Laminate

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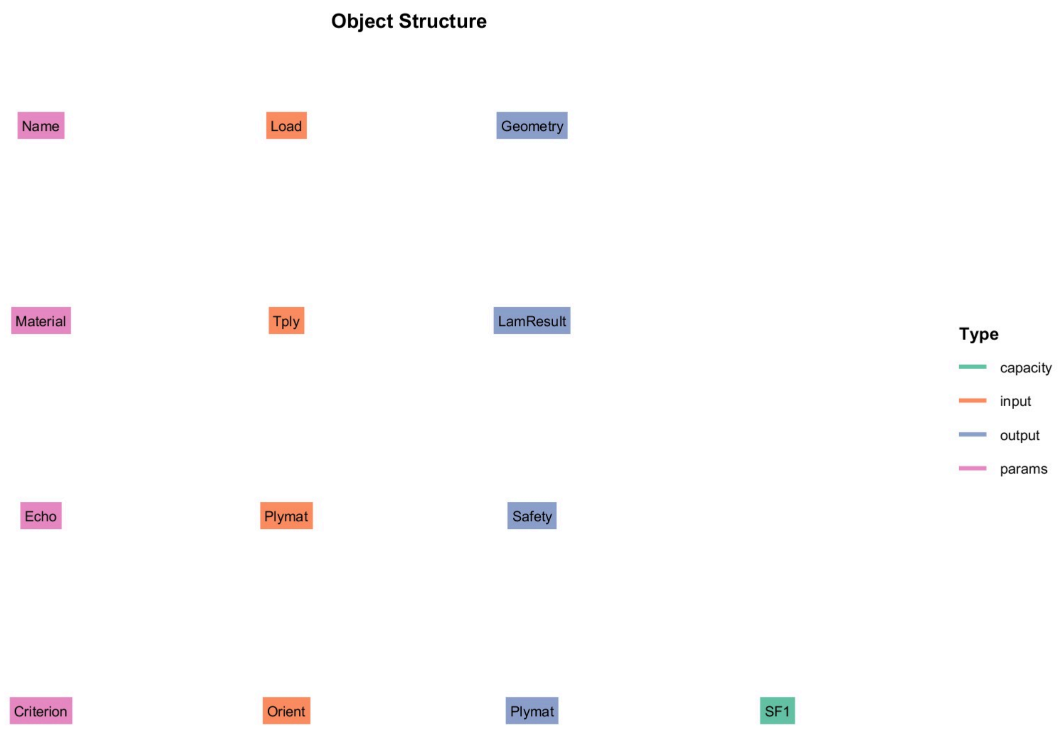
1 介绍

Laminate类用于层合板校核分析，集成了Practical Micromechanics of Composite Materials一书中部分的开源代码[1]。该类用经典的复合材料层合板理论进行校核，可以初步对层合板进行选型计算，但在实际工程中还是要考虑将实际几何和边界考虑进仿真中。

2 类结构



输入 input:

- Load : 载荷
- Tply : 铺层厚度
- Plymat : 铺层材料
- Orient : 铺层角度

参数 params:

- Name ： 名称
- Material : 材料
- Ctiterion : 失效准则

输出 output :

- Geometry : 几何

- LamResult : 壳单元装配
- Safety : 截面
- Plymat : 实体网格

能力 capacity ：

- SF1 ： 总体极限安全系数

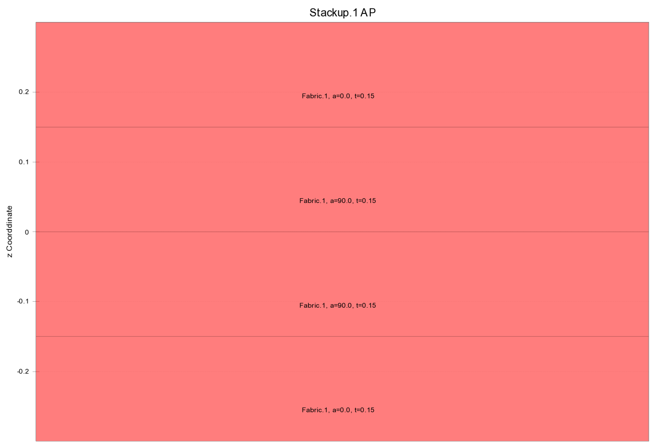
3 案例

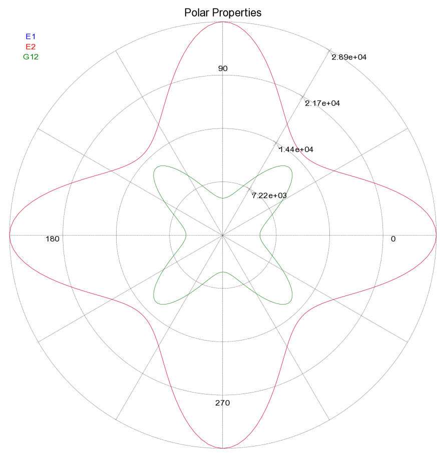
3.1 Compare to ANSYS ACP (Flag=1)

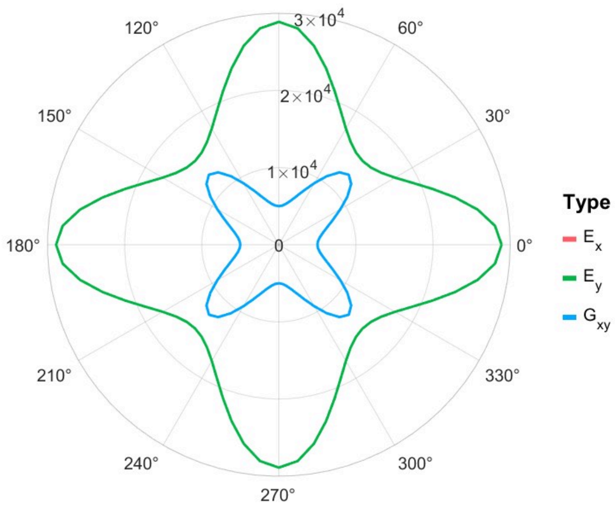
此案例用Workbench ACP和Laminate类比较了几种比较常见的铺层方式（对称、反对称等）下层合板宏观力学参数，材料属性为E-Glass/Epoxy, 参数如下。

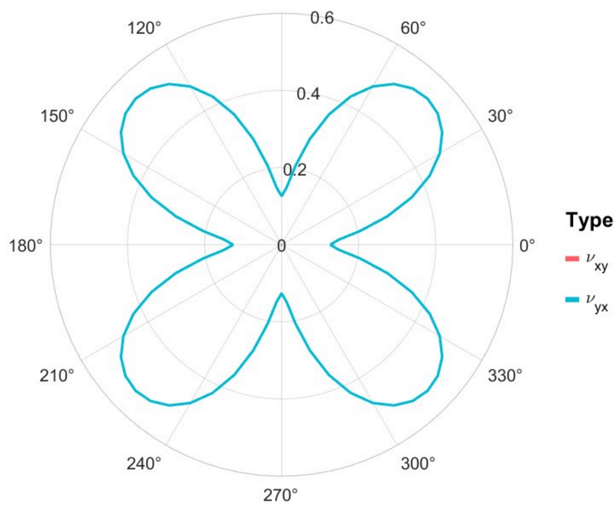
Density	**Ex**	**Ey**	**Ez**	**Gxy**	**Gyz**	**Gxz**	μ_{xy}	μ_{yz}	μ_{xz}
t/mm^3	MPa	MPa	MPa	MPa	MPa	MPa			
1.987e-9	44000	13400	13400	5000	4600	5000	0.27	0.45	0.45

```
S=RMaterial('Composite');
mat=GetMat(S,5);
type=1;
switch type
case 1
 % Symmetric layout 1
 inputStruct.Orient=[0,90,90,0]';
 inputStruct.Tply=repmat(0.15,4,1);
 inputStruct.Plymat=ones(4,1);
case 2
% Symmetric layout 2
inputStruct.Orient=[30,45,0,0,30,45]';
inputStruct.Tply=epmat(0.15,6,1);
inputStruct.Plymat=ones(6,1);
case 3
% Antisymmetric layout 1
inputStruct.Orient=[-45,30,-30,45]';
inputStruct.Tply=repmat(0.15,4,1);
inputStruct.Plymat=ones(4,1);
case 4
% Antisymmetric layout 2
inputStruct.Orient=[45,-60,-30,30,60,-45]';
inputStruct.Tply=repmat(0.15,6,1);
inputStruct.Plymat=ones(6,1);
end
inputStruct.Load.Type  = [2, 2, 2, 2, 2, 2];
inputStruct.Load.Value = [15, 0, 0, 0, 0, 0];
% inputStruct.Load.Value = [0, 0, 0, 15, 0, 0];
paramsStruct.Material=mat;
L= plate.Laminate(paramsStruct, inputStruct);
L=L.solve();
PlotResult(L);
PlotResult(L,'MC',1);
PlotLaminateProperty(L);
```

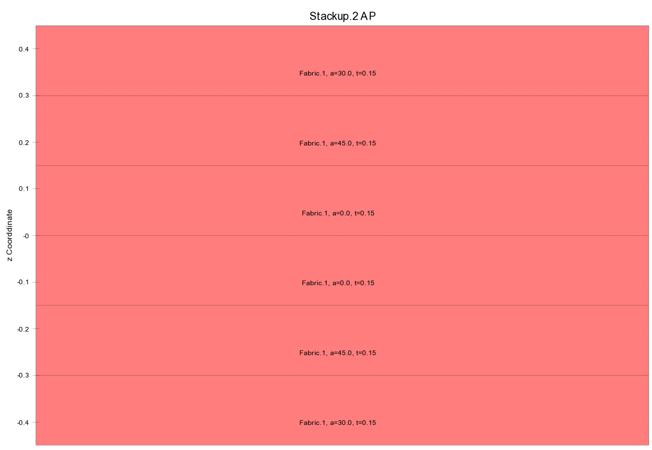


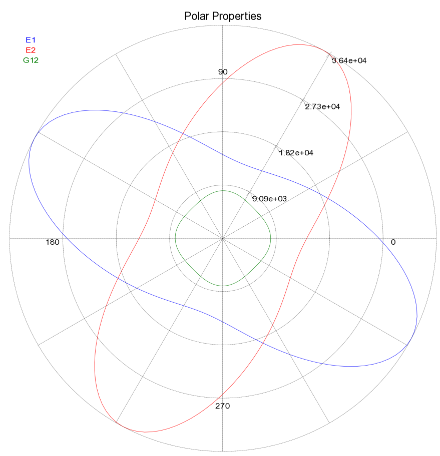


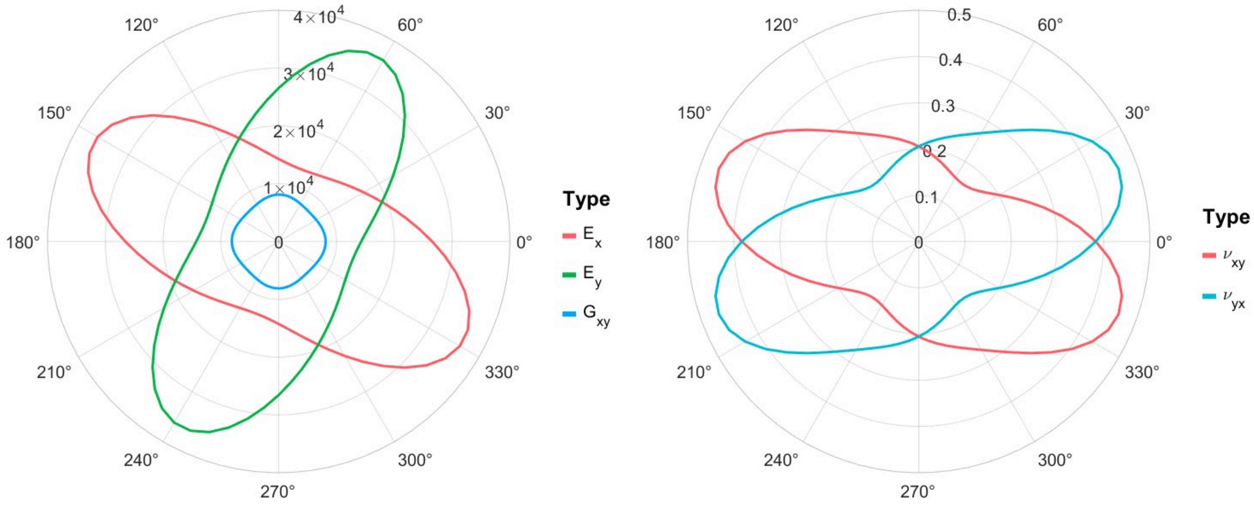




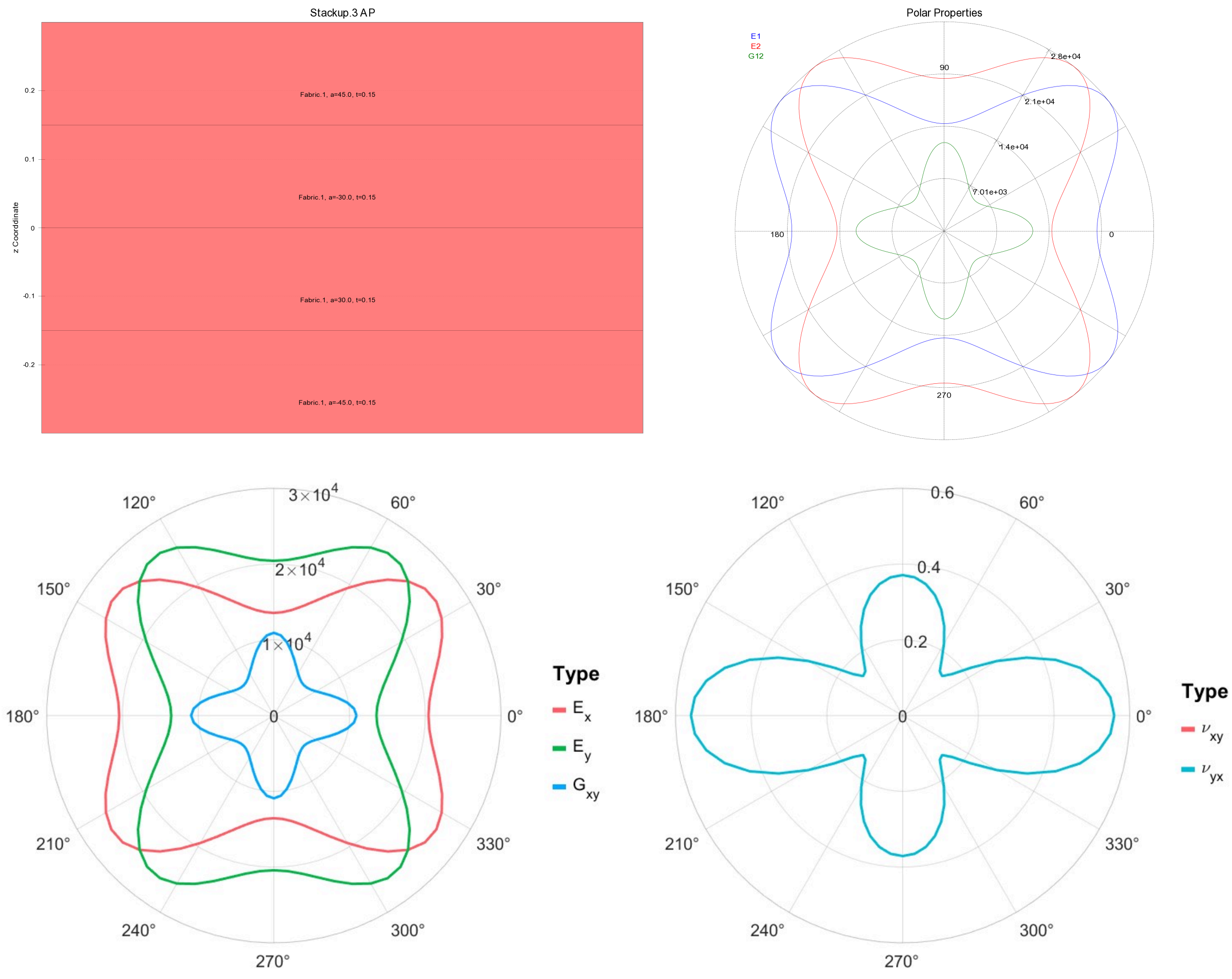
0/90/90/0 stackups



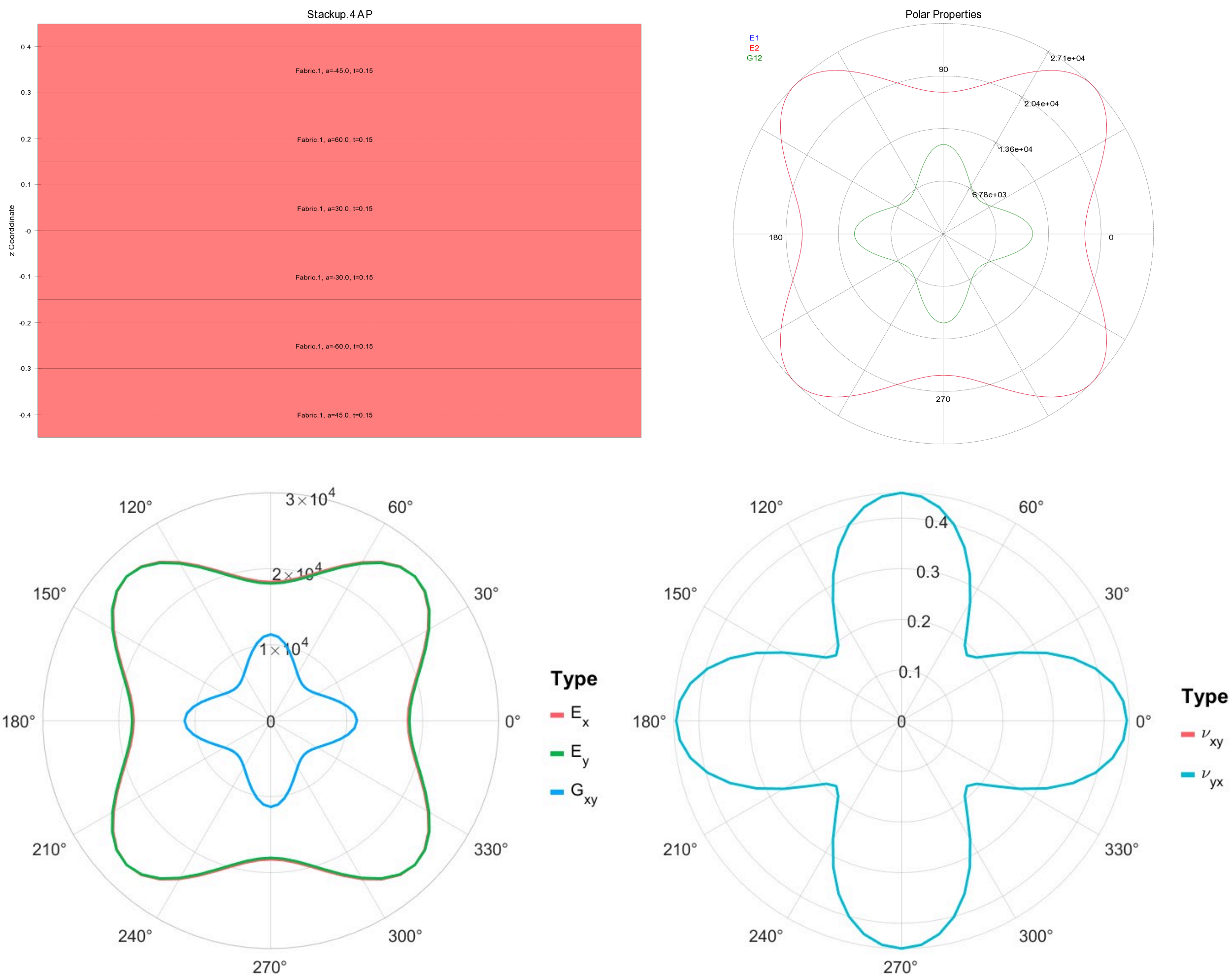




45/30/0/0/30/45 stackups



-45/30/-30/45 stackups



45/-60/-30/30/60/-45 stackups

3.2 UD laminate with 45° (Flag=2)

```
S=RMaterial('Composite');
mat=GetMat(S,22);
inputStruct.Orient=45;
inputStruct.Tply=0.15;
inputStruct.Plymat=1;
inputStruct.Load.Type  = [2, 2, 2, 2, 2, 2];
inputStruct.Load.Value = [1, 0, 0, 0, 0, 0];
paramsStruct.Material=mat;
L= plate.Laminate(paramsStruct, inputStruct);
L=L.solve();
PlotResult(L);
```

A Matrix :.

1.0e+03 *

2.8580	1.8230	1.2236
1.8230	2.8580	1.2236
1.2236	1.2236	1.8656

B Matrix :.

0	0	0
0	0	0
0	0	0

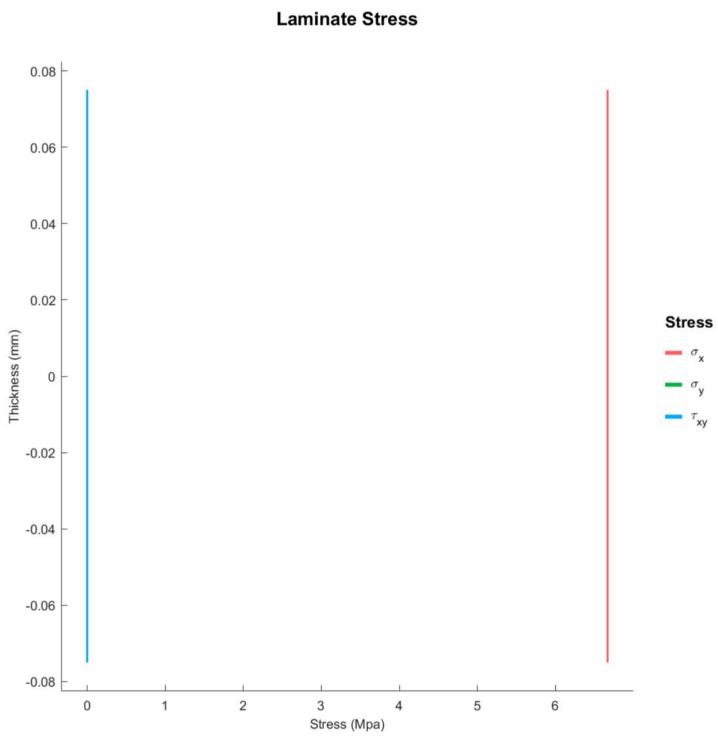
D Matrix :.

5.3587	3.4181	2.2942
3.4181	5.3587	2.2942
2.2942	2.2942	3.4980

Laminate effective properties :.

Ex Ey Nuxy Gxy Alpha_x Alpha_y Alpha_xy.

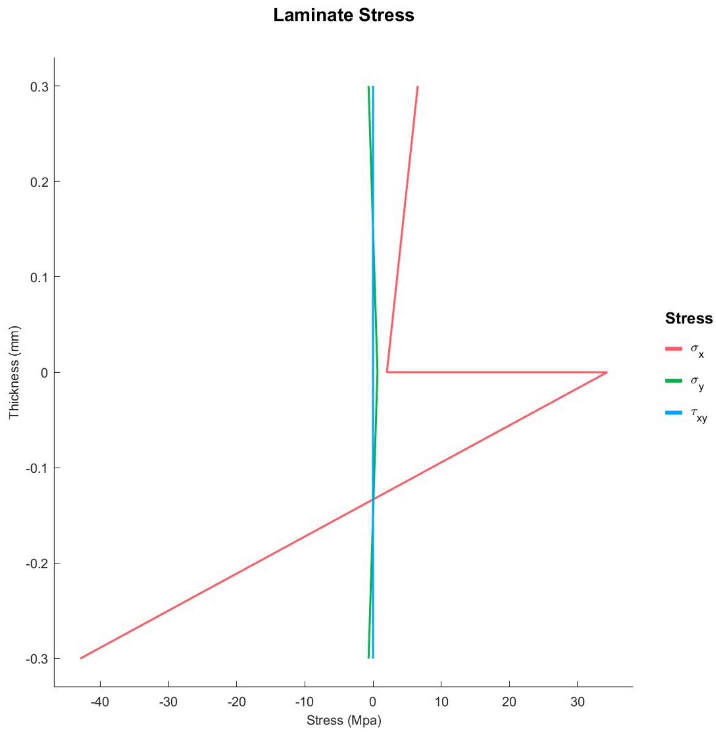
10325.6102 10325.6102 0.496465246 8172.6842 1.792e-05 1.792e-05



3.3 Cross ply (Flag=3)

```
S=RMaterial('Composite');
mat=GetMat(S,21);
type=3;
switch type
  case 1
    inputStruct.Orient=[0,90,90,0]';
  case 2
    inputStruct.Orient=[90,0,0,90]';
  case 3
    inputStruct.Orient=[0,0,90,90]';
end

inputStruct.Tply=repmat(0.15,4,1);
inputStruct.Plymat=ones(4,1);
inputStruct.Load.Type  = [2, 2, 2, 2, 2, 2];
% inputStruct.Load.Value = [1, 0, 0, 0, 0, 0];
inputStruct.Load.Value = [0, 0, 0, 1, 0, 0];
paramsStruct.Material=mat;
L= plate.Laminate(paramsStruct, inputStruct);
L=L.solve();
PlotResult(L);
```



3.4 Plot material coordinate laminate results (Flag=4)

```
S=RMaterial('Composite');
mat=GetMat(S,21);
inputStruct.Orient=[45,-45,-45,45]';
inputStruct.Tply=repmat(0.15,4,1);
inputStruct.Plymat=ones(4,1);
inputStruct.Load.Type  = [2, 2, 2, 2, 2, 2];
inputStruct.Load.Value = [0, 0, 0, 1, 0, 0];
paramsStruct.Material=mat;
L= plate.Laminate(paramsStruct, inputStruct);
L=L.solve();
PlotResult(L);
PlotResult(L,'MC',1);
```

A Matrix :.

1.0e+04 *

1	2.7401	2.1209	0.0000
2	2.1209	2.7401	0.0000
3	0.0000	0.0000	2.2626

B Matrix :.

1.0e-12 *

-0.2274	0	0.2274
0	-0.2274	0.2274
0.2274	0.2274	-0.2274

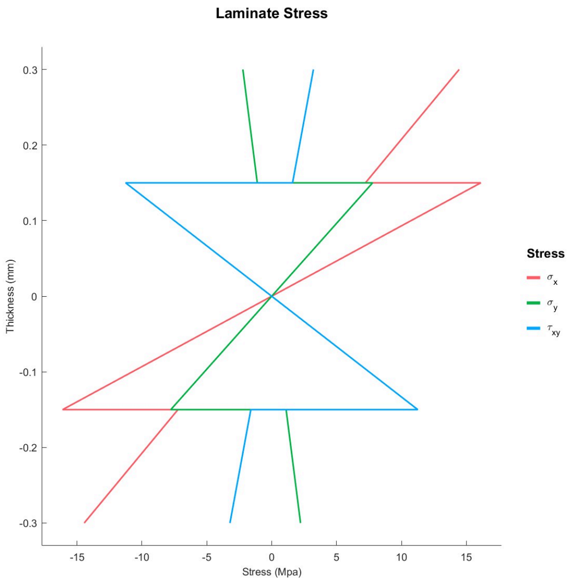
D Matrix :.

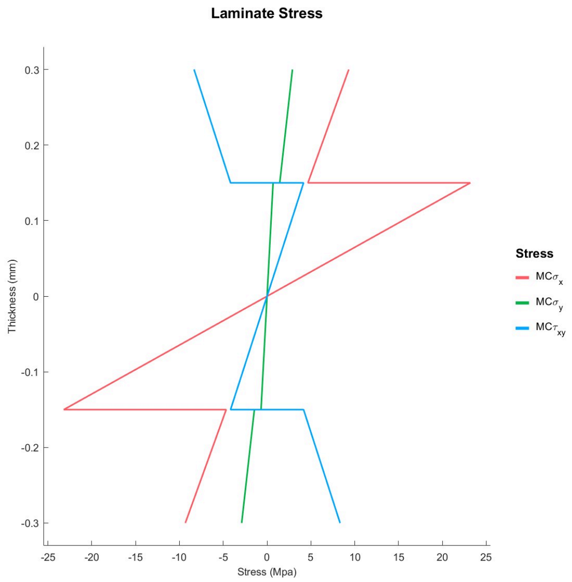
822.0321	636.2721	468.9640
636.2721	822.0321	468.9640
468.9640	468.9640	678.7924

Laminate effective properties :.

Ex Ey Nuxy Gxy Alpha_x Alpha_y Alpha_xy.

18307.9217 18307.9217 0.774023421 37710.6905 2.11507815e-06 2.11507815e-06





3.5 Calculate UD lamminate failure Criterion (Flag=5)

```
S=RMaterial('Composite');
mat=GetMat(S,21);
type=2;
switch type
  case 1
    inputStruct.Orient=0;
    inputStruct.Tply=1;
    inputStruct.Plymat=1;
  case 2
    inputStruct.Orient=45;
    inputStruct.Tply=1;
    inputStruct.Plymat=1;
end
inputStruct.Load.Type  = [2, 2, 2, 2, 2, 2];
inputStruct.Load.Value = [1000, 0, 0, 0, 0, 0];
paramsStruct.Material=mat;
paramsStruct.Criterion=7;% Change method to get different results
L= plate.Laminate(paramsStruct, inputStruct);
L=L.solve();
PlotResult(L,'MC',1);
```

A Matrix :.

1.0e+04 *

1	4.5668	3.5348	3.4738
2	3.5348	4.5668	3.4738
3	3.4738	3.4738	3.7711

B Matrix :.

0 0 0

0 0 0

0 0 0

D Matrix :.

1.0e+03 *

```
3.8057     2.9457     2.8948
2.9457     3.8057     2.8948
2.8948     2.8948     3.1426
```

Laminate effective properties :.

Ex Ey Nuxy Gxy Alpha_x Alpha_y Alpha_xy.

12848.2864 12848.2864 0.244988988 7921.01413 1.545e-05 1.545e-05

Successfully add output geometry .

Successfully Calculate Laminate safety .

Laminate min MoS :

-0.9123

-0.9123

Laminate min SF :

0.0877

0.0877

3.6 Calculate lamminate [60,-60,0]s failure Criterion (Flag=6)

```
S=RMaterial('Composite');
mat=GetMat(S,21);
inputStruct.Orient=[60;-60;0;0;-60;60];
inputStruct.Tply=repmat(0.15,6,1);
inputStruct.Plymat=ones(6,1);
inputStruct.Load.Type  = [2, 2, 2, 2, 2, 2];
% inputStruct.Load.Value = [300, 0, 0, 0, 0, 0];
inputStruct.Load.Value = [0, 300, 0, 0, 0, 0];
paramsStruct.Material=mat;
paramsStruct.Criterion=5;% Change method to get different results
L= plate.Laminate(paramsStruct, inputStruct);
L=L.solve();
PlotResult(L,'MC',1);
```

A Matrix :.

1.0e+04 *

```
5.5749     1.7166    -0.0000
1.7166     5.5749    -0.0000
```

-0.0000 -0.0000 1.9292

B Matrix :.

1.0e-12 *

-0.6821 0 0.3411

0.4547 0.9095 0.4547

0.3411 0.4547 0.4547

D Matrix :.

1.0e+03 *

```
1.4478    1.5981    0.4317
1.5981    5.1995    1.1928
0.4317    1.1928    1.7416
```

Laminate effective properties :.

Ex Ey Nuxy Gxy Alpha_x Alpha_y Alpha_xy.

56070.9982   56070.9982   0.307909847   21435.3452 2.11507815e-06 2.11507815e-06

Successfully add output geometry .

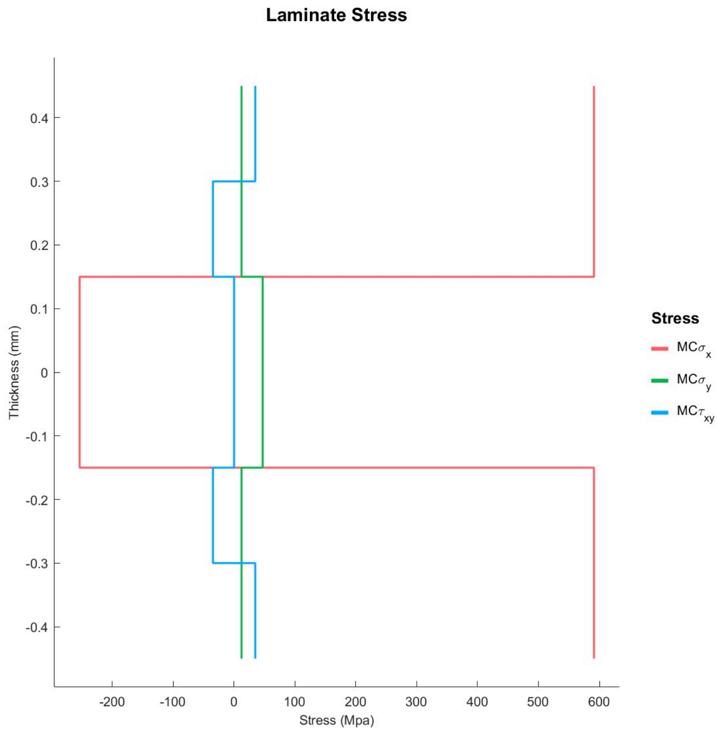
Successfully Calculate Laminate safety .

Laminate min MoS :

0.9730
0.9730
0.9730
0.9730
-0.0052
-0.0052
-0.0052
-0.0052
0.9730
0.9730
0.9730
0.9730

Laminate min SF :

1.9730
1.9730
1.9730
1.9730
0.9948
0.9948
0.9948
0.9948
1.9730
1.9730
1.9730
1.9730



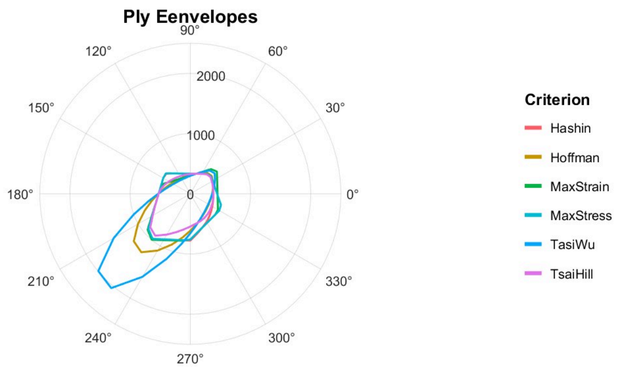
3.7 Ply-level failure envelopes (Flag=7)

```
S=RMaterial('Composite');
mat=GetMat(S,21);
Type=2;
switch Type
  case 1
    inputStruct.Orient=0;
    inputStruct.Tply=1;
    inputStruct.Plymat=1;
  case 2
    inputStruct.Orient=[60;-60;0;0;-60;60];
    inputStruct.Tply=repmat(0.15,6,1);
    inputStruct.Plymat=ones(6,1);
end
paramsStruct.Material=mat;
Env=NaN(37,6);

for i=1:37
  theta=(i-1)*10;
  inputStruct.Load.Type  = [2, 2, 2, 2, 2, 2];
  inputStruct.Load.Value = [cos(theta/180*pi), sin(theta/180*pi), 0, 0, 0, 0];
  for j=1:6
    paramsStruct.Criterion=j;
    L= plate.Laminate(paramsStruct, inputStruct);
    L=L.solve();
    Env(i,j)=min(L.output.Safety.SFmin);
  end
end

% Plot Env
x=0:360/36:360;
Env=mat2cell(Env',ones(1,6));
```

```
g=Rplot('x',x,'y',Env,'Color',
{'MaxStress','MaxStrain','TsaiHill','Hoffman','TasiWu','Hashin'});
g=geom_radar(g);
g=set_title(g,'Ply Eenvelopes');
g=set_names(g,'column','Origin','color','Criterion');
figure('Position',[100 100 800 400]);
draw(g)
```



4 参考文献

[1] Practical Micromechanics of Composite Materials