperSizer database, therefore this message tells us that a material needs to be created to complete the laminate for component 40.
- If this occurs, the error is not fatal, however these missing materials must be manually applied to the created components after import is completed.

Step 4a: Open the Laminate Editor to view the generated composite laminates

During import into HyperSizer, for the following PCOMP, as defined in the FEM, laminates and layups will automatically be created that contain the ply sequence, materials and thicknesses

```
MAT8*                   450   .233502500E+08   .165047100E+07   .320000000E+00
*          .749818700E+06   .749818700E+06   .629441600E+06   .148550725E-03
*         -.100000000E-06   .150000000E-04   .720000000E+02
*
MAT8*                   560   .100000000E-03   .100000000E-03   .333330000E+00
*          .100000000E-03   .170000000E+05   .430000000E+05   .615424431E-05
*          .000000000E+00   .000000000E+00   .720000000E+02
*

PCOMP          39                     .149E+03    HOFF     72.0
+              450    .0050   45.000              450    .0050 -45.000
+              450    .0050     .000              450    .0050  90.000
+              450    .0050     .000              450    .0050  90.000
+              450    .0050   45.000              450    .0050 -45.000
+              450    .0050     .000              450    .0050    .000
+              450    .0050  -45.000              450    .0050  45.000
+              450    .0050   90.000              450    .0050    .000
+              450    .0050   90.000              450    .0050    .000
+              450    .0050  -45.000              450    .0050  45.000
+              560   2.5000     .000              450    .0050  45.000
+              450    .0050  -45.000              450    .0050    .000
+              450    .0050   90.000              450    .0050    .000
+              450    .0050   90.000              450    .0050  45.000
+              450    .0050  -45.000              450    .0050    .000
+              450    .0050     .000              450    .0050 -45.000
+              450    .0050   45.000              450    .0050  90.000
+              450    .0050     .000              450    .0050  90.000
+              450    .0050     .000              450    .0050 -45.000
+              450    .0050   45.000
```

Composite Ply Data

Core Data

Bottom Facesheet

Top Facesheet

2.5” Core Material with ID = 560

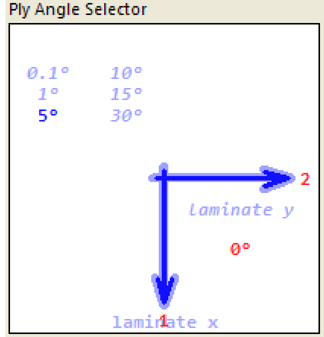
Step 4b: Open the Laminate Editor to view the generated composite laminates

From the PCOMP shown in Step 4a, two Laminate materials are created that represent the top and bottom faces of a honeycomb sandwich:

- Laminate (38)
  - Material Family "Collier Laminates" (6)
  - Material Family "Laminate Ply Angle Percentages" (28)
  - Material Family "User Laminates" (2)
  - Material Family "FEM Imported Materials" (2)
    - PCOMP 39 (bottom face) [Laminate]
    - PCOMP 39 (top face) [Laminate]

The top face laminate looks like this:

Ply Angle Selector



Definition Name

PCOMP 39 (bottom face) [Laminate]

Definition Description

Composite created from sandwich lower facesheet of PCOMP 39

Material List (Foams, Honeycombs, Isotropics, and Orthotropics)

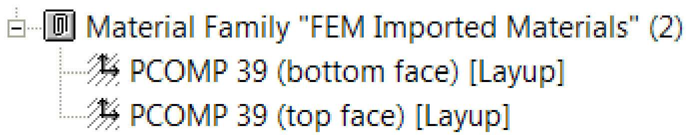
[O-1] Graphite/Epoxy "IM7/8552_Tape, KMAT8%450", Form: Tape, Sp

Ply Sequence Top to Bottom

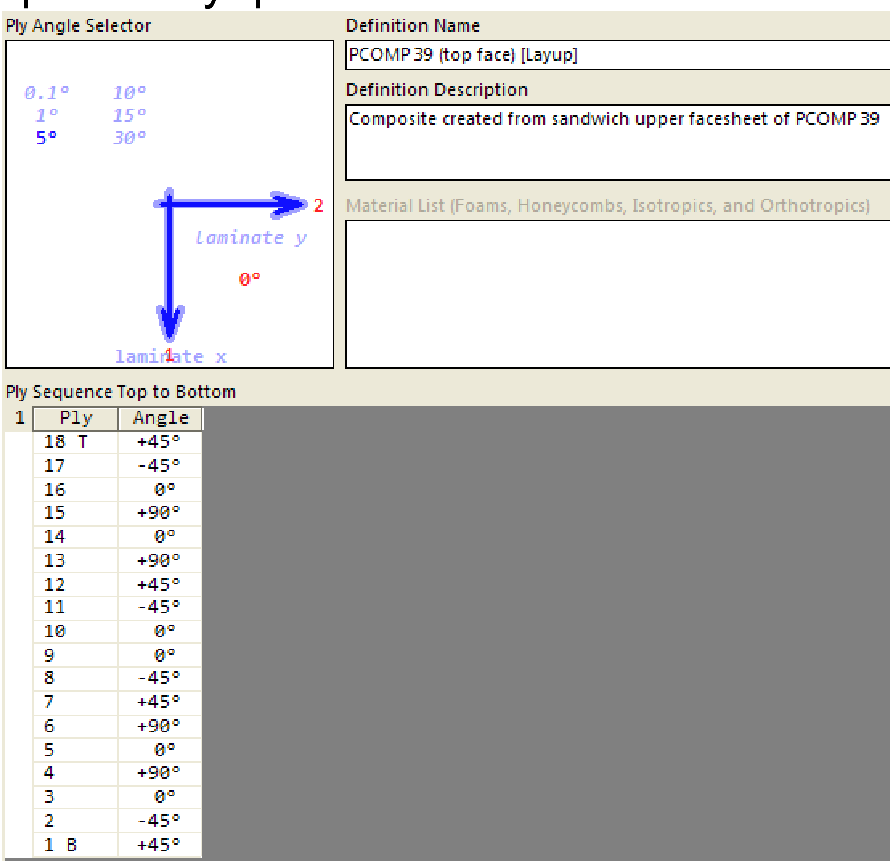
1 Ply	Angle	Thickness	Density	Material
18 T	+45°	0.005	0.0574	[O-1] Graphite/Epoxy "IM7/8552_Tape, KMAT8%450",
17	-45°	0.005	0.0574	[O-1] Graphite/Epoxy "IM7/8552_Tape, KMAT8%450",
16	0°	0.005	0.0574	[O-1] Graphite/Epoxy "IM7/8552_Tape, KMAT8%450",
15	+90°	0.005	0.0574	[O-1] Graphite/Epoxy "IM7/8552_Tape, KMAT8%450",
14	0°	0.005	0.0574	[O-1] Graphite/Epoxy "IM7/8552_Tape, KMAT8%450",
13	+90°	0.005	0.0574	[O-1] Graphite/Epoxy "IM7/8552_Tape, KMAT8%450",
12	+45°	0.005	0.0574	[O-1] Graphite/Epoxy "IM7/8552_Tape, KMAT8%450",
11	-45°	0.005	0.0574	[O-1] Graphite/Epoxy "IM7/8552_Tape, KMAT8%450",
10	0°	0.005	0.0574	[O-1] Graphite/Epoxy "IM7/8552_Tape, KMAT8%450",
9	0°	0.005	0.0574	[O-1] Graphite/Epoxy "IM7/8552_Tape, KMAT8%450",
8	-45°	0.005	0.0574	[O-1] Graphite/Epoxy "IM7/8552_Tape, KMAT8%450",
7	+45°	0.005	0.0574	[O-1] Graphite/Epoxy "IM7/8552_Tape, KMAT8%450",
6	+90°	0.005	0.0574	[O-1] Graphite/Epoxy "IM7/8552_Tape, KMAT8%450",
5	0°	0.005	0.0574	[O-1] Graphite/Epoxy "IM7/8552_Tape, KMAT8%450",
4	+90°	0.005	0.0574	[O-1] Graphite/Epoxy "IM7/8552_Tape, KMAT8%450",
3	0°	0.005	0.0574	[O-1] Graphite/Epoxy "IM7/8552_Tape, KMAT8%450",
2	-45°	0.005	0.0574	[O-1] Graphite/Epoxy "IM7/8552_Tape, KMAT8%450",
1 B	+45°	0.005	0.0574	[O-1] Graphite/Epoxy "IM7/8552_Tape, KMAT8%450",

Step 4c: Open the Laminate Editor to view the generated composite layups

In addition to the Laminates, two Layup Materials are created:



The top face layup looks like this:



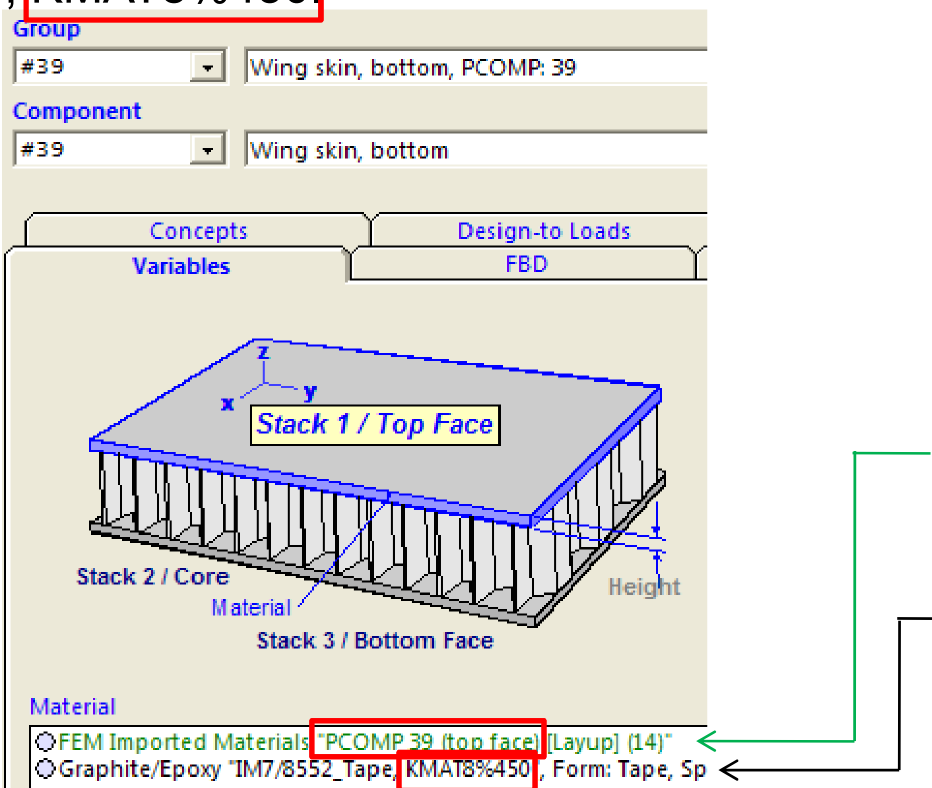
A HyperSizer "Layup" material type is a ply sequence without an associated orthotropic material. Layups are useful for sizing structures where combinations of layups and ply materials can be evaluated to get an optimal design.

The PCOMP import process creates both layup and laminate materials to give the user the choice of the most convenient modeling technique.

Step 5a: Open the Sizing form to analyze the components and obtain margins-of-safety

A Group/Component will be created in HyperSizer with the following layups/materials and dimensions:

First, the “Top Face” variable will contain the layup called “PCOMP 39 (top face) [Layup]” along with the orthotropic material created in Step 1, KMAT8%450.

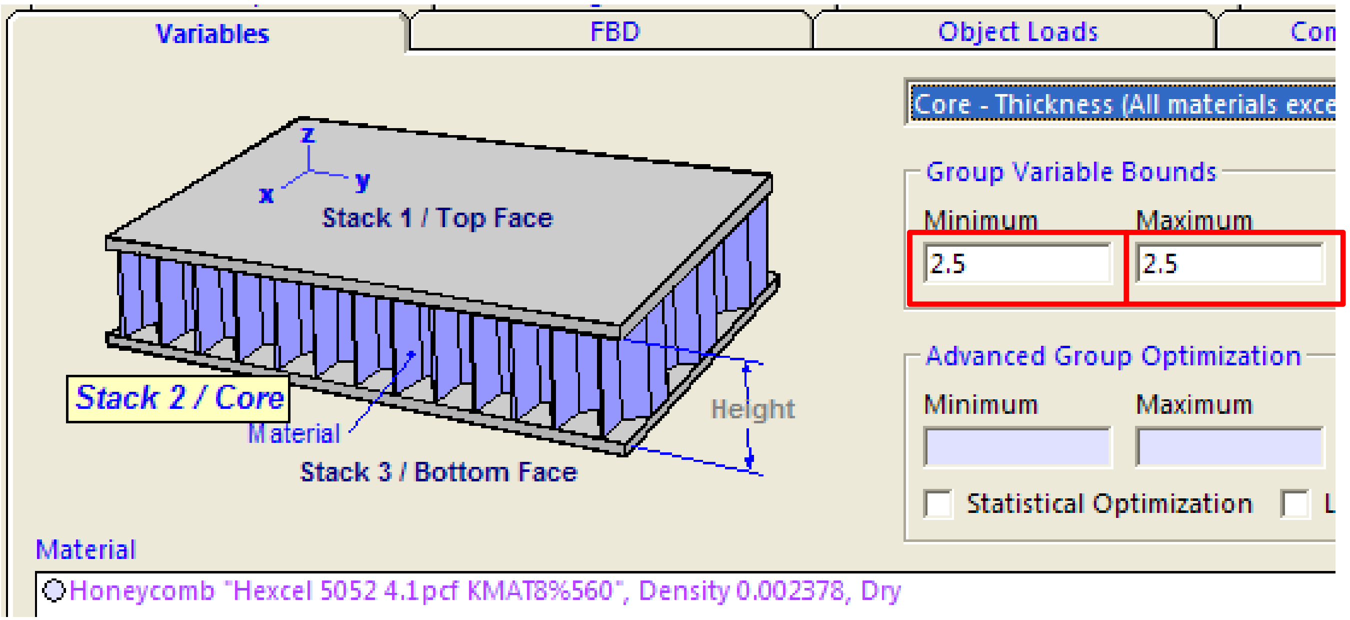


Green Color = HyperSizer Layup

Black Color = HyperSizer Orthotropic Ply Material

Step 5b: Open the Sizing form to analyze the components and obtain margins-of-safety

The “Core” variable will be filled out with the following material and dimension. Note the Minimum and Maximum dimensions are set to the thickness of the core from the PCOMP and the material included is the honeycomb material defined in step 1.

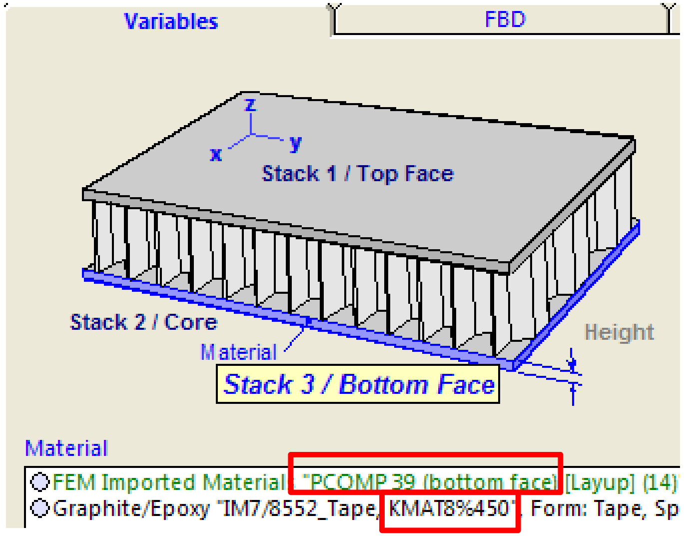


Core Thickness of 2.5“ as imported from the NASTRAN PCOMP

Purple Color = HyperSizer Honeycomb Material

Step 5c: Open the Sizing form to analyze the components and obtain margins-of-safety

Finally, the lower face variable contains a layup called "PCOMP 39 (bottom face) [Layup]" along with the same orthotropic material created in Step 1 (KMAT8%450).



Note here that the layup material included for the bottom face is not the same layup included for the top face. When the overall sandwich PCOMP was imported, it was split into two separate layups representing the top and bottom faces. The name of each layup indicates that it was created from PCOMP 39 with either "top face" or "bottom face" in parentheses. The KMAT8%450 orthotropic material is the same for both faces.

Creation of Honeycomb Sandwich Components, Notes slide 1

- While processing a PCOMP, HyperSizer analyzes each layer and if that layer is determined to be a honeycomb core, HyperSizer will treat this PCOMP as a honeycomb sandwich rather than as a bare laminate.
- Rules for determining if a layer is a honeycomb material:
  - The current layer is not the first or last layer in the PCOMP
  - The thickness of this layer is greater than ten times the thickness of the previous layer
  - The transverse shear stiffness (G1z) of the material of this layer is greater than the in-plane stiffness (E1) of this material. This should never happen for a composite ply material but is very common for a honeycomb which has very little in-plane stiffness.

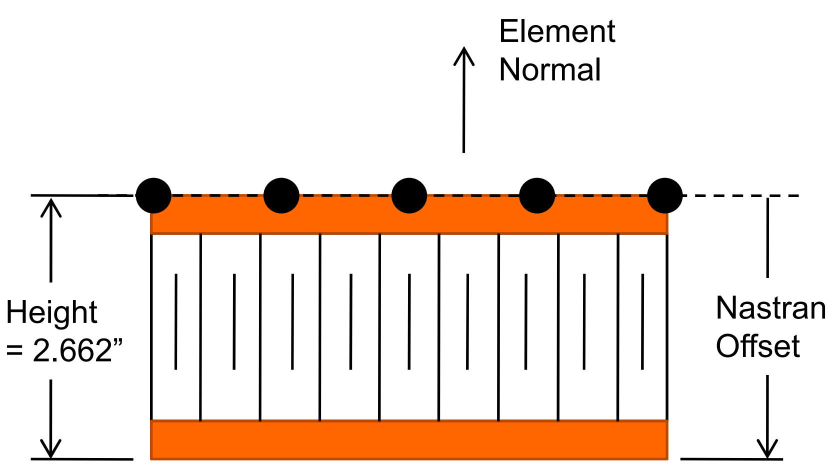
Creation of Honeycomb Sandwich Components, Notes slide 2

- If all of these rules are satisfied, HyperSizer splits the PCOMP into three separate objects when importing into HyperSizer.
  - All layers above the core (layers i+1 through N) will be treated as a “Top Face” laminate.
  - All layers below the core (layers 1 through i-1) will be treated as a “Bottom Face” laminate.
  - The current layer (layer i) will be used as the core object in HyperSizer.
- After sizing, HyperSizer will “re-assemble” the honeycomb back into a single PCOMP and MAT8 combination when exporting to the *.PM1 file for iteration with FEA.

Import of NASTRAN Offsets, Notes Slide 3

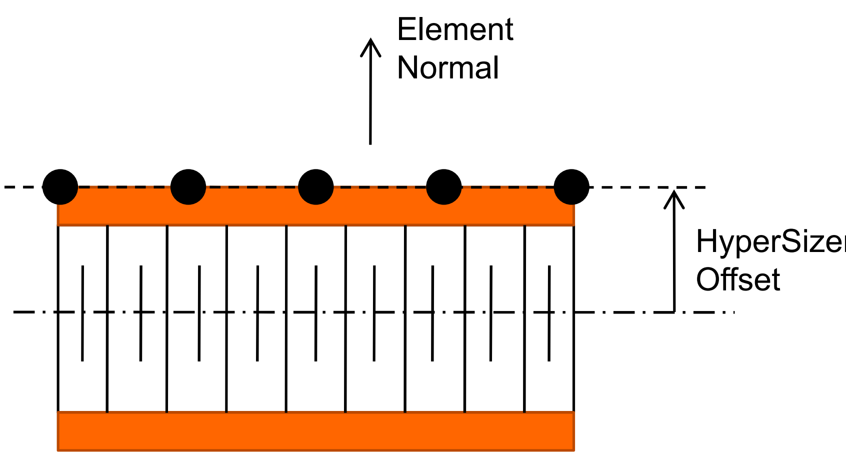
The NASTRAN offset is defined FROM the grid point TO the bottom surface of the laminate.   In the examples shown here, where grid points are defined on the OML, the Nastran Offset is equal to negative overall thickness.

Nastran Offset = -2.662



The HyperSizer offset is defined FROM the default reference plane TO the grid points. For laminates or sandwiches, the default reference plane is the mid-plane. Therefore, the offset will be positive overall thickness divided by two.

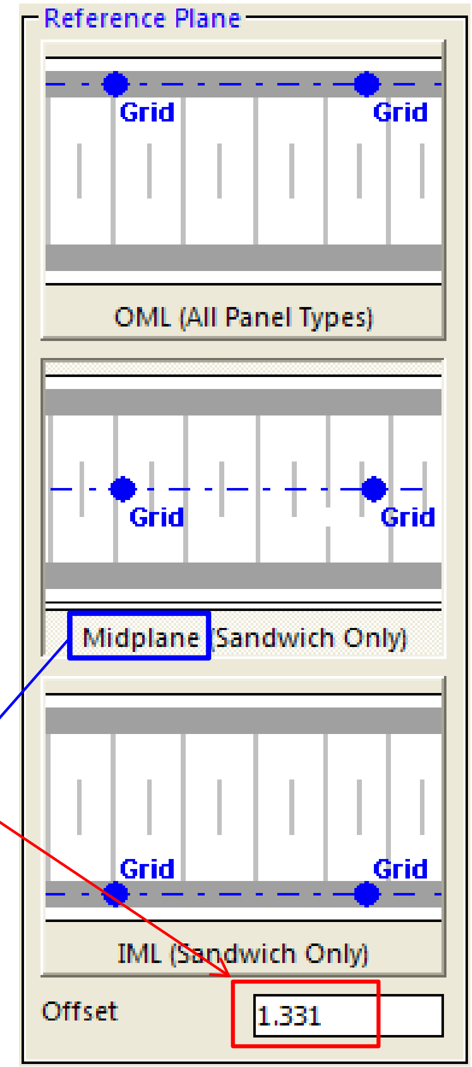
HyperSizer Offset = +1.331



Import of NASTRAN Offsets, Notes Slide 4

HyperSizer reads the offsets from the PCOMP card and automatically converts the offset from NASTRAN format to HyperSizer format.

```
PCOMP          40  -2.662.288E-05.149E+03    HOFF    72.0
+             250   .0081  45.000             250   .0081     .000
+             250   .0081  45.000             250   .0081   45.000
+             250   .0081  45.000             250   .0081   45.000
+             250   .0081  45.000             250   .0081   45.000
+             250   .0081    .000             250   .0081   45.000
+             560  2.5000    .000             250   .0081   45.000
+             250   .0081    .000             250   .0081   45.000
+             250   .0081  45.000             250   .0081   45.000
+             250   .0081  45.000             250   .0081   45.000
+             250   .0081  45.000             250   .0081     .000
+             250   .0081  45.000
```



The imported offset can be viewed on the Options tab of the Sizing form.   For the shown example, the NASTRAN offset of -2.662" is converted to a HyperSizer offset of 1.331“, (** as paired with the selection of panel midplane as reference plane)

Note that offsets on individual element cards are not considered, only offsets on PCOMP cards are read and converted on the Sizing form.

Limitations

- Import of PCOMP/MAT8 into HyperSizer layups/laminates and group creation works only for Honeycomb or solid laminates. If a component is to be defined as a stiffened panel (uniaxial, hat, orthogrid, etc.), this import method will not work.
- If the property in NASTRAN is defined with a PSHELL/MAT1 or PSHELL/MAT2, then no material, laminate, layup or group will be created.
- If a material has not been created in HyperSizer with the KMAT% designation required for a PCOMP, then HyperSizer will create a "Layup" material (ply sequence with no material), however HyperSizer will not attempt to create a "Laminate" material (ply sequence with materials)

Limitations

- If a PCOMP contains multiple composite materials or a combination of composite and metallic materials (i.e. a hybrid laminate), then a "Laminate" material is created and assigned to the created group. However, no "Layup" material is created. For a hybrid laminate, if a MAT8% or MAT1% required material is missing from the HyperSizer database, then no laminate or layup will be created.
- MAT8 or MAT1 cards that are not used by PCOMP or PBARL cards in the FEM will be ignored by HyperSizer.
- Reference plane offsets that are defined on element cards will be ignored by HyperSizer. HyperSizer will only consider offsets if they are defined on the PCOMP cards.

IMPORT PROCESS FOR PBARL BEAM GEOMETRY AND MAT1 MATERIALS FROM THE FEM

Steps for Importing PBARLs with MAT1 Materials into HyperSizer

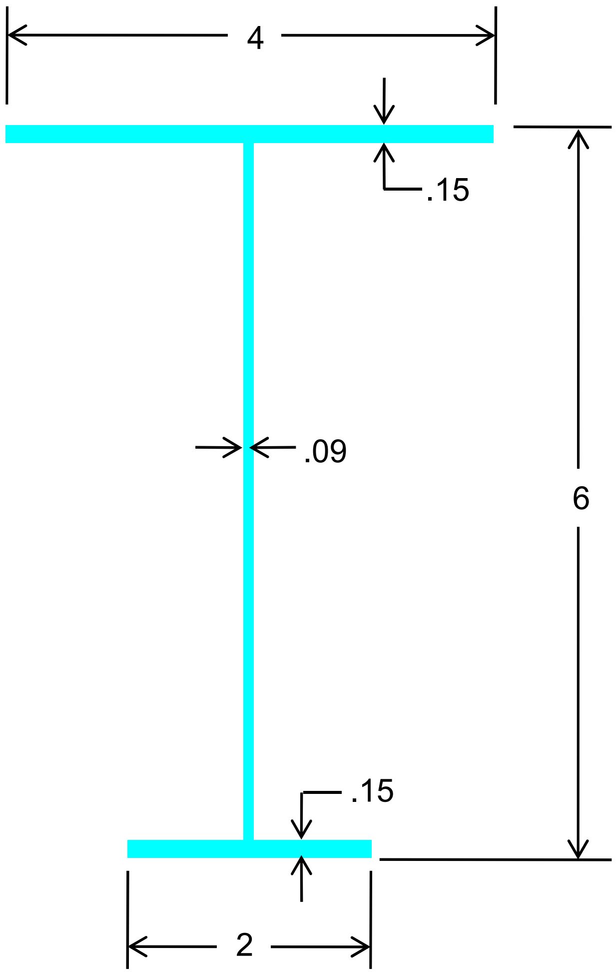
The process of importing the PBARL is similar to the import of PCOMPs. However no laminates or layups are created, so examining imported layups is not included here.

1. Create Materials in the HyperSizer Database corresponding to MAT1 cards in the FEM
2. Select the PCOMP/PBARL Import Options on the Project Setup Form
3. Import the FEM
4. Open the Sizing form to analyze the components and obtain margins-of-safety

Each step will be discussed on the following slides

Example problem to illustrate PBARL import process

The example problem is a metallic I-Beam where the upper and lower flange and web thicknesses and widths are all independent.




```
$ Al 7075 Room Temperature Property
MAT1            180  .104E+8    .4E+7                   0.  .123E-4   .70E+2
```

```
$ I-Beam Ringframe
PBARL             18        180  MSCBML0        I
+                6.0        2.0       4.0      .09      .15      .15 .369E-3
```

Height	=	6.0"
Bottom Flange Width	=	2.0"
Top Flange Width	=	4.0"
Web Thickness	=	0.09"
Bottom Flange Thickness	=	0.15"
Top Flange Thickness	=	0.15"

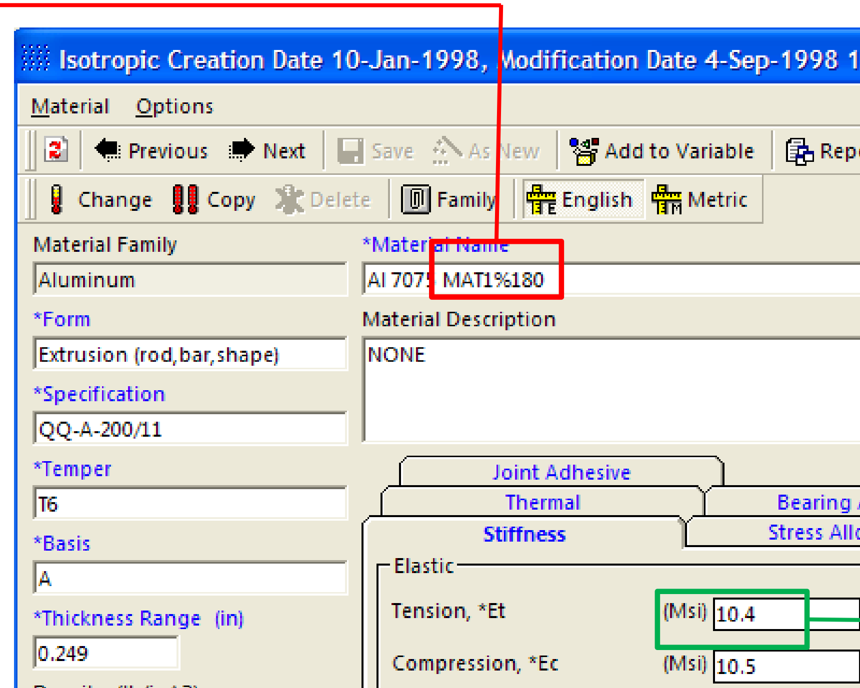
Step 1a: Create Materials in the HyperSizer Database corresponding to FEM MAT1 and MAT8 cards in the FEM

For every MAT1 card in the FEM, create a material in the HyperSizer database and at the END of the material name, append the string KMAT1%<MATID>

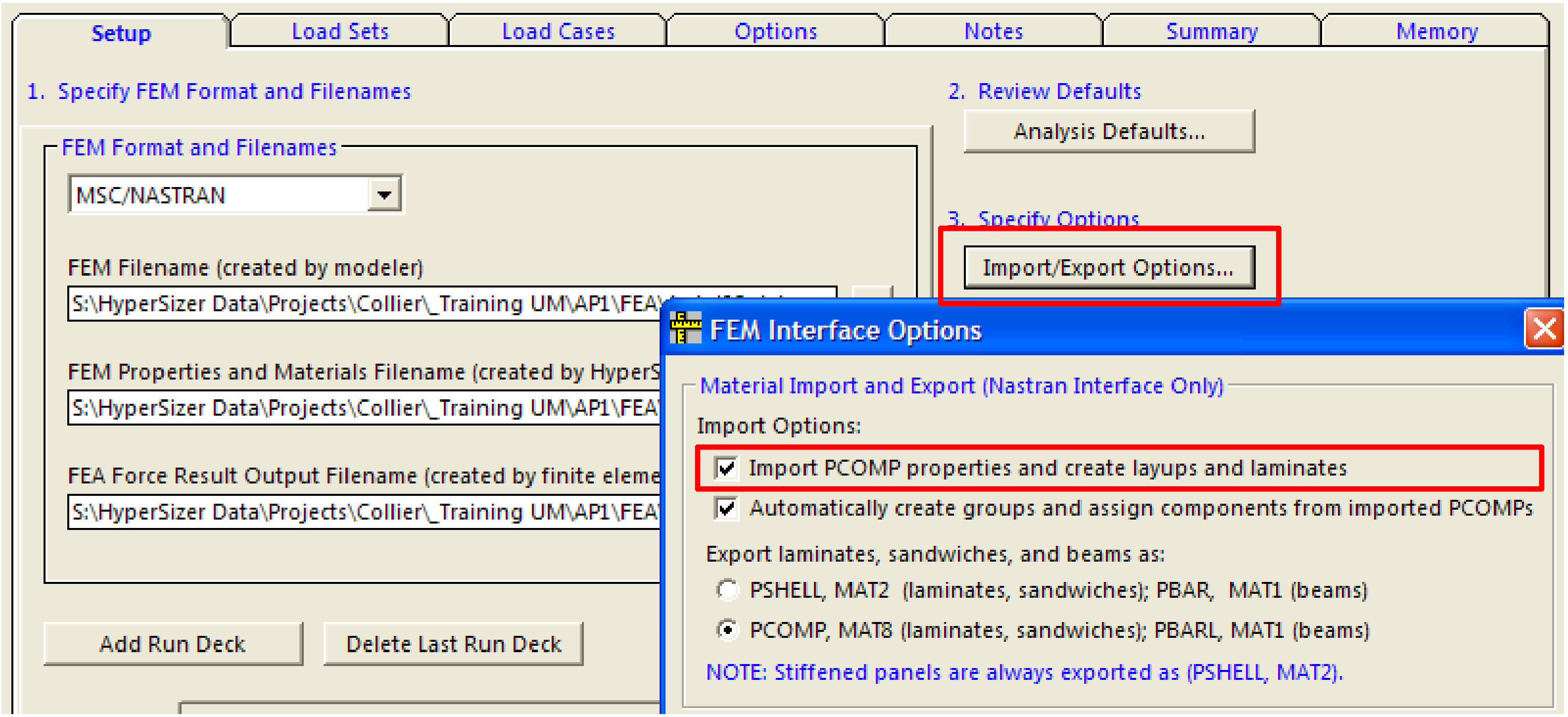
For example, the following MAT1 card has MATID=180,

```
$ Al 7075 Room Temperature Property
MAT1          180 .104E+8   .4E+7              0.  .123E-4  .70E+2
```

Create a material in the HyperSizer database. The material name is arbitrary, but it must end with "KMAT1%180" in order to establish the association between the HyperSizer material and the NASTRAN material.

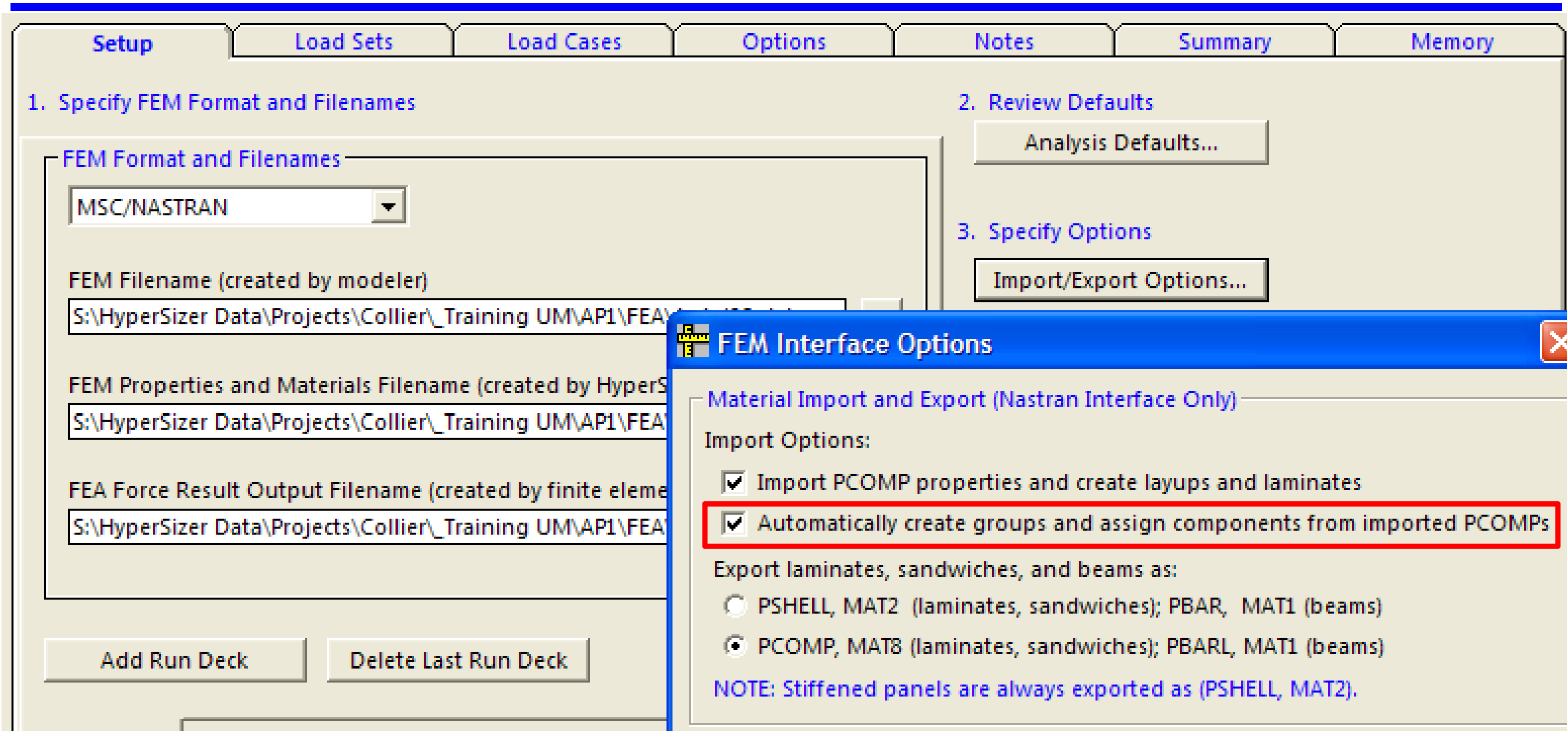


Step 2a: Select the PCOMP/PBARL Import Option on the Project Setup Form



- The first flag to turn on is "Import PCOMP properties and create layups and laminates". Although the checkbox label only mentions PCOMPs, this flag also tells HyperSizer to read the MAT1 cards from the FEM and associate these materials to HyperSizer Isotropic materials.

Step 2b: Select the PCOMP/PBARL Import Option on the Project Setup Form

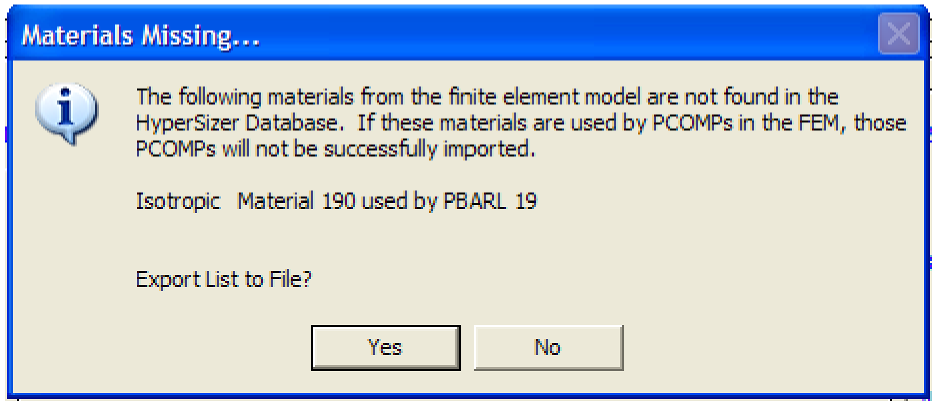


- The second flag to activate, “Automatically create groups and assign components from imported PCOMPs” *, tells HyperSizer that for every PBARL imported from the FEM, create a Sizing Group and assign the component corresponding to the imported PBARL into that group. Every group created in this way will have exactly one component.

* Although the checkbox mentions only PCOMPs, this same checkbox also controls the import of PBARL cards

Step 3: Import the FEM

- **If materials are in the FEM that do not have corresponding materials in HyperSizer, the following message will be displayed**

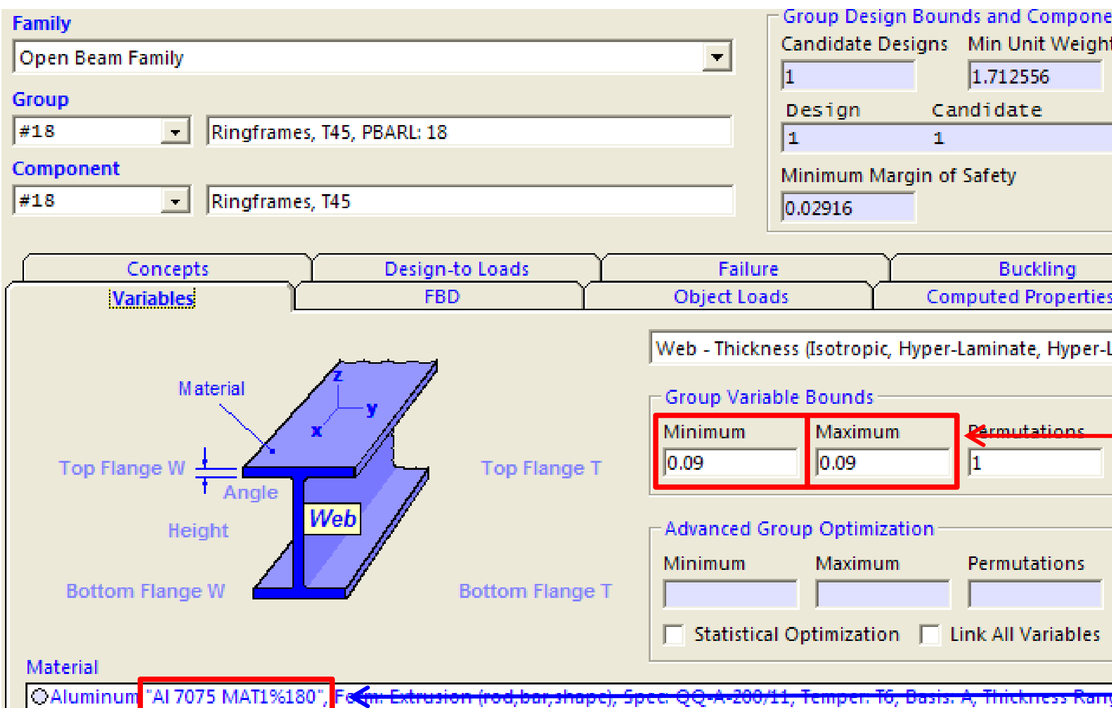


- **In this example, no material with ID = KMAT1%190 exists in the HyperSizer database, therefore this message tells us that a material needs to be created to complete the definition of component 19.**
- **If this occurs, the error is not fatal, however these missing materials must be manually applied to the created components after import is completed.**

Step 4a: Open the Sizing form to analyze the components and obtain margins-of-safety

A Group/Component will be created in HyperSizer with the following materials and dimensions:

First, the "Web" variable will contain the isotropic material created in Step 1, KMAT1%180. The web thickness minimum and maximum values are set to 0.09" as spelled out in the PBARL card and the number of permutations is set to 1.

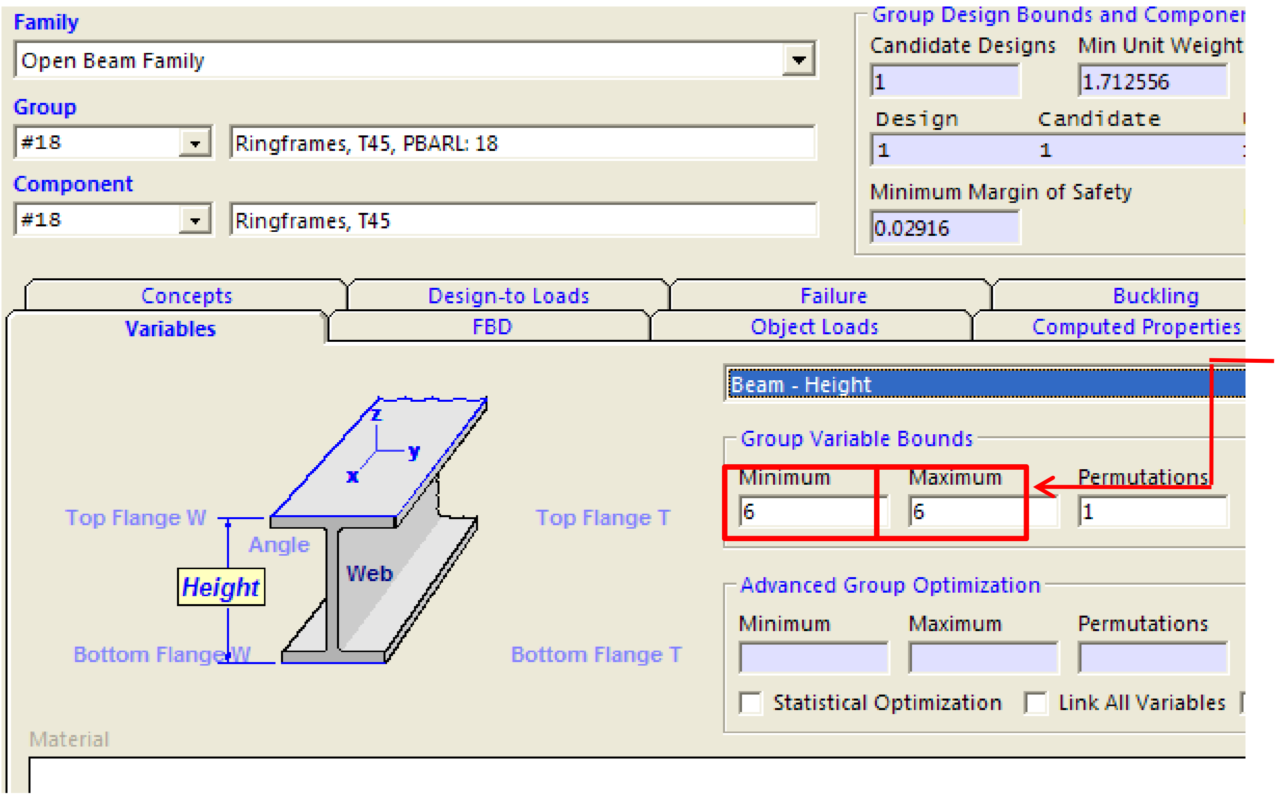


Web Thickness of 0.09" as imported from the NASTRAN PBARL

Blue Color = HyperSizer Isotropic Material

Step 4b: Open the Sizing form to analyze the components and obtain margins-of-safety

The “Beam Height” variable will be filled out with the dimensions from the Height Dimension (DIM1) from the PBARL card. Note the Minimum and Maximum dimensions are both set to this dimension and the number of permutations is set to 1.



Beam Height of 6" as imported from the NASTRAN PBARL

The other dimensions of the beam component are set to those imported from the PBARL in the same way.

Limitations

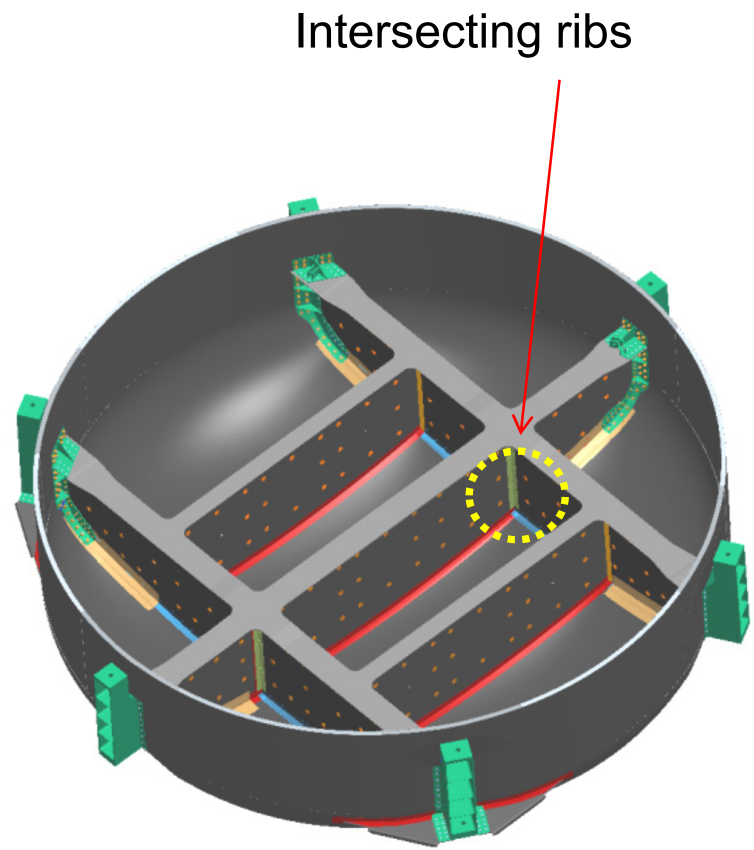
- Import of PBARL/MAT1 for group creation works only for beam concepts that are included in HyperSizer. For example, if geometry type of the PBARL is “HEXA”, which is not a beam type in HyperSizer, this PBARL will not be imported.
- If the property in NASTRAN is defined with a PBAR instead of a PBARL then no material, layup or group will be created.
- MAT1 cards that are not used by PCOMP or PBARL cards will be ignored

Advanced Example: Modeling a Hybrid Metallic/Composite Bonded Joint with HyperSizer and FEA

Problem Definition: Modeling a Bonded Joint in the Loads ‘Master’ FEM

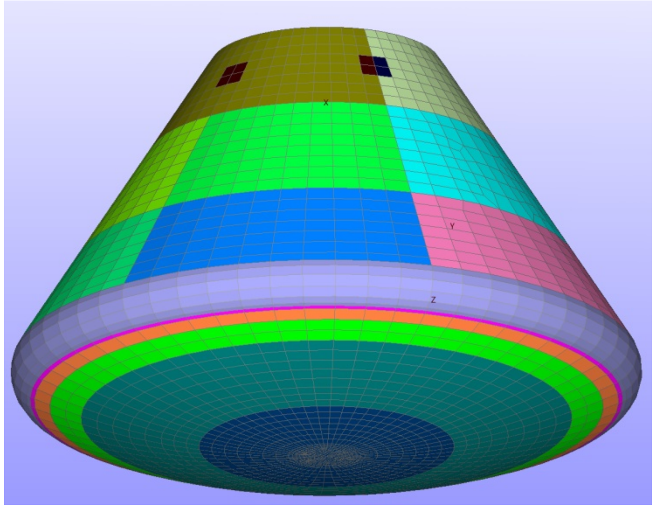
- The challenge is getting the proper stiffness and load path eccentricity (plate offsets) of a metallic/composite laminate bonded joint
- The following techniques apply to all adhesive joints or bonded doublers
- This particular example is a clevis type joint in the NASA Crew Module. The location is the intersecting ribs of the backbone known as the cruciform joint. The ribs are composite honeycomb sandwich.
- There are two primary different ways to model the joint with FEA. HyperSizer can quickly generate the data for both.
  - 1) Single plane of shell elements to model entire sandwich panel
  - 2) Two planes of shell elements to model facesheets, and a solid element to model sandwich core

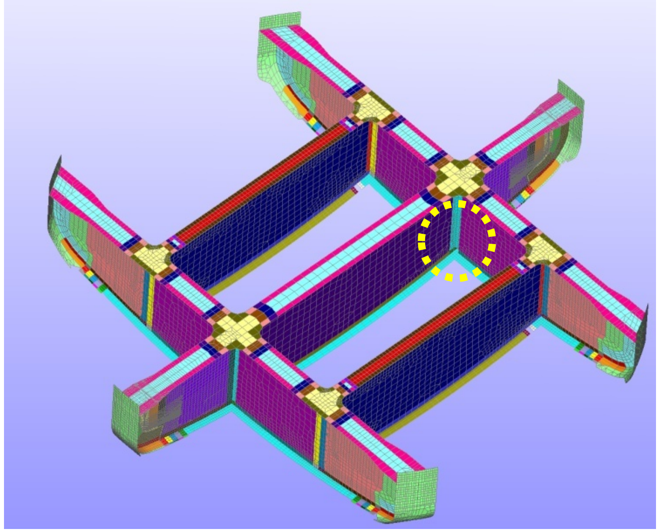
NASA Astronaut Crew Module, Composite Materials



The CCM ‘Loads’ FEM

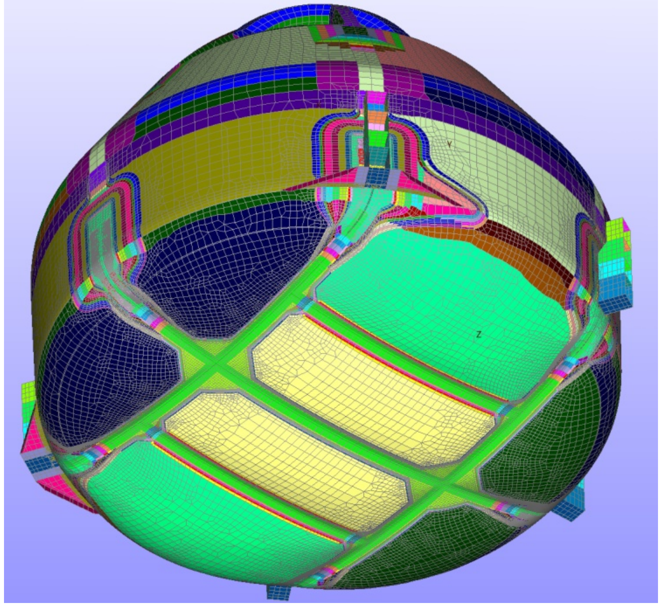
1) External Aeroshell

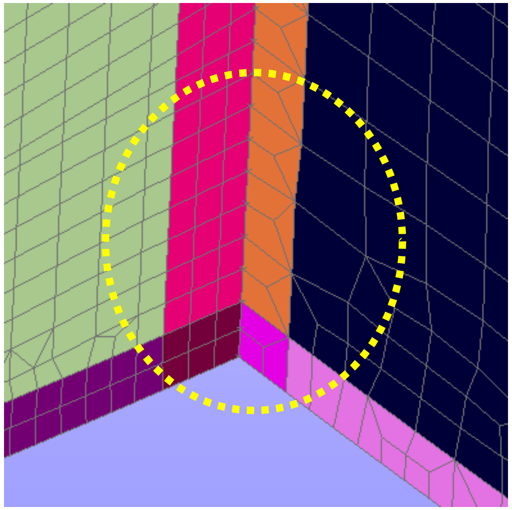




3) Backbone Ribs are composite honeycomb sandwich

2) Internal Pressure Shell

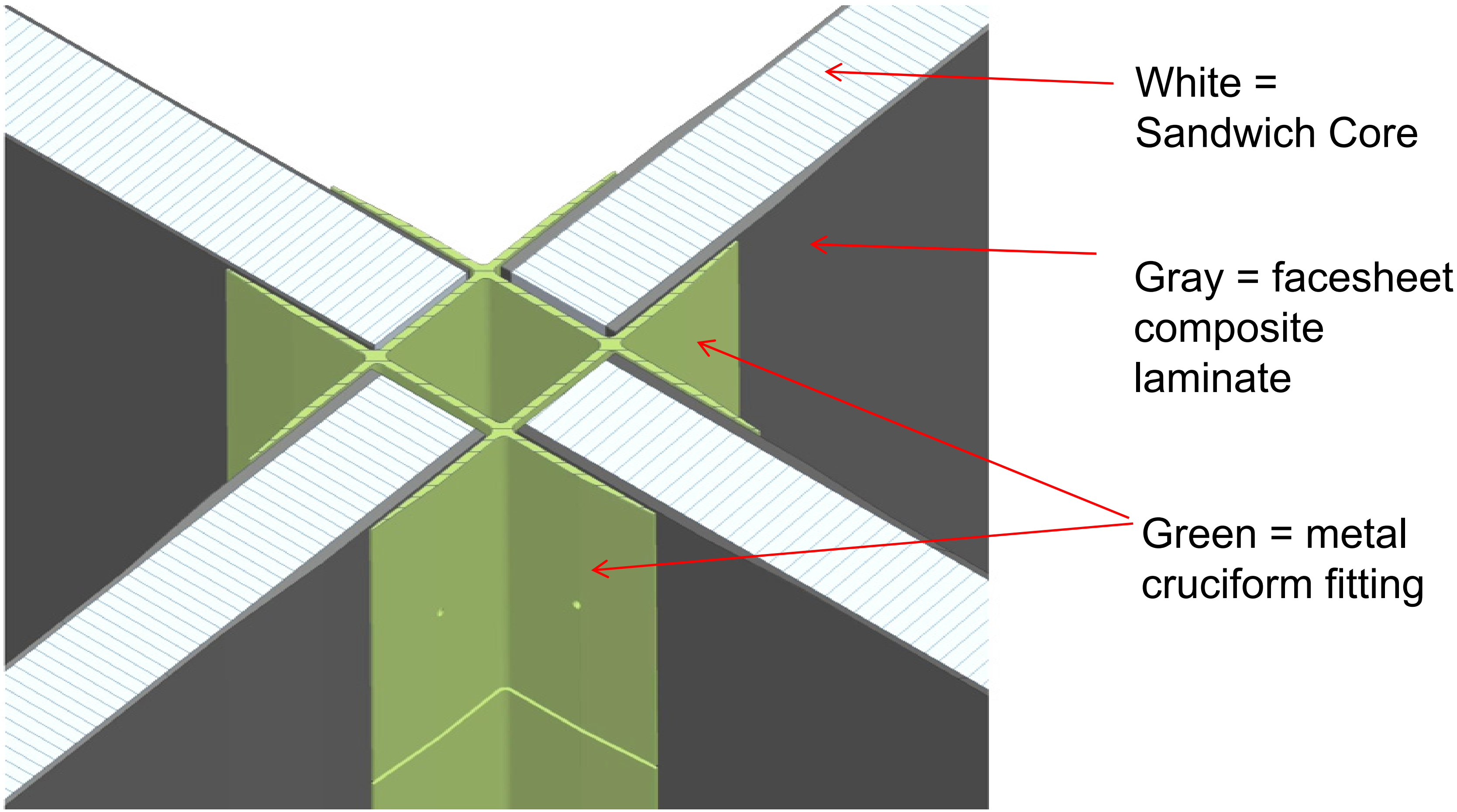




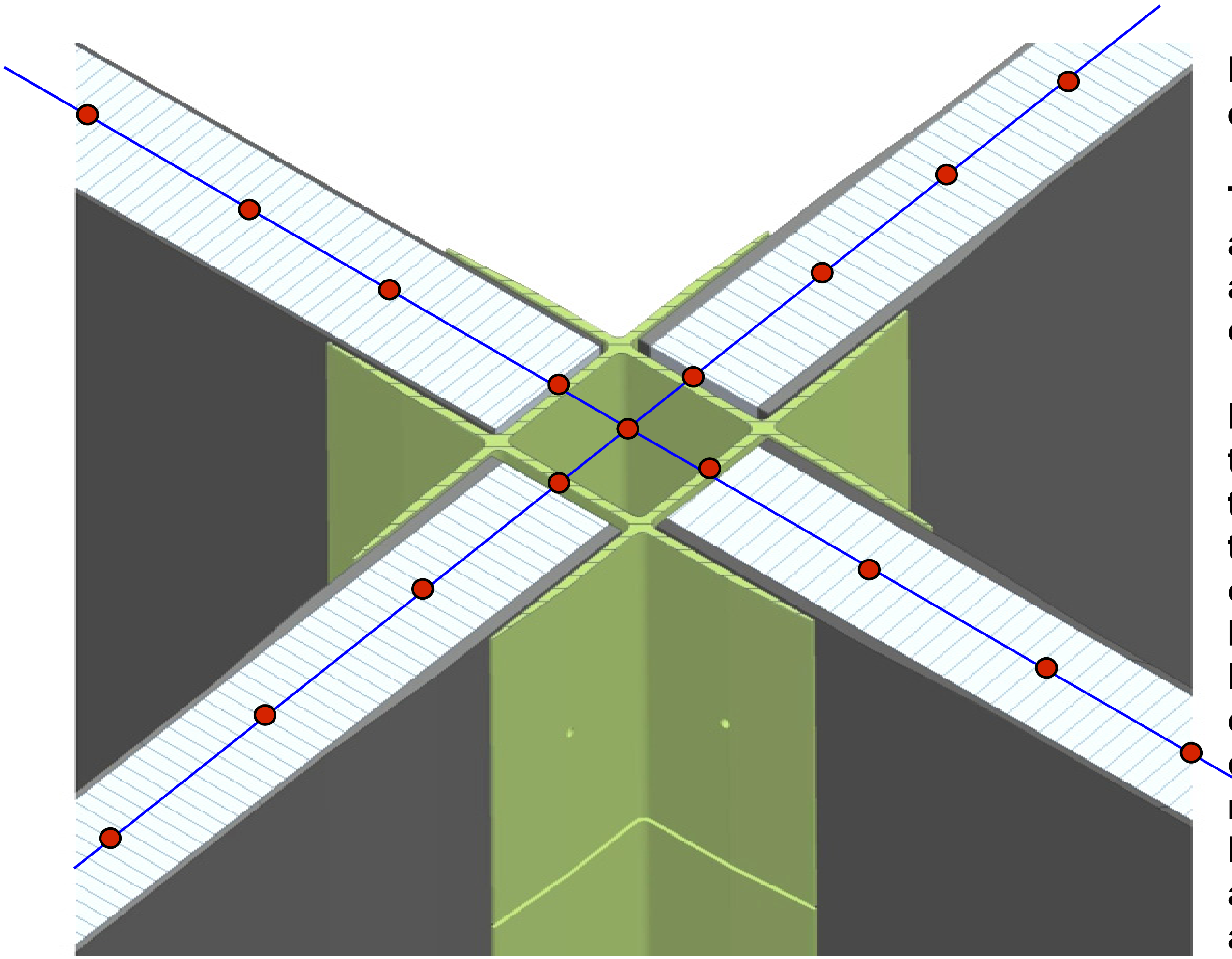
4) Mesh size in area of interest. Single plane of elements for each rib. Each color is a different FEM property.

Problem Definition: Modeling a Bonded Joint in the Loads 'Master' FEM

Intersecting Webs Bonded to Cruciform Metal Fitting



Approach 1: Single Plane Modeling a Bonded Joint in the Loads 'Master' FEM



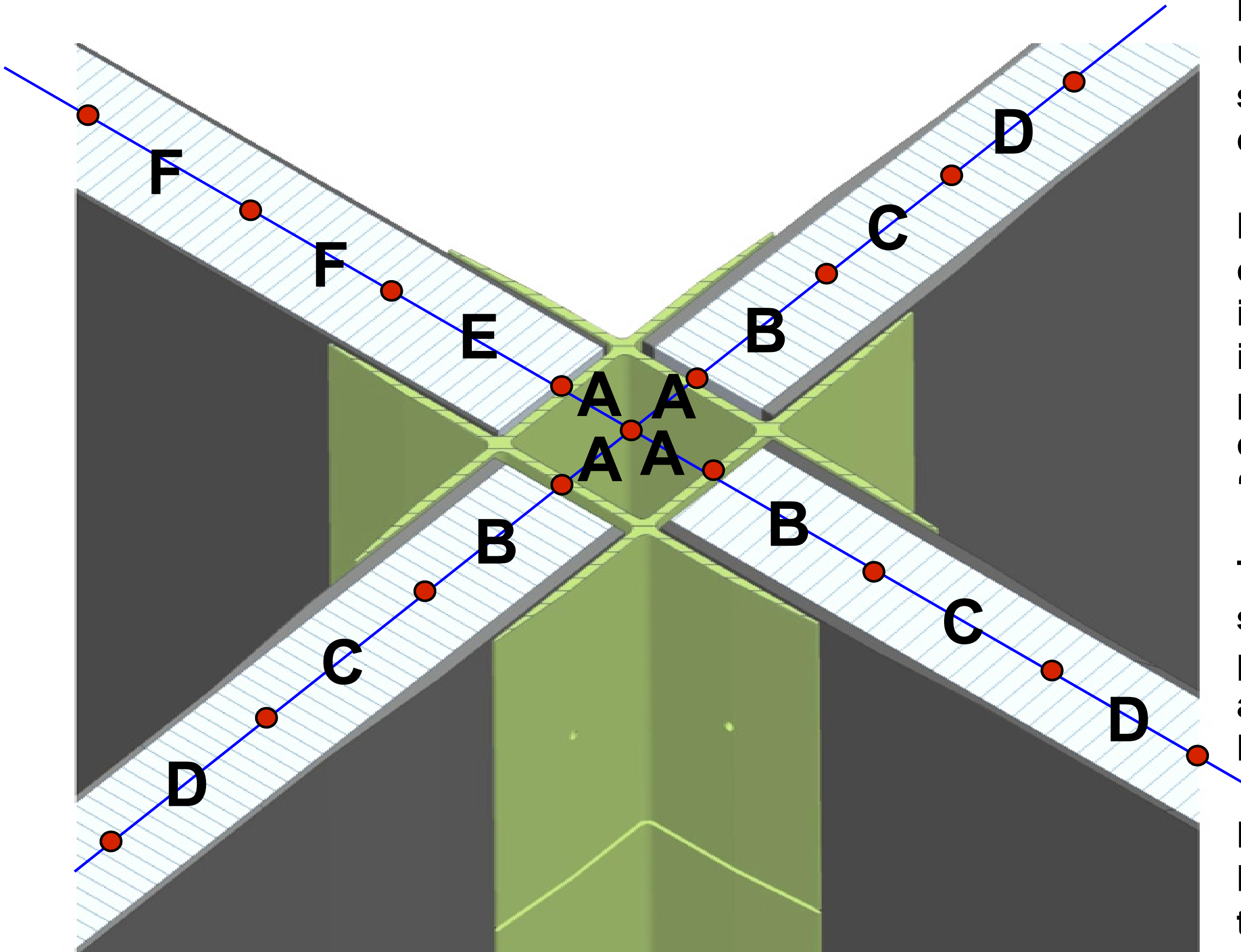
Red Circle = grid

Blue Line = edge of shell element

The complete stack of core and the two facesheet bonds are modeled in the FEM as one plane of shell elements

No eccentricity is captured in this modeling approach due to load path joggles such as that caused by the plate offset of the facesheet and bonded metal fitting. However, HyperSizer will capture this effect and quantify the induced bending moments. As such, with HyperSizer coupling, this is an efficient and accurate approach.

Approach 1: Single Plane Modeling a Bonded Joint in the Loads 'Master' FEM



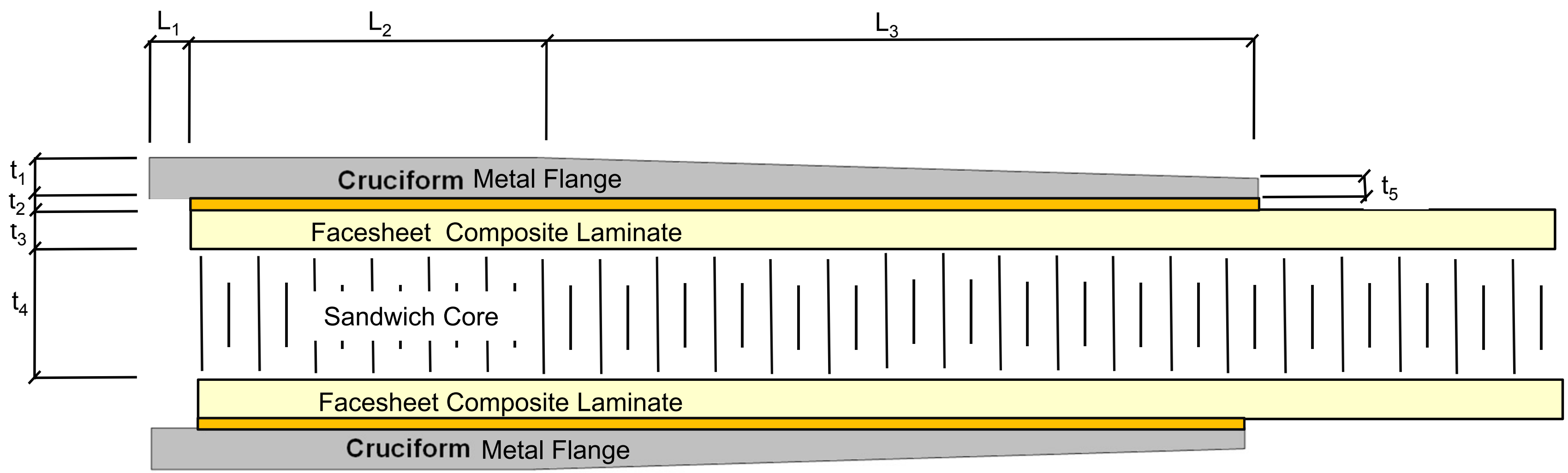
Each letter represents a unique FEM property and a separate HyperSizer component.

Property A captures the compliance (softness) of the internal metal box, which is important in getting the proper load path distribution computed with the global 'loads' FEM.

Three of the ribs are the same and share the same properties. One rib is thinner and has separate properties E and F.

Properties B and E use a hybrid laminate to represent the bonded composite facesheet and metal joint, shown next

All Possible Material Selections and Dimensions are Available as HyperSizer Sizing Variables for the Bonded Joint



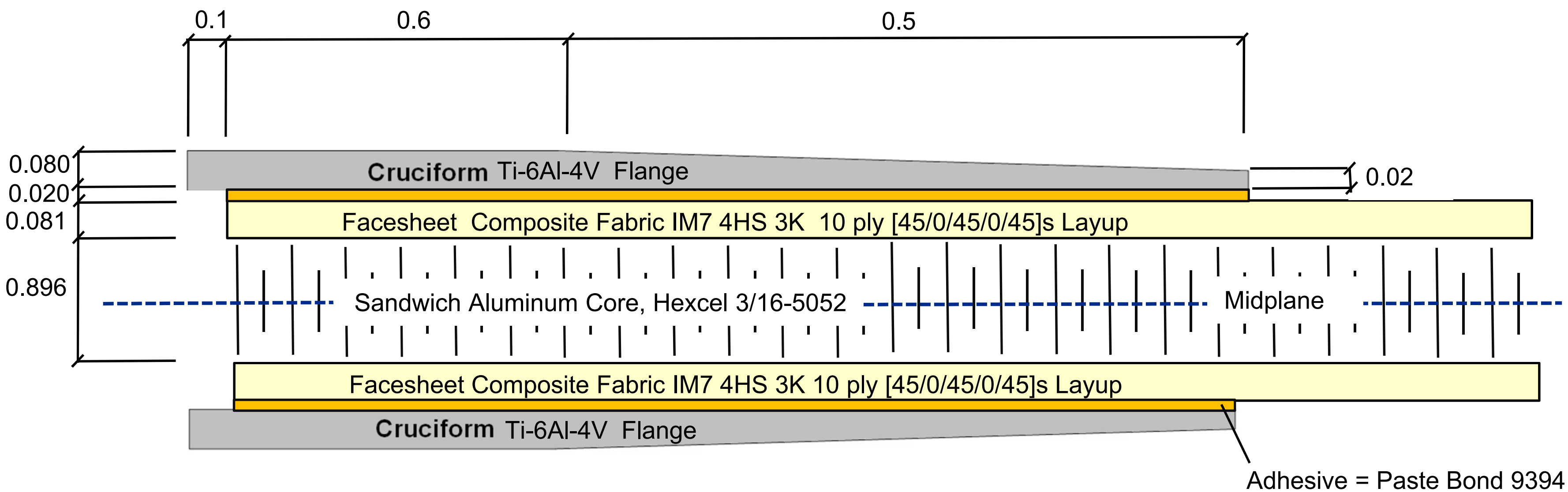
- 5 thickness variables
- 3 length variables
- 4 material variables (cruciform flange, adhesive, composite ply, and core)
- 1 variable for the layup
- <u>13 unique variables that can be optimized simultaneously</u>

The Composite/Metal Adhesively Bonded Joint is Modeled with one NASTRAN PCOMP

- The 13 unique sizing variables for the clevis bonded joint can generate a wide spectrum of design alternatives
- The goal is to accurately and efficiently represent all of the possible design alternatives with a NASTRAN PCOMP
- The NASTRAN PCOMP can be either
  - 1st defined in the FEM and then imported into HyperSizer
  - 1st defined in HyperSizer and then exported to the FEM
- In either case, the PCOMP is be modified by HyperSizer during sizing optimization and exported to the FEM for computing updated loads

As Fabricated and Tested Design

Not to scale, Units = inch



- The ‘loads’ FEM has one property (Property ‘B’) to define the 1.2” cruciform length, therefore an average cruciform thickness of 0.065” is used. Since this data is not going into a stress model, but rather a loads model, this is accurate. HyperSizer will then know and account for the actual taper of the metal flange.
- Note that the total Height = 1.226”, distance from midplane to OML = 0.614”
- All of these thicknesses, composite layup, and materials go directly into the NASTRAN PCOMP data, see next slide

As Fabricated and Tested Design
NASTRAN Imported and Exported PCOMP Data

```
$ Structural Component ID =    20013          material properties = TENSION
MAT1*                  30001   .162000000E+08  .620000000E+07  .306451613E+00
*             .414078675E-03   .490000000E-05  .720000000E+02  .000000000E+00
MAT1*                  30036   .610000000E+06  .230000000E+06  .326086957E+00
*             .517598344E-04   .123000000E-04  .720000000E+02  .000000000E+00
MAT8*                     59   .105300000E+08  .105300000E+08  .360000000E-01
*             .760000000E+06   .760000000E+06  .760000000E+06  .146092133E-03
*            -.100000000E-06   .150000000E-04  .720000000E+02  .947699900E+05
*             .789750000E+05   .947699900E+05  .789750000E+05  .228000000E+05
MAT8*                    510   .100000000E-03  .100000000E-03  .333330000E+00
*             .100000000E-03   .680000000E+05  .300000000E+05  .658902692E-05
*             .000000000E+00   .000000000E+00  .720000000E+02
*
PCOMP          20013  -.6140          .220E+03    HOFF    72.0
+              30001   .0650    .000               30036   .0200    .000
+                 59   .0081  45.000                  59   .0081    .000
+                 59   .0081  45.000                  59   .0081    .000
+                 59   .0081  45.000                  59   .0081  45.000
+                 59   .0081    .000                  59   .0081  45.000
+                 59   .0081    .000                  59   .0081  45.000
+                510   .8960    .000                  59   .0081  45.000
+                 59   .0081    .000                  59   .0081  45.000
+                 59   .0081    .000                  59   .0081  45.000
+                 59   .0081  45.000                  59   .0081    .000
+                 59   .0081  45.000                  59   .0081    .000
+                 59   .0081  45.000               30036   .0200    .000
+              30001   .0650    .000
$
```

Ti 6Al-4V

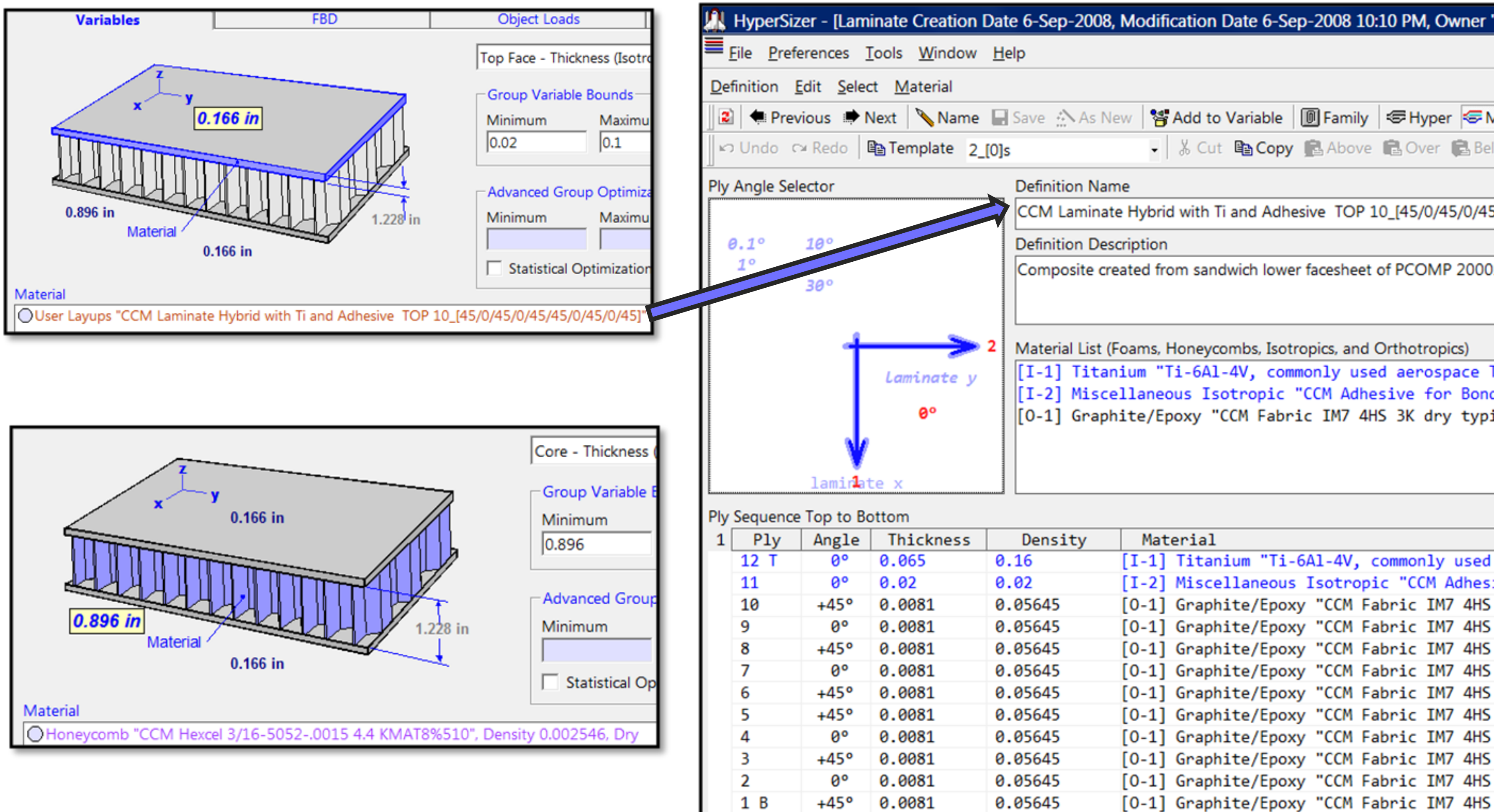
Paste Adhesive

Gr/Ep IM7 Fabric

Sandwich Core

NASTRAN offset
(Refer to the beginning of this PPT)

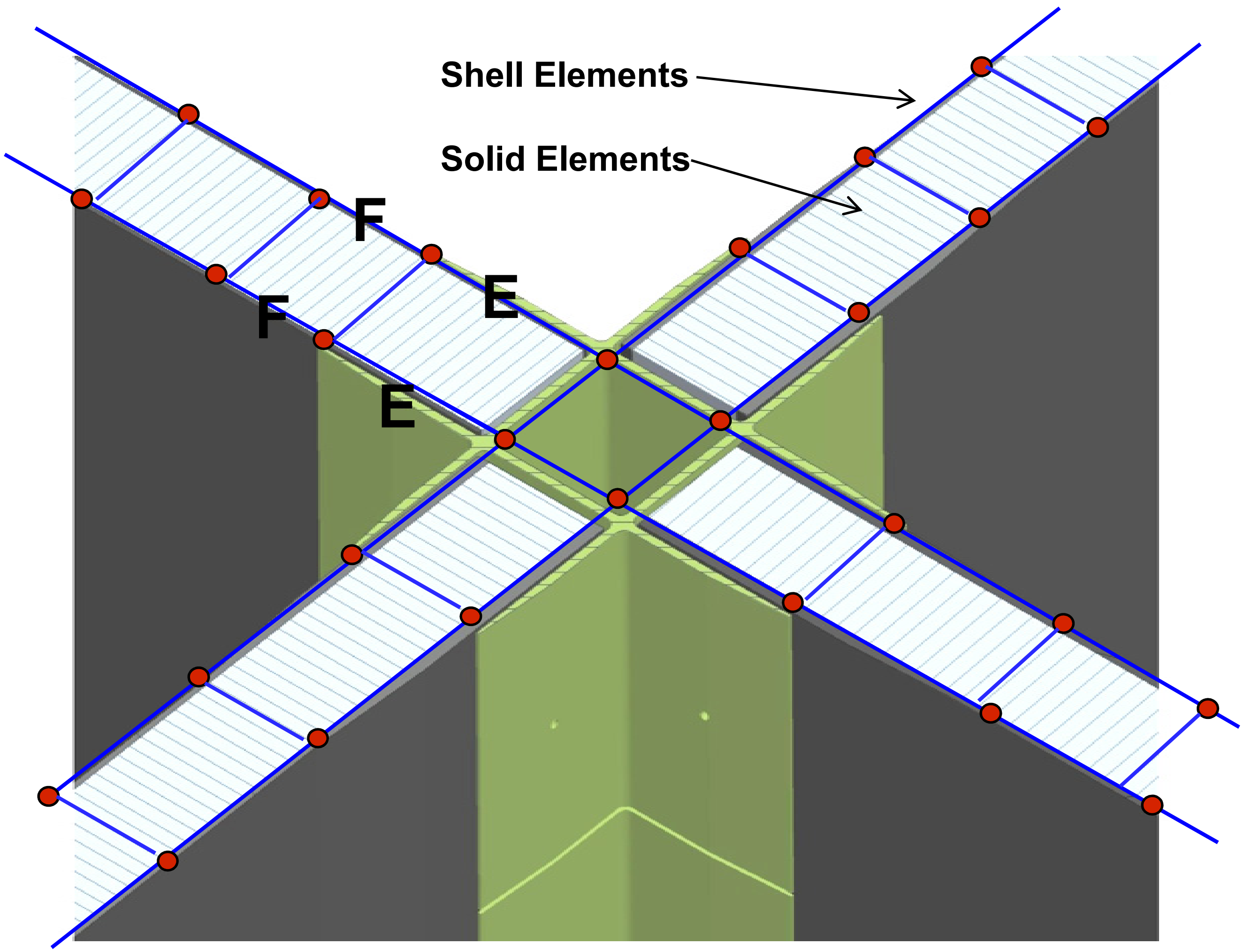
After FEM Import, the NASTRAN PCOMP is Automatically Setup in HyperSizer



Summary Comments

- A ‘loads’ FEM usually has only one property and few elements (in this case one property, ‘B’, and two elements) to define structural transitions. Such a model with the proper stiffness terms is very capable of obtaining an accurate load path prediction
- This type of model is not refine enough to capture stresses properly
- For the cruciform bonded clevis joint, an extremely high number of elements is required to capture the stress intensity at the bonded flange tip. This is especially true for computing interlaminar shear and out-of-plane peel stresses.
- HyperSizer is adept at computing these stresses while coupling to the FEA computed loads
- The next series of slides present an alternative approach for modeling the clevis joint with a loads FEM.

Approach 2: Two Planes Modeling a Bonded Joint in the Loads 'Master' FEM



Red Circle = grid

Blue Line = edge of shell element

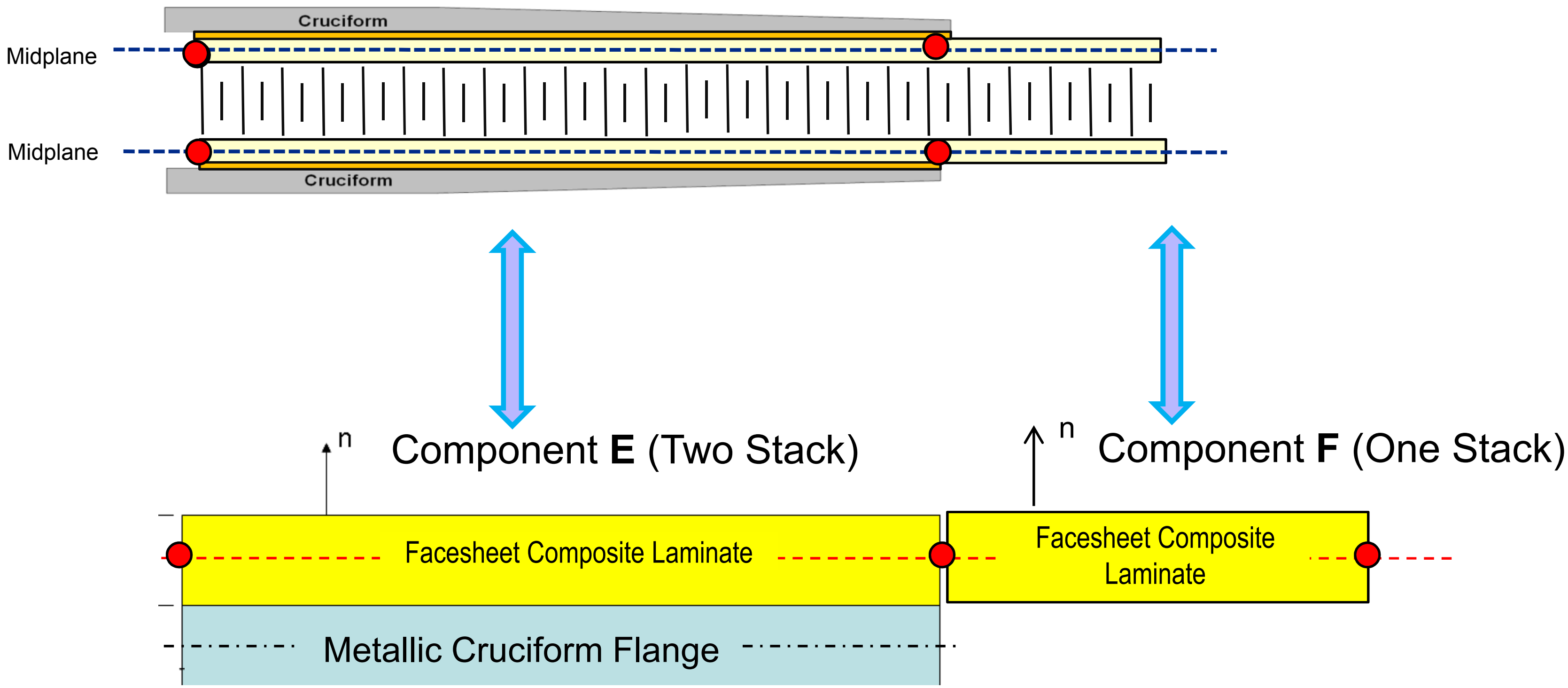
Two planes of shell elements for the facesheets.

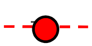
Sandwich core modeled with solid elements

Approach 2: Two Planes Modeling a Bonded Joint in the Loads 'Master' FEM, HyperSizer Two-Stack Concept

- This problem is represented with two HyperSizer components (illustrated on the next slide)
  - Component E includes both the metallic flange and the composite facesheet laminate
  - Component F includes only the composite facesheet laminate
- In the FEM, Components E and F are both modeled using a single plane of CQUAD finite elements
- In Component E, the metallic flange and the composite facesheet laminate are sized
  - with independent variables but simultaneously in HyperSizer using the "Two-Stack" concept
  - this permits user flexibility in sizing the metal with a continuous thickness variable and the laminate as a discrete variable

Approach 2: Two Planes Modeling a Bonded Joint in the Loads 'Master' FEM, HyperSizer Two-Stack Concept



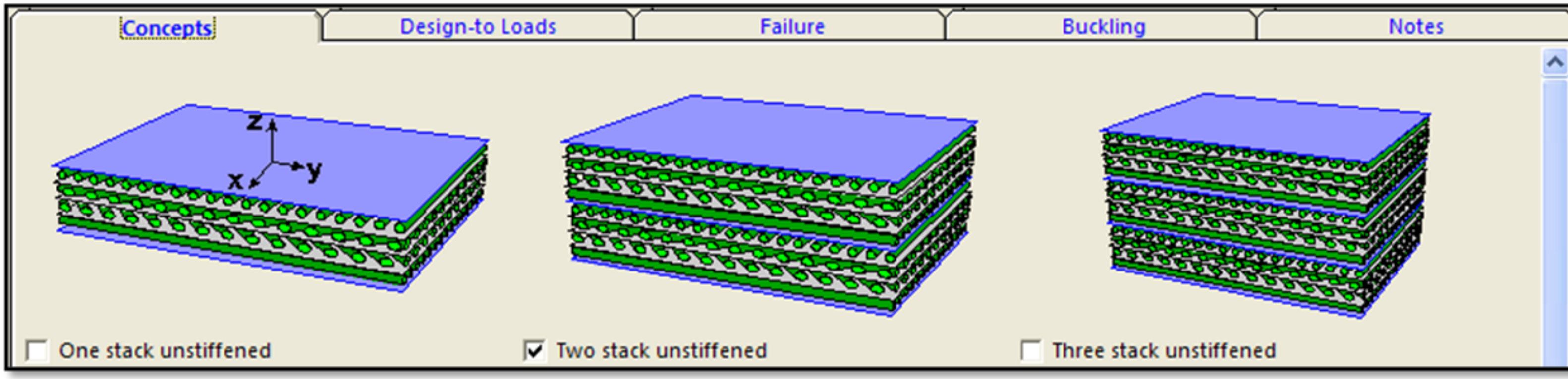


Plane of Grids and Elements in FEM

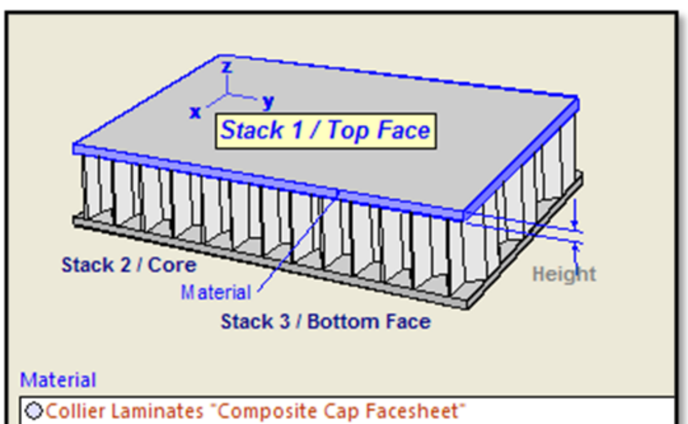
(1 plane of elements models metallic flange and composite facesheet)

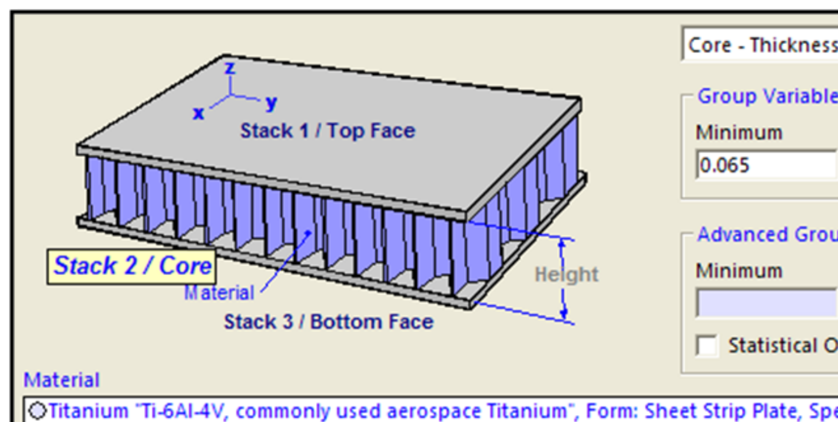
The HyperSizer Two-Stack Concept

- The Two-Stack concept is activated on the Concepts Tab of the Sizing Form



- Specify materials and dimensions for “Stack 1” and “Stack 2” on the Variables Tab. Stack 2 = 0.065” metal flange and not the core.

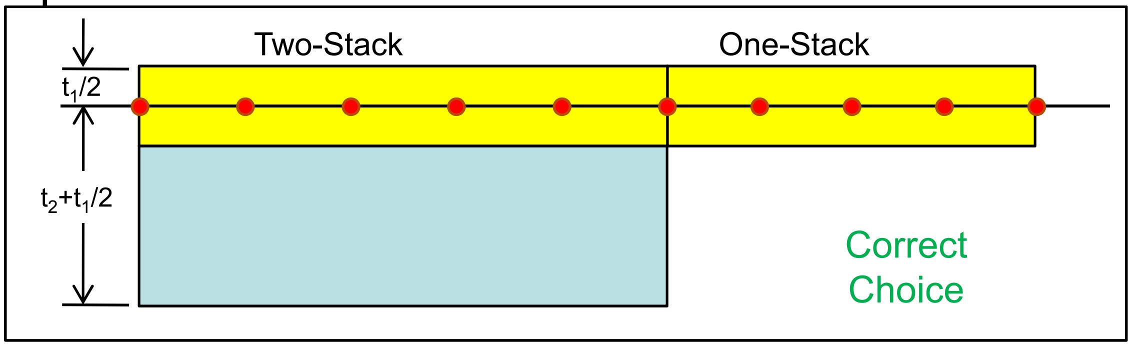




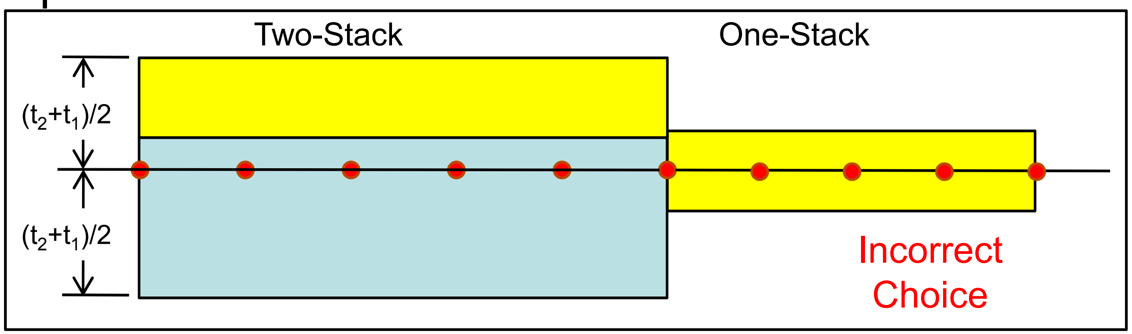
 FEM Imported and Exported Data

Two Stack - Three Choices for Reference Plane on the Options Tab of the Sizing Form

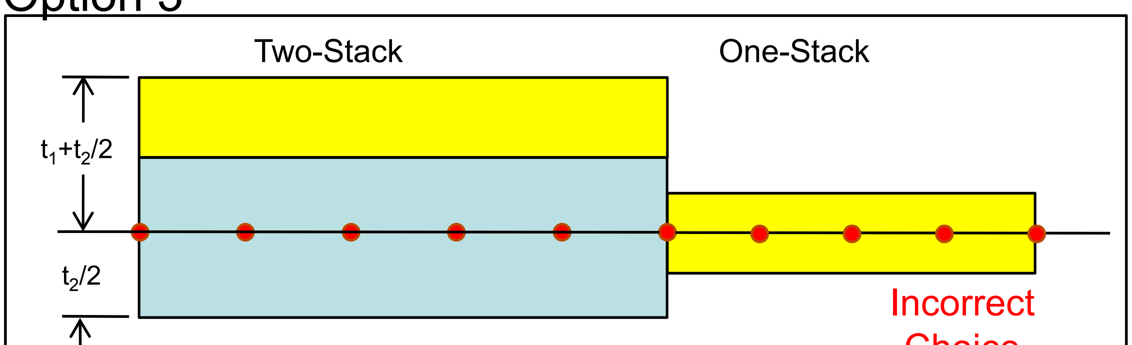
Option 1



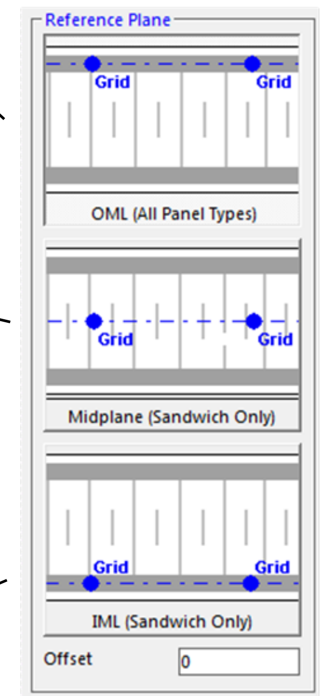
Option 2



Option 3



The two-stack representing the composite facesheet and metal flange can be represented three ways. Option 1 is the desired modeling for this example. Options 2 or 3 will give incorrect loads when passed to the FEM.



Conclusions

- HyperSizer can correctly model many different structural configurations using One-Stack, Two-Stack or Sandwich options
- The choice of reference plane is key, both in HyperSizer and the FEM to ensure modeling the correct physical problem
- Both on FEM Import and Export, HyperSizer tracks the correct reference plane on the PCOMP cards so that the HyperSizer and FEA solutions are consistent