
Pro/MECHANICA®

Hints & Tips

Ray Ellender, Managing Director, Elite Consulting Ltd

Presented at the Mechanica User Group Meeting 9 July 2008

© Elite Consulting Ltd, 2007, 2008, www.elite-consulting.com

Hints & Tips

- ❑ Rigid Links
- ❑ Interface
- ❑ Surface Regions
- ❑ 3-Point Constraints
- ❑ Fasteners with 3-Layers
- ❑ Modelling Convection on Shells
- ❑ Modelling PCB's with Transversely Isotropic Materials

Rigid Connections

- Rigid Connections are now only available in the Advanced Licence
- They used to be in the Basic licence, but were then withdrawn from the Basic licence. This may cause a problem with models previously made with Rigids in a Basic licence.
- Rigid Connections connect entities such as surfaces, curves and points so that they are rigidly connected together. This means the following:
 - All the entities connected in this way move together as one.
 - The entities themselves are 'rigidized', and so cannot deform or move relative to one another.
 - This means that if you connect a point to a surface with a Rigid Connection, as well as connecting the point to the surface, **it also makes the whole of the surface completely rigid**. It can move as a rigid body, but it cannot deform in any way.

Rigid Connections

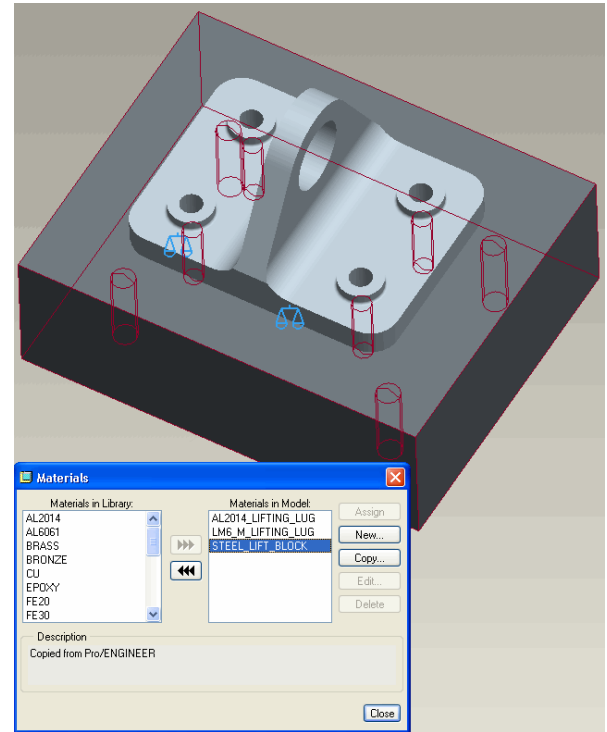
Rigid Connections

- You can connect together any combinations of points, curves, surfaces
 - Point to Point
 - Point to Curve
 - Point to Surface
 - Curve to Surface
 - Surface to Surface
- However Points with Rigid Connections have some special rules; e.g. they must have an element connected to them (beam, spring or shell), or must have a constraint or load on them (See Mechanica help for more info)
- All the entities that you put into a single rigid connection will move as one, so if you want points A & B to move together and points C & D to move together but not with points A & B, make 2 separate Rigid Connections, one containing A & B, the other C & D.
- You can collect a number of entities, e.g. surfaces together in one Rigid, but remember you will rigidize each one as well as connecting together.
- For this reason it can be better to choose curves rather than surfaces, (e.g. around the edge of a hole rather than the surface of a hole) for a rigid link, as this minimises the rigidity imposed on the structure.
- Because Rigid really means Rigid, you may see a stress concentration around the edges of a rigidized entity, because of the sudden change in stiffness, similar to what you may see around the edge of a constraint. This is probably unrealistic, because in real life nothing is absolutely rigid.

Rigid Links

Rigid Connections & Interfaces

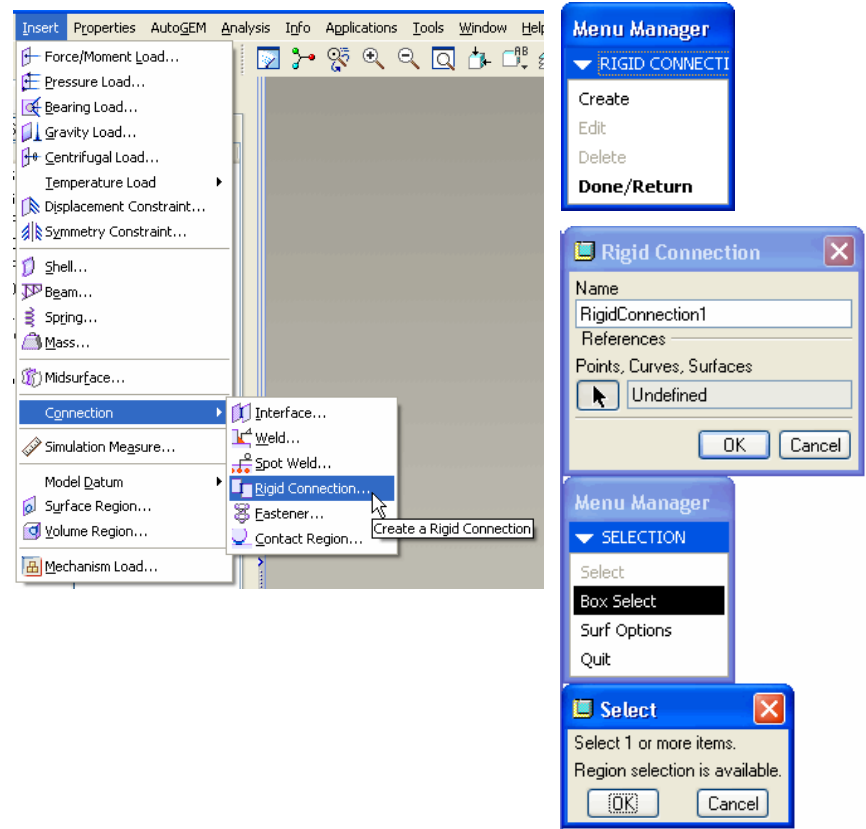
- ❑ Open assembly 'lifting_assy.asm'
- ❑ This was used in the Basic course where we allowed Mechanica to 'bond' the parts together. Now you are going to take more control over how it is connected by using Rigid Connections and an Interface to connect the bolt holes to the block.
- ❑ For no other reason than to show you different ways of connecting rigid entities and their effects we will do each hole differently.
- ❑ Go into Mechanica
- ❑ If not already done, Apply materials to each part



Rigid Links

Rigid Connections

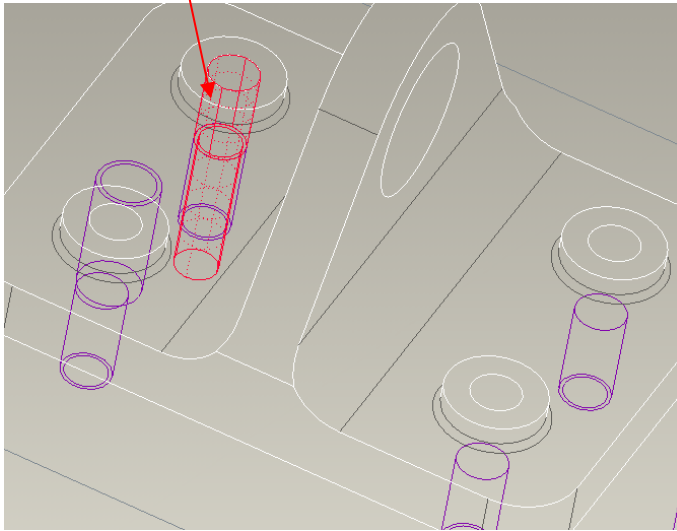
- ❑ Click on Insert > Connection > Rigid Connection
- ❑ A Small box comes up. Select Create
- ❑ A second set of boxes comes up allowing you to create a rigid link by selecting appropriate entities.



Rigid Links

Rigid Connections

- We will connect the first hole by making a Rigid Connection between the bores of the holes in the lug and the block
- Select the surfaces shown (the surfaces of the bore in the bolt hole of the lug and of the in bore of the hole in the block (not the thread surface, as this just cosmetic)), and click OK, OK.



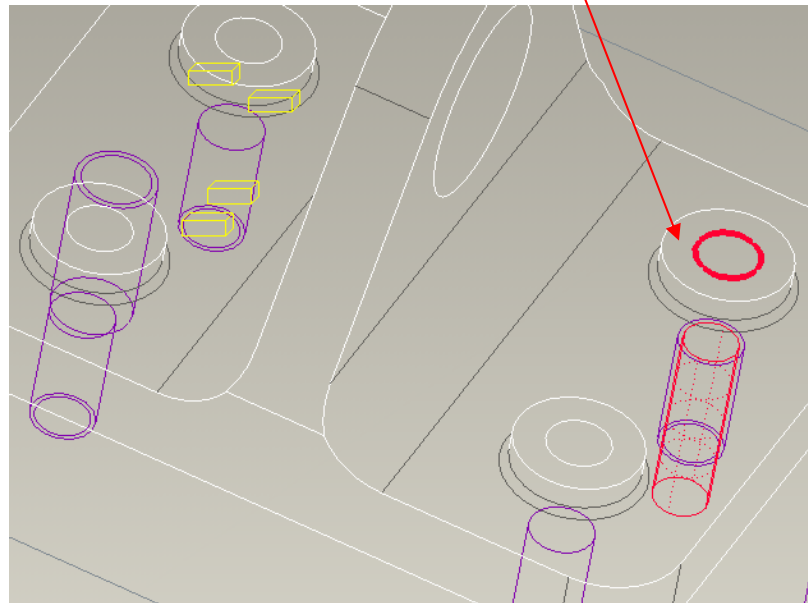
Some box-like icons will appear in the graphics window.



Rigid Links

Rigid Connections

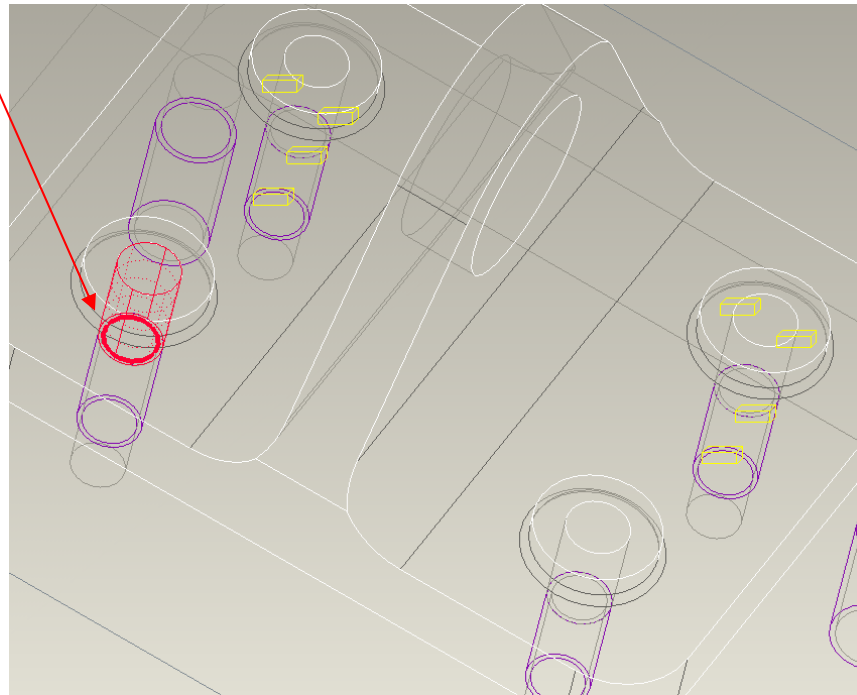
- We will connect the second hole by making a Rigid Connection between the curve around the bolt-up surface the hole in the lug and the thread surface of the hole in the block. In the small box click Create again.
- Select the curves and surfaces shown (the curves at the top of the bolt hole of the lug and of the in bore of the hole in the block (not the thread surface, as this just cosmetic)), and click OK, OK.



Rigid Links

Rigid Connections

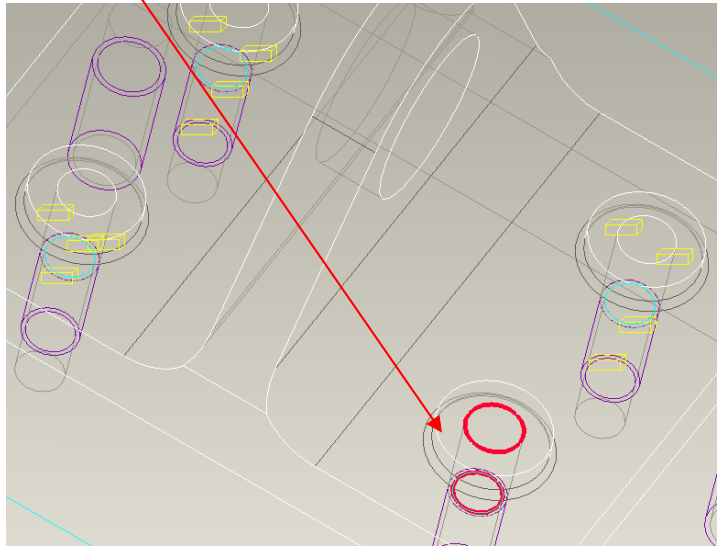
- We will connect the third hole by making a Rigid Connection between the bore surface the hole in the lug and curve around the top of the thread surface of the hole in the block. In the small box click Create again.
- Select the curves and surfaces shown (the curves at the top of the bolt hole of the lug and of the threads in the hole in the block), and click OK, OK.



Rigid Links


Rigid Connections

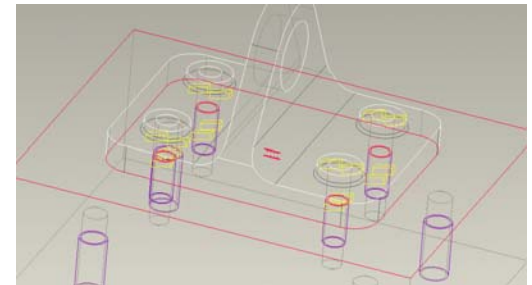
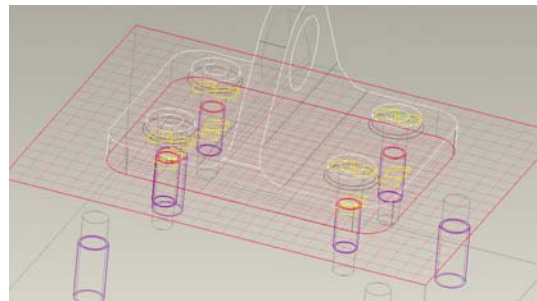
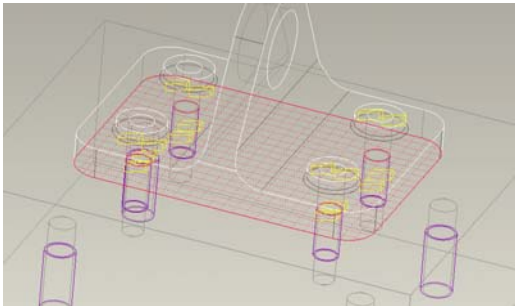
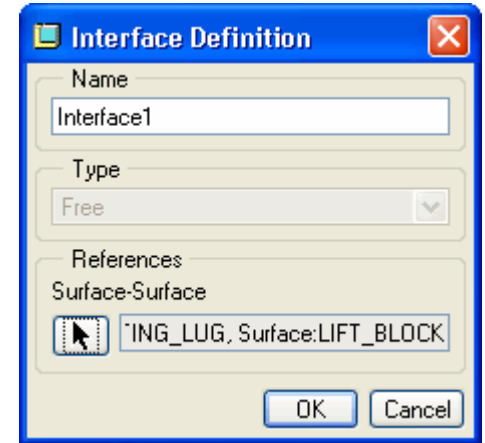
- We will connect fourth hole by making a Rigid Connection between curve around the top of the bore surface the hole in the lug and the curve around the top of the thread surface of the hole in the block. In the small box click Create again.
- Select the curves shown (the curves at the top of the bolt hole of the lug and of the threads in the hole in the block), and click OK, OK.



Interface

Interface

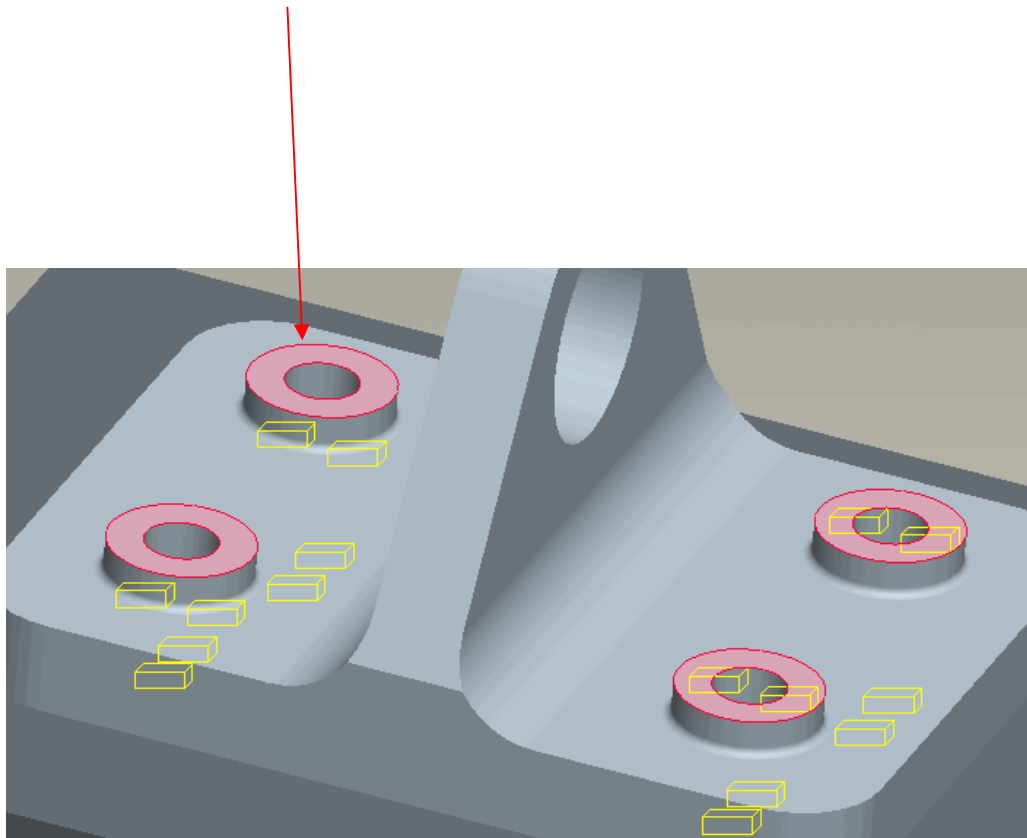
- Because we don't want the two parts to bond together, we will create an Interface between them.
- To create an Interface click on the Interface  or Insert>Connections>Interface, and a Window comes up. Then click on the 2 surfaces that you want to remain separated as shown.
- Click OK and an Icon appears in the graphic window



Surface Regions

Surface Regions

- ❑ You can use surface regions to split surfaces onto smaller patches. This can be very helpful when using Rigid Links
- ❑ Especially useful when Pro/E makes an unhelpful continuous surface.



3 Point Constraint System

3-Point Constraint

This is sometimes known as a 3-2-1 constraint system and is very useful if you need to allow free expansion or free movement

Make 3 co-planar points on your part

Constrain Translations, not Rotations

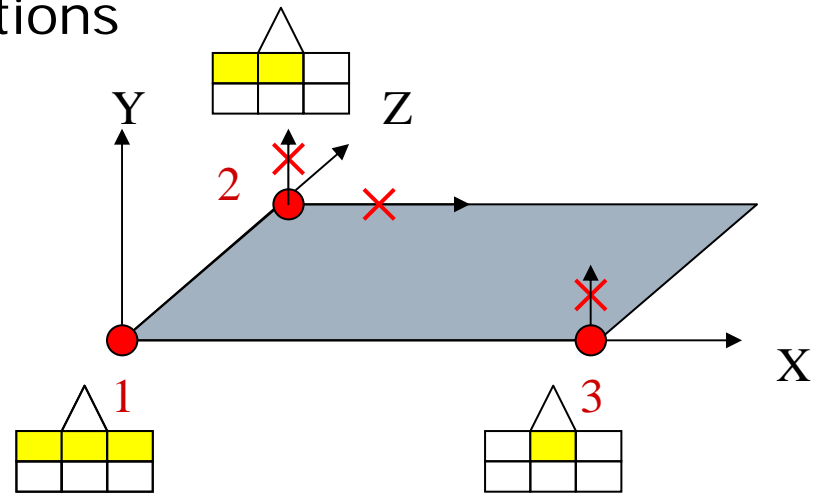
Constrain point 1 in X, Y & Z

Constrain point 2 in X & Y, not Z

(to stop rotations around X & Y,
But allow expansion in Z)

Constrain point 3 in Y

(to stop rotations around Z,
But allow expansion in X & Z)



3 Point Constraint System

3-Point Constraint

Note: - If you applying other loads apart from a thermal load, then contrary to normal practice, apply the loads AND the reaction forces, so that the nominal load balance is zero.

The point constraints would normally cause singularities, but because the loads are balanced there will be very little stress concentration there (You can exclude elements if you wish). However their presence means that the model is fully constrained and will run.

Tip. Make the points away from areas of interest.

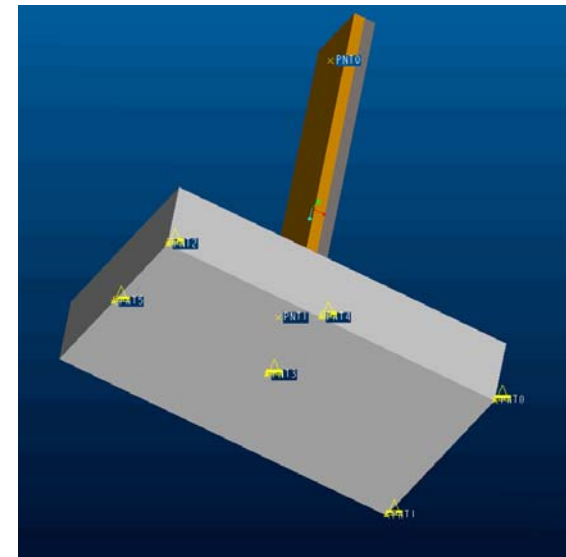
3 Point Constraint System

- 3-Point Constraints v Inertia Relief
 - Inertia Relief does not control the centre of movement, hence results can sometimes be difficult to interpret
 - A 3-point constraint system can be designed to place the centre of movement at a known position.

3 Point Constraint System

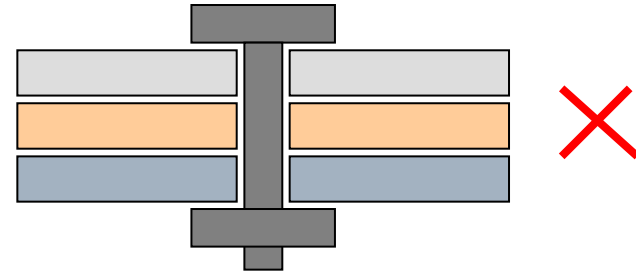
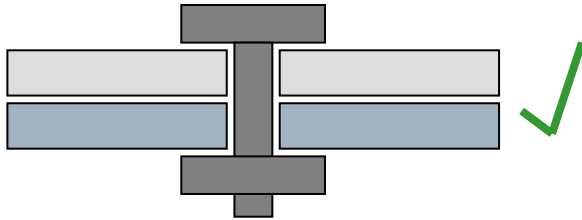
- Bimetallic Strip
- Set up 3 different datum points that are designed to minimize extraneous movement at the point of interest. Make a point on the base immediately under the strip measurement point, then 2 more corners at the side and front edges. Pts 3,4,5 on the base. You can do this by using 'Three Srf' and choosing appropriate datum planes and surfaces. Then constrain the following translations in a new Constraint Set, ThreePointB (The Rotations should be free).

- Pt3: X, Y, Z
- Pt4: Z (to constrain rotation about X)
- Pt5: Y (to constrain rotation about Z)
: Z (to constrain rotation about Y)



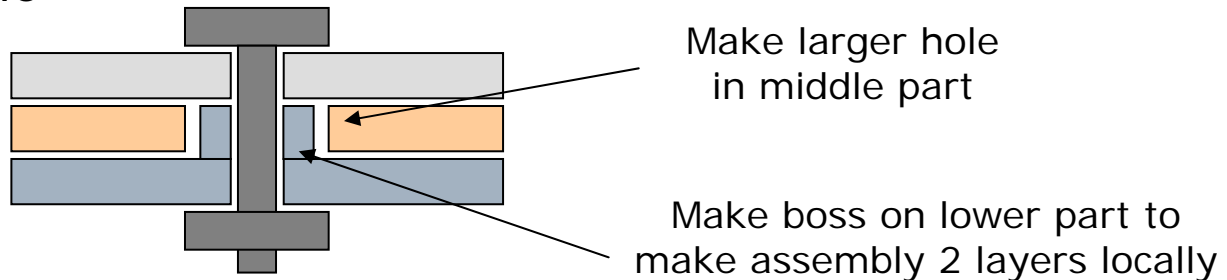
Fasteners

- Fasteners can only be used with 2 layers



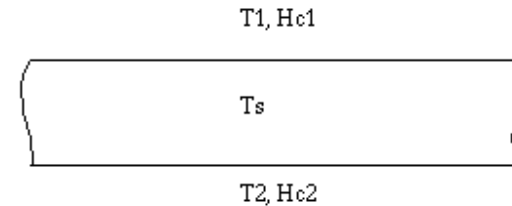
- How to deal with 3 or more layers?

- Modify the parts
- Make larger hole in middle part
- Add boss to lower part, to make assembly only 2 layers at hole



Appendix - Modelling Convection Conditions on Shells

- Shell elements are often used to model thin walled components with relatively high conductivities. This is possible because the temperature gradient through the wall thickness is small, and has little or no impact on component's behaviour. When modelling parts in this manner, it is often required to apply convections on both top and bottom faces of the shells.
- Pro/MECHANICA does not allow defining more than one convection conditions on a shell or a surface since convections are grouped as constraints in the heat transfer model. This technique is used to combine convection boundary conditions acting on two sides of a shell or surface together into a single equivalent convection condition.
 - H_{eq} equals the sum of the h-values on each surface
 - T_{eq} equals the weighted average of the bulk temperatures on each surface



where:

- T1 = ambient fluid temperature on top surface
- Hc1 = convection coefficient on top surface
- T2 = ambient fluid temperature on bottom surface
- Hc2 = convection coefficient on bottom surface
- Ts = average wall temperature
- Q = total heat flux

The total heat flux on the shell due to convection is

$$Q = Hc1 (T1 - Ts) + Hc2 (T2 - Ts)$$

Rearrange,

$$Q = Hc1 T1 + Hc2 T2 - (Hc1 + Hc2) Ts$$

$$Q = (Hc1 + Hc2) [(Hc1 T1 + Hc2 T2) / (Hc1 + Hc2) - Ts]$$

$$Q = H_{eq} (T_{eq} - Ts)$$

The equivalent boundary condition can be written as follows:

$$H_{eq} = (Hc1 + Hc2)$$

$$T_{eq} = (Hc1 T1 + Hc2 T2) / (Hc1 + Hc2)$$

Appendix – Transversely Isotropic Materials

- With the Mechanica Advanced licence, one can specify Transversely Isotropic Materials
- This is particularly useful for PCB's which potentially have a different conductivity along the board compared to through thickness.
- Example FR4 Board
- There are 4 copper layers 0.07 mm thick, and 5 epoxy layers 0.1 mm thick, giving a total of 0.78 mm for the whole stack. Calculate the through-thickness and transverse conductivity using the Composite wall method of thermal resistance.
- $k_{\text{Copper}} = 390 \text{ W/mmk}$, $k_{\text{Epoxy}} = 0.25 \text{ W/mmk}$.

Through thickness

$$\frac{t}{k_t} = 4 \left(\frac{0.07}{390} \right) + 5 \left(\frac{0.1}{0.25} \right) = \frac{0.78}{k_t}$$

$$\Rightarrow k_t = 0.40$$

In-Plane

$$k_{trans} = \frac{(390 \times (4 \times 0.07))}{0.78} = 140$$

Any Others?

- Other tips from members