ANSYS中复合材料的分析

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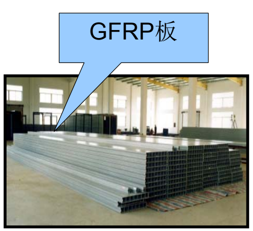
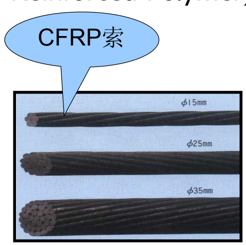
内容简介

- 复合材料的定义
- 复合材料的建模
  - 选择单元类型
  - 定义层合板参数
  - 确定失败准则
- 注意事项

复合材料的定义

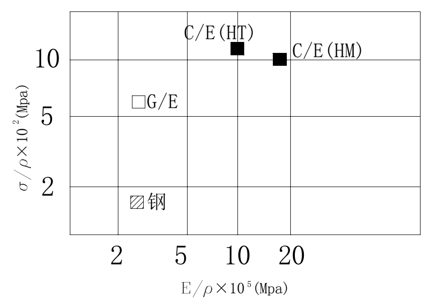
- 复合材料是由两种或两种以上不同性质的材料粘合而成具有新性能的一种材料。常用的复材主要为FRP(Fibre Reinforced Polymer)





复合材料的优点

- 比强度高



可选用的单元类型

- Shell99:线性层合结构壳单元

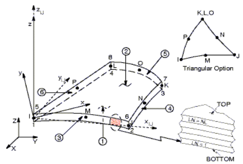
8结点，3D壳单元

每个节点6DOF

模拟薄板、中厚板(宽/厚≥10)

线弹性材料

最多可以模拟250均厚层合板



可选用的单元类型

- Shell91:非线性层合结构壳单元

8结点，3D壳单元，每个节点6DOF

非线性材料

最多可模拟100层

- Shell181:有限应变壳单元

4结点，3D壳单元，每个节点6DOF

模拟薄板、中厚板(宽/厚≥10)

最多可模拟255层

可选用的单元类型

- Solid46:3D层合结构实体单元

8结点，3D实体单元，每个节点3FOD

模拟层合厚板、层合实体

最多可模拟250层

- Solid191 :层合结构实体单元

20结点，3D实体单元，每个节点3FOD

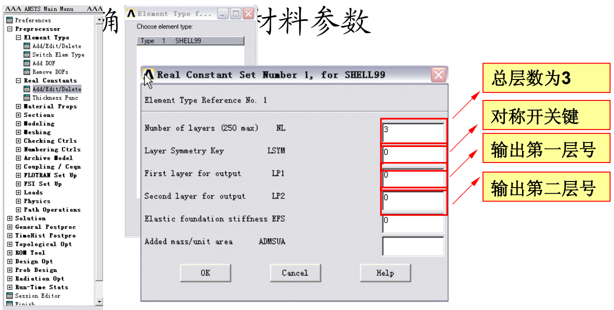
最多可模拟100层

其它可选用的单元类型

- Shell63
- Solid65
- Solid95
- Beam188
- Beam189

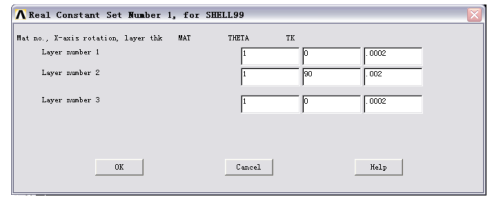
定义层合参数

…材料参数

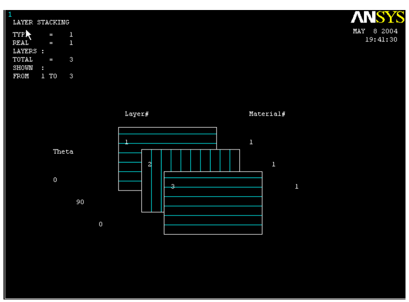


定义层合参数

确定每层的材料、厚度、与角度



定义层合参数



复合材料常用的失效准则

- 最大应变准则

$$\xi_1 = \text{maximum of} \begin{cases} \dfrac{\varepsilon_{xt}}{\varepsilon_{xt}^f} \text{ or } \dfrac{\varepsilon_{xc}}{\varepsilon_{xc}^f} \text{ whichever is applicable} \\ \dfrac{\varepsilon_{yt}}{\varepsilon_{yt}^f} \text{ or } \dfrac{\varepsilon_{yc}}{\varepsilon_{yc}^f} \text{ whichever is applicable} \\ \dfrac{\varepsilon_{zt}}{\varepsilon_{zt}^f} \text{ or } \dfrac{\varepsilon_{zc}}{\varepsilon_{zc}^f} \text{ whichever is applicable} \\ \dfrac{|\varepsilon_{xy}|}{\varepsilon_{xy}^f} \\ \dfrac{|\varepsilon_{yx}|}{\varepsilon_{yz}^f} \\ \dfrac{|\varepsilon_{xz}|}{\varepsilon_{xz}^f} \end{cases}$$

where:

ξ_1 = value of maximum strain failure criterion

$$\varepsilon_{xt} = \begin{cases} 0 \\ \varepsilon_x \end{cases} \text{ whichever is greater}$$

ε_x = strain in layer x-direction

$$\varepsilon_{xc} = \begin{cases} \varepsilon_x \\ 0 \end{cases} \text{ whichever is lesser}$$

复合材料常用的失效准则

- 最大应力准则

$$\xi_2 = \text{maximum of} \begin{cases} \dfrac{\sigma_{xt}}{\sigma^f_{xt}} \text{ or } \dfrac{\sigma_{xc}}{\sigma^f_{xc}} \text{ whichever is applicable} \\ \dfrac{\sigma_{yt}}{\sigma^f_{yt}} \text{ or } \dfrac{\sigma_{yc}}{\sigma^f_{yc}} \text{ whichever is applicable} \\ \dfrac{\sigma_{zt}}{\sigma^f_{zt}} \text{ or } \dfrac{\sigma_{zc}}{\sigma^f_{zc}} \text{ whichever is applicable} \\ \dfrac{|\sigma_{xy}|}{\sigma^f_{xy}} \\ \dfrac{|\sigma_{yx}|}{\sigma^f_{yz}} \\ \dfrac{|\sigma_{xz}|}{\sigma^f_{xz}} \end{cases}$$

where:

ξ_2 = value of maximum stress failure criterion

$$\sigma_{xt} = \begin{cases} 0 \\ \sigma_x \end{cases} \text{ whichever is greater}$$

σ_x = stress in layer x-direction

$$\sigma_{xc} = \begin{cases} \sigma_x \\ 0 \end{cases} \text{ whichever is lesser}$$

复合材料常用的失效准则

- Tsai-Wu准则(二次准则)

$$\xi_3 = A + B$$

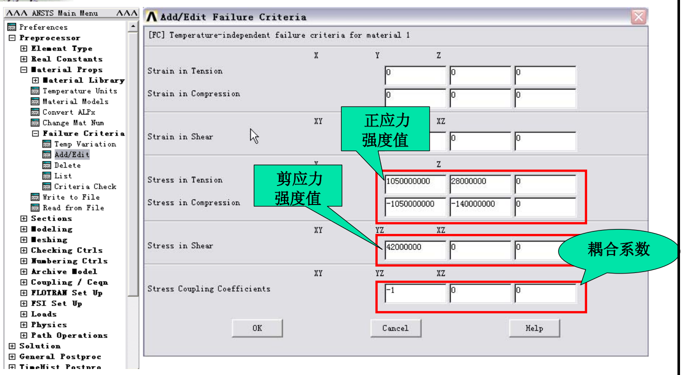
ξ_3 = value of Tsai-Wu failure criterion

$$A = -\frac{(\sigma_x)^2}{\sigma^f_{xt}\sigma^f_{xc}} - \frac{(\sigma_y)^2}{\sigma^f_{yt}\sigma^f_{yc}} - \frac{(\sigma_z)^2}{\sigma^f_{zt}\sigma^f_{zc}} + \frac{(\sigma_{xy})^2}{(\sigma^f_{xy})^2} + \frac{(\sigma_{yz})^2}{(\sigma^f_{yz})^2} + \frac{(\sigma_{xz})^2}{(\sigma^f_{xz})^2} + \frac{C_{xy}\sigma_x\sigma_y}{\sqrt{\sigma^f_{xt}\sigma^f_{xc}\sigma^f_{yt}\sigma^f_{tc}}} + \frac{C_{yz}\sigma_y\sigma_z}{\sqrt{\sigma^f_{yt}\sigma^f_{yc}\sigma^f_{zt}\sigma^f_{zc}}} + \frac{C_{xz}\sigma_x\sigma_z}{\sqrt{\sigma^f_{xt}\sigma^f_{xc}\sigma^f_{zt}\sigma^f_{zc}}}$$

$$B = \left(\frac{1}{\sigma^f_{xt}} + \frac{1}{\sigma^f_{xc}}\right)\sigma_x + \left(\frac{1}{\sigma^f_{yt}} + \frac{1}{\sigma^f_{yc}}\right)\sigma_y + \left(\frac{1}{\sigma^f_{zt}} + \frac{1}{\sigma^f_{zc}}\right)\sigma_z$$

C_{xy}, C_{yz}, C_{xz} = x-y, y-z, x-z, respectively, coupling coefficient for Tsai-Wu theory

定义失效准则(Tsai-Wu)



命令流(定义材性与失效准则)

```
/PREP7
ET,1,SHELL99
RMODIF,1,1,3,0,0,0,0,0
RMODIF,1,13,1,0,.0002,1,90,.002,
RMODIF,1,19,1,0,.0002,
LAYLIST,ALL,,,EX,EX
!*
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,EX,1,,5.4e10
MPDATA,EY,1,,1.8e10
MPDATA,EZ,1,,
MPDATA,PRXY,1,,0.25
MPDATA,PRYZ,1,,
MPDATA,PRXZ,1,,
MPDATA,GXY,1,,8.8e9
MPDATA,GYZ,1,,
MPDATA,GXZ,1,,
```

```
FC,1,S,XTEN,1.05e9
FC,1,S,YTEN,2.8e7
FC,1,S,ZTEN,
FC,1,S,XCMP,-1.05e9
FC,1,S,YCMP,-1.4e8
FC,1,S,ZCMP,
FC,1,S,XY,4.2e7
FC,1,S,YZ,
FC,1,S,XZ,
FC,1,S,XYCP,-1
FC,1,S,YZCP,0
FC,1,S,XZCP,0
!*
FC,1,EPEL,XTEN,
FC,1,EPEL,YTEN,
FC,1,EPEL,ZTEN,
FC,1,EPEL,XCMP,
FC,1,EPEL,YCMP,
FC,1,EPEL,ZCMP,
FC,1,EPEL,XY,
FC,1,EPEL,YZ,
FC,1,EPEL,XZ,
```

注意事项

- 复合材会呈现几种耦合效应：拉弯、弯扭；这是因为各层的材料性质不同造成的；
- 由于复合材料的输入数据较多，在求解之前应对输入数据进行校核。常用命令有：

  ELIST **EPLOT** **LAYLIST** **LAYPLOT**

  PSYMB,LAYR,*n*

  PSYMB,ESYS,1 (显示单元局部坐标)

  SECPLOT

注意事项

- 对于层合结构分析的数据，一般只有底层与顶层的数据被写入结果文件，如果要保存每层的数据，请设置KEYOPT(8) = 1.
- Ansys默认，Post1显示的结果都是在整体的笛卡尔坐标系下的值。