GENLAM: GENERAL LAMINATE

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GENLAM: TABLE OF CONTENTS

GENLAM: FIRST WINDOW – START UP

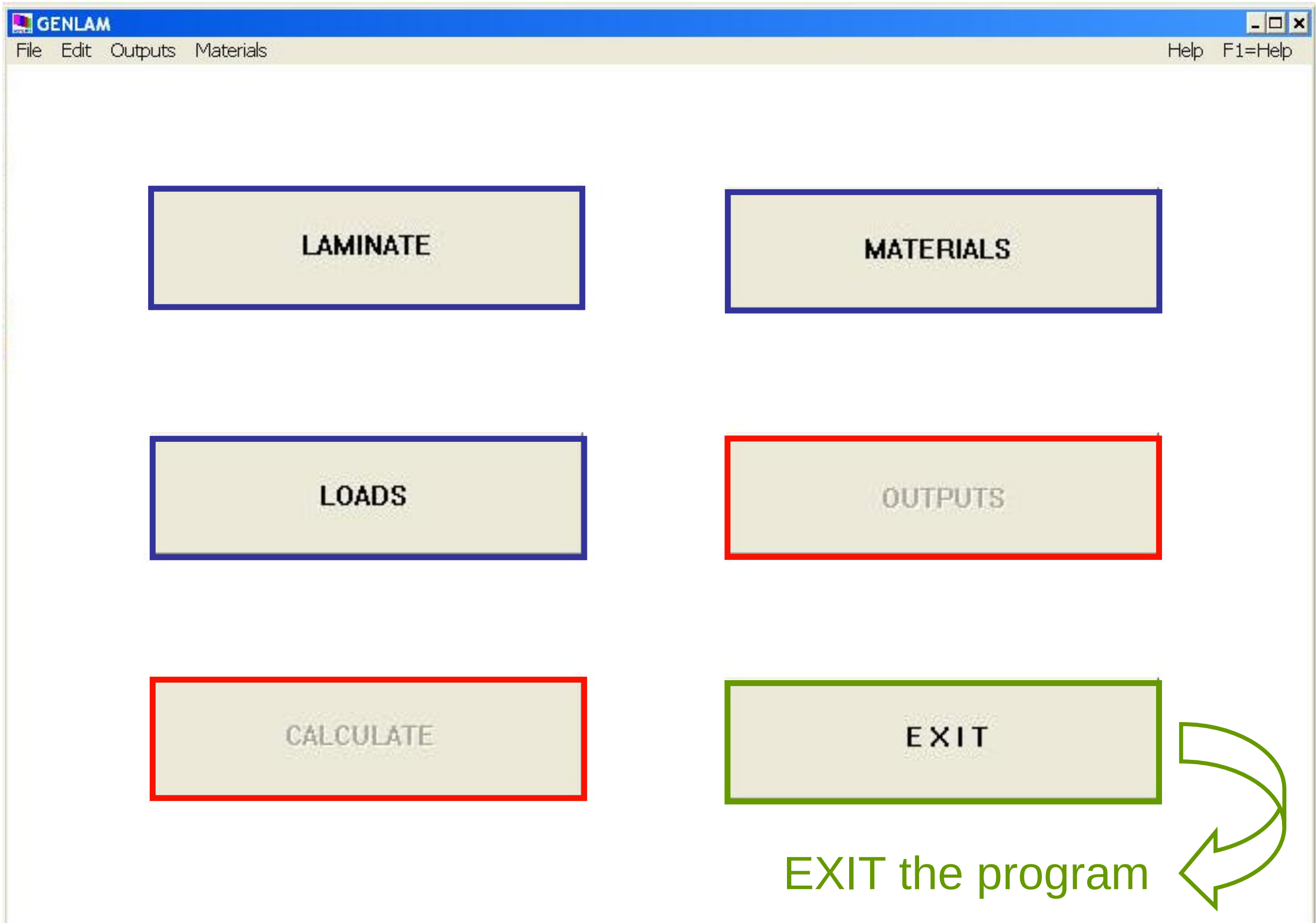
Continue to the GenLam Main Window

Go to HELP on-line

GENLAM: SECOND WINDOW – MAIN WINDOW

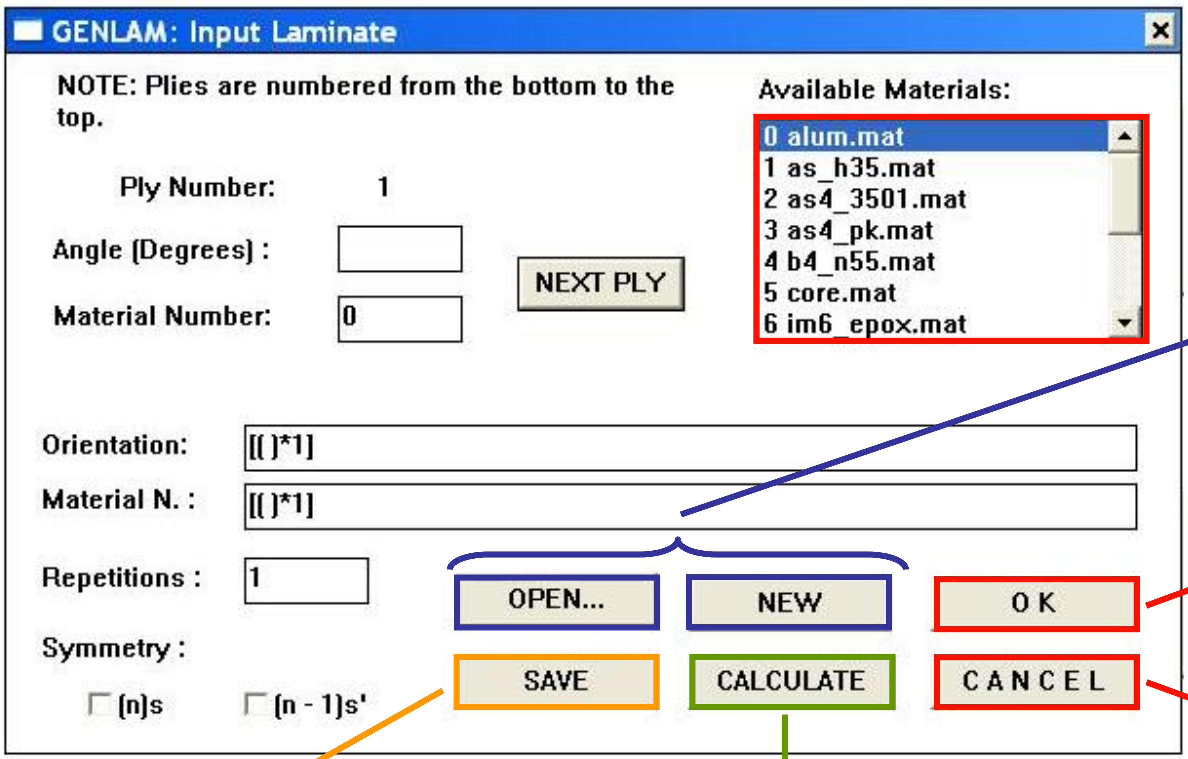
INPUT (highlighted):
LAMINATE / MATERIALS / LOADS

After INPUT is given:
CALCULATE / OUTPUTS



GENLAM: INPUT LAMINATE

Material database



User can OPEN an existing saved laminate or start a NEW laminate

OK returns the user to GenLam Main Window

CANCEL clear this input and returns the user to the Main Window

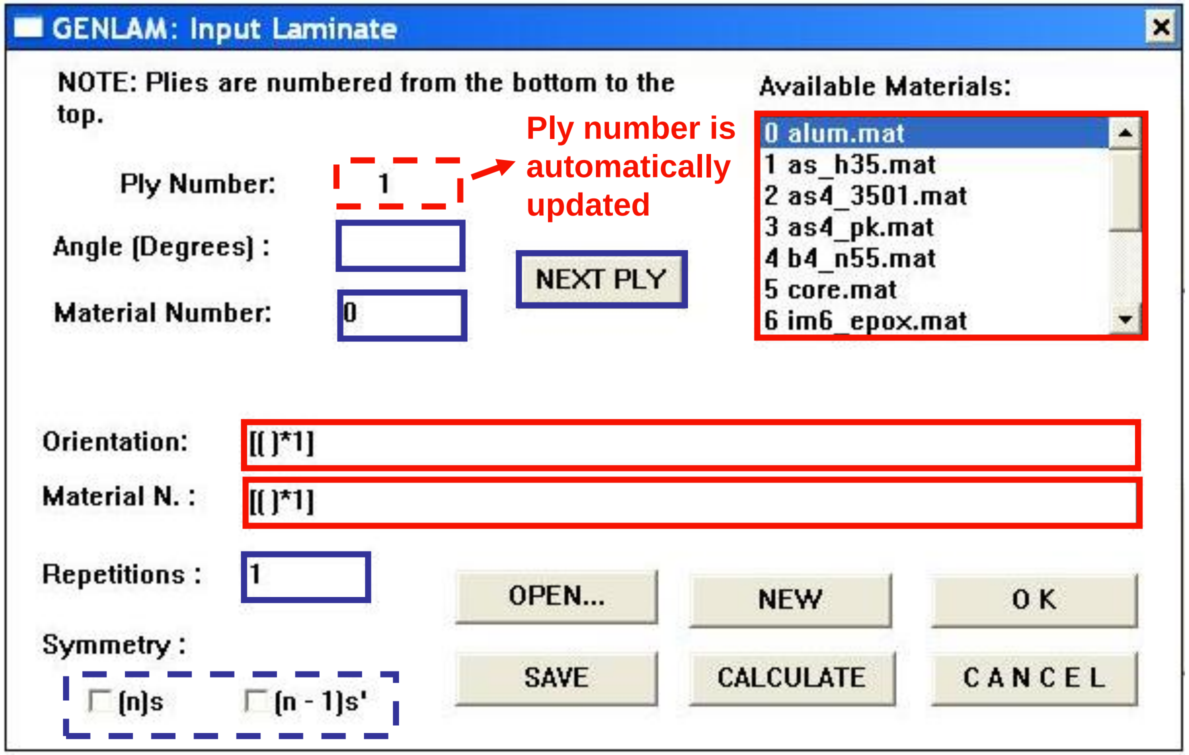
SAVE will save the input laminate to a file

User have the option of CALCULATE from this window without having to go back to the Main Window

GENLAM: INPUT LAMINATE

Angle (degrees) and Material Number should be given ply-by-ply (NEXT PLY)

Material database



Number of repetitions and symmetry condition should also be given (mark)

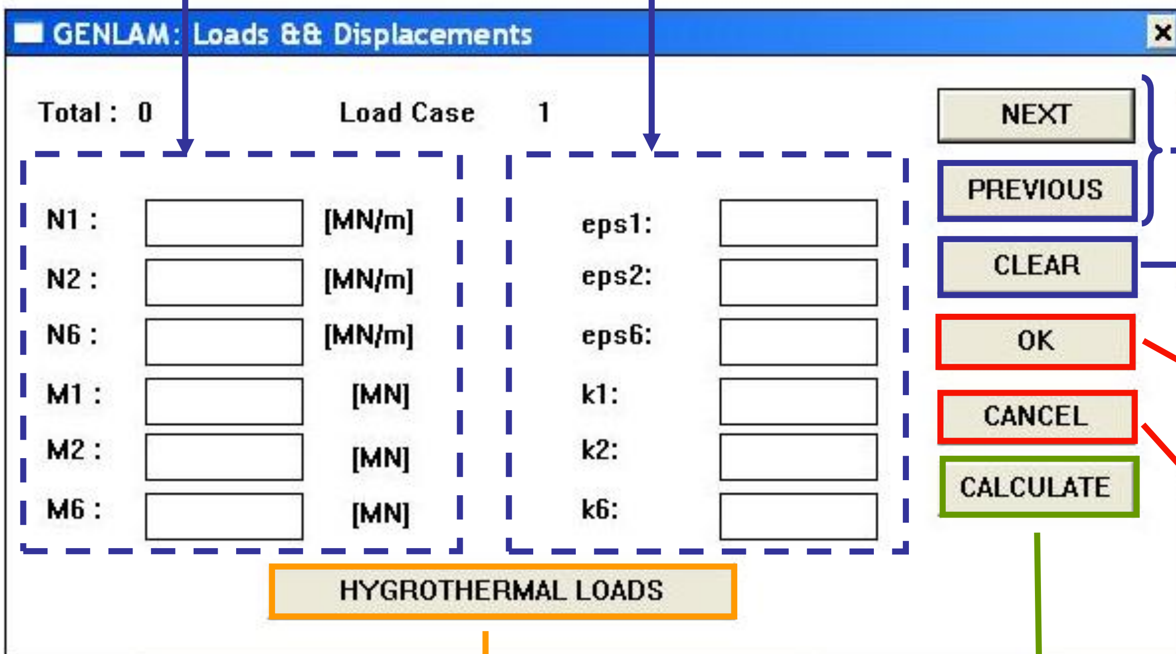
Lay-up Orientation and Material Number are automatically filled ply-by-ply

GENLAM: INPUT LOADS & DISPLACEMENTS

Hybrid input

Loads
(load vector)

Displacements
(strains and curvatures)



NEXT and PREVIOUS change the window to sequential load cases

User can CLEAR the input data at any time

OK returns the user to GenLam Main Window

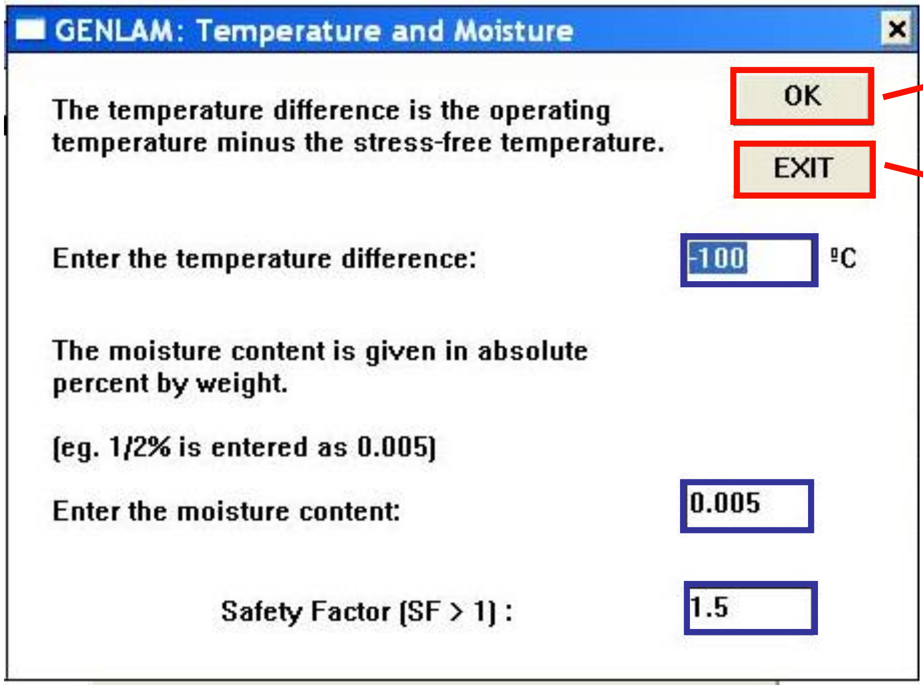
CANCEL clear this input and returns the user to the Main Window

HYGROTHERMAL LOADS may be given using this button

User have the option of CALCULATE from this window without having to go back to the Main Window

GENLAM: INPUT LOADS & DISPLACEMENTS

HYGROTHERMAL LOADS (TEMPERATURE & MOISTURE)



OK returns the user to Load Window

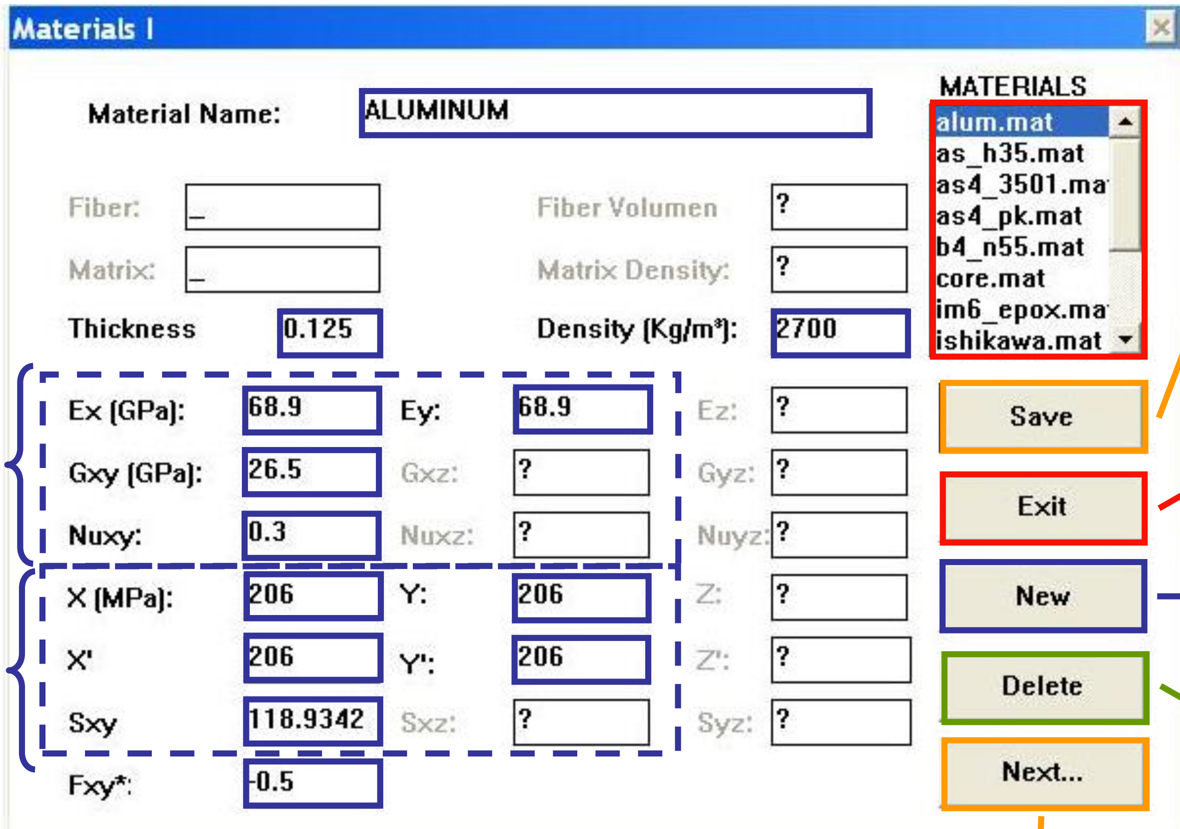
EXIT clear this input and returns the user to the Load Window

Temperature Difference (ΔT), Moisture Content (Δc) and Safety Factor should be given

GENLAM: INPUT MATERIALS I

Material Name and ply properties should be given

Material database



Ply Stiffness

Ply Strength

Tsai-Wu coupling coefficient

SAVE the input material to a file

EXIT returns to Main Window

Input NEW material

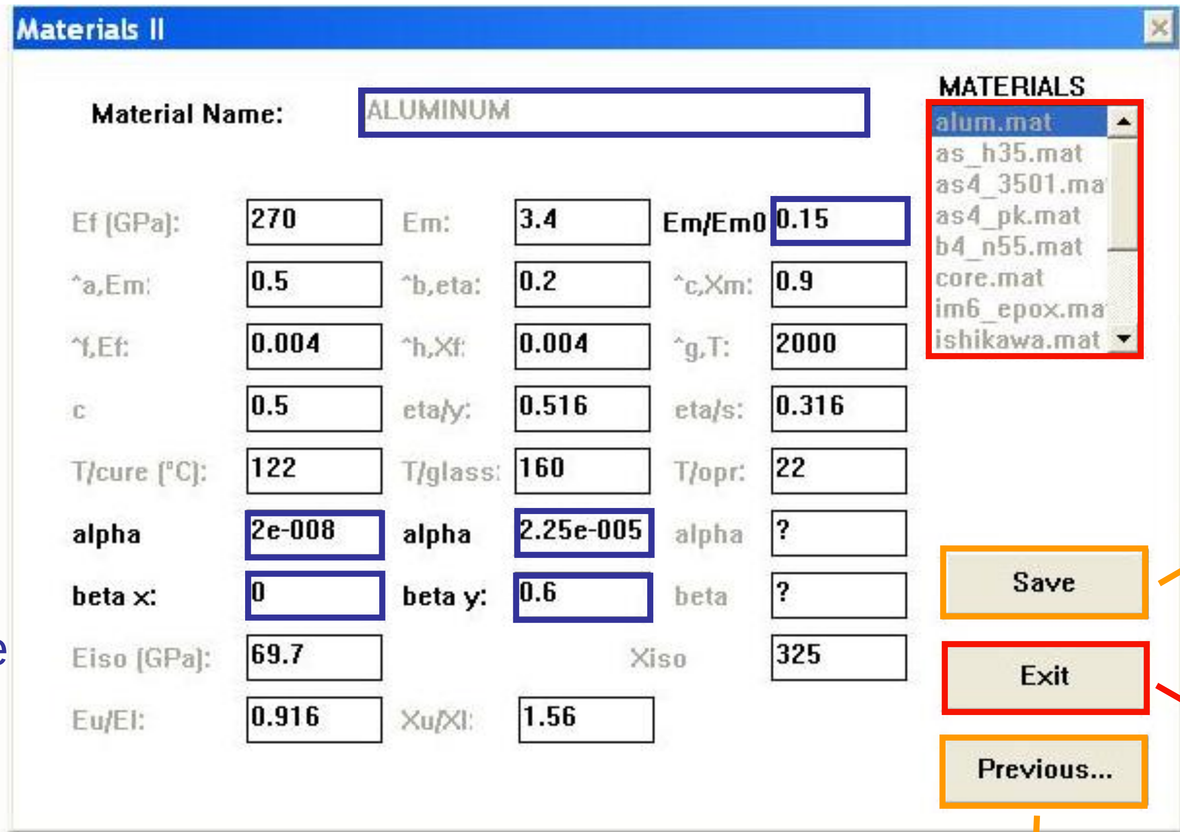
DELETE material

NEXT takes the user to the Materials II Window

GENLAM: INPUT MATERIALS II

Ply hygrothermal coefficients should be given

Material database



Ply thermal expansion coefficients

Ply moisture expansion coefficients

SAVE the input material to a file

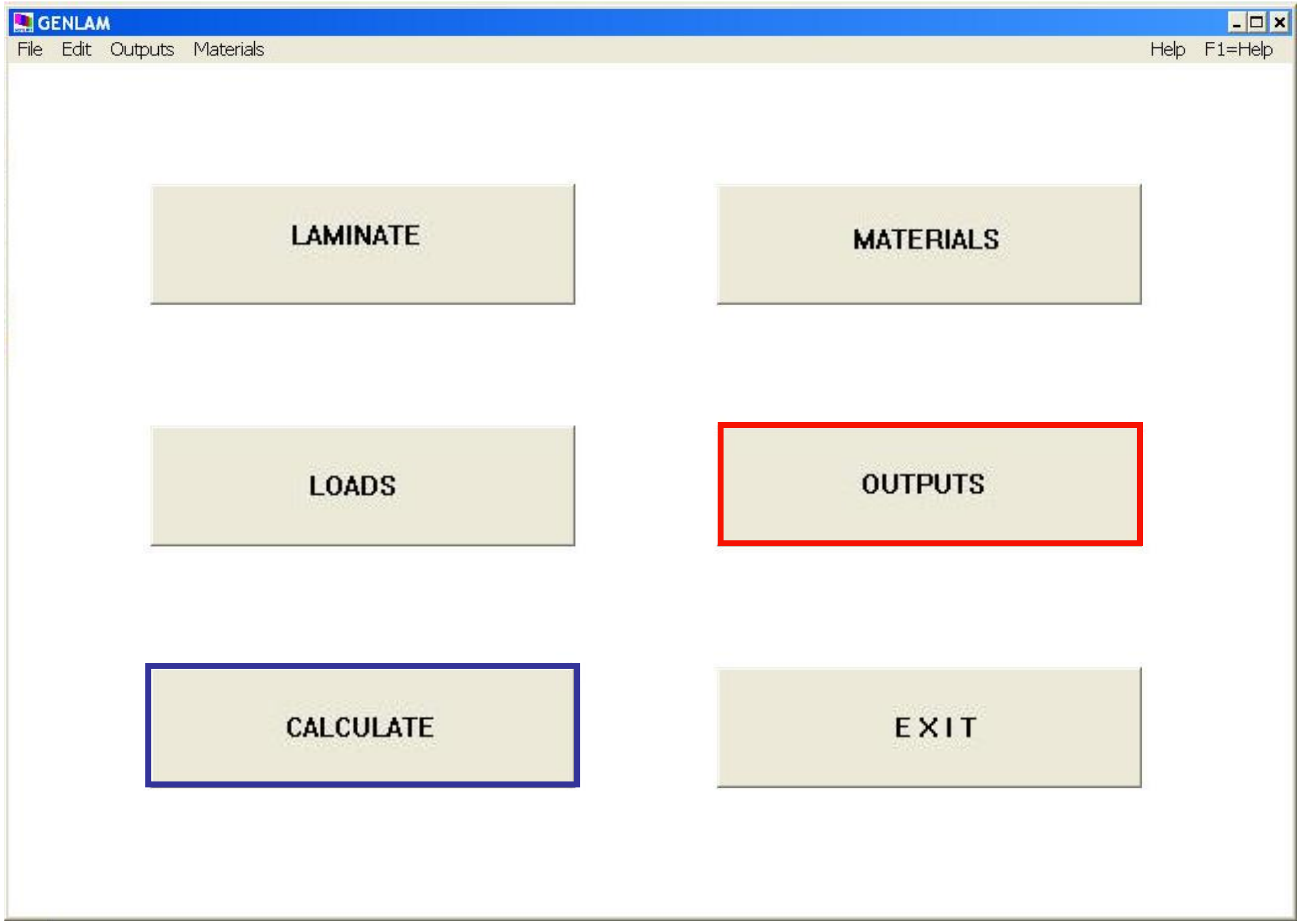
EXIT returns to Main Window

PREVIOUS takes the user to the Materials I Window

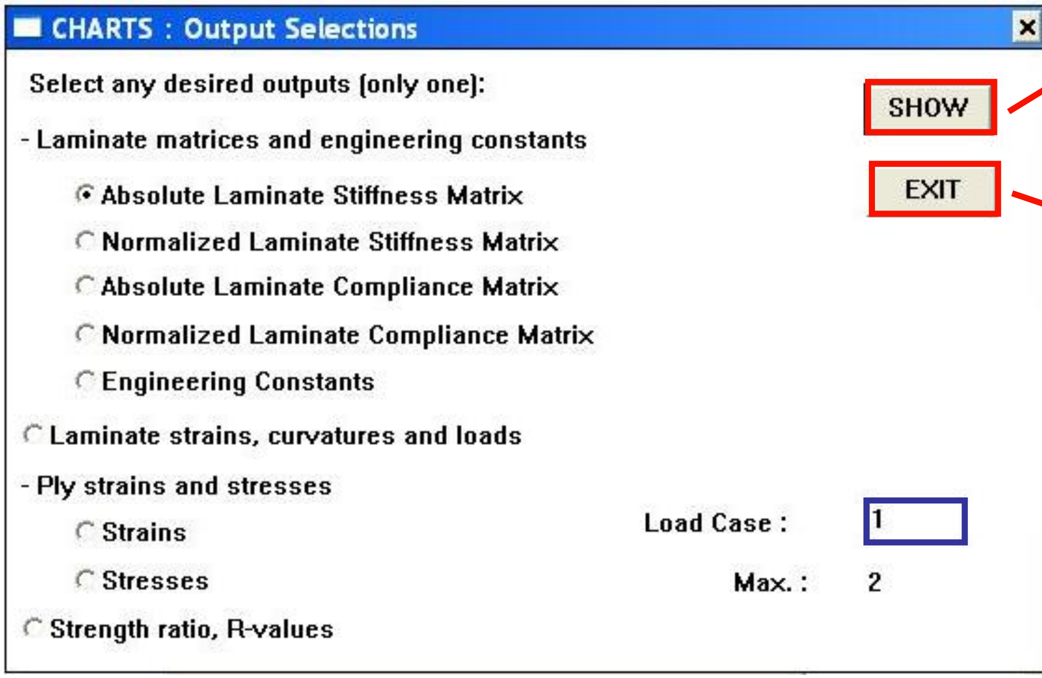
GENLAM: CALCULATE

CALCULATE is highlighted after given LAMINATE / MATERIALS / LOADS

After CALCULATE user can see the OUTPUTS (also highlighted)



GENLAM: OUTPUTS

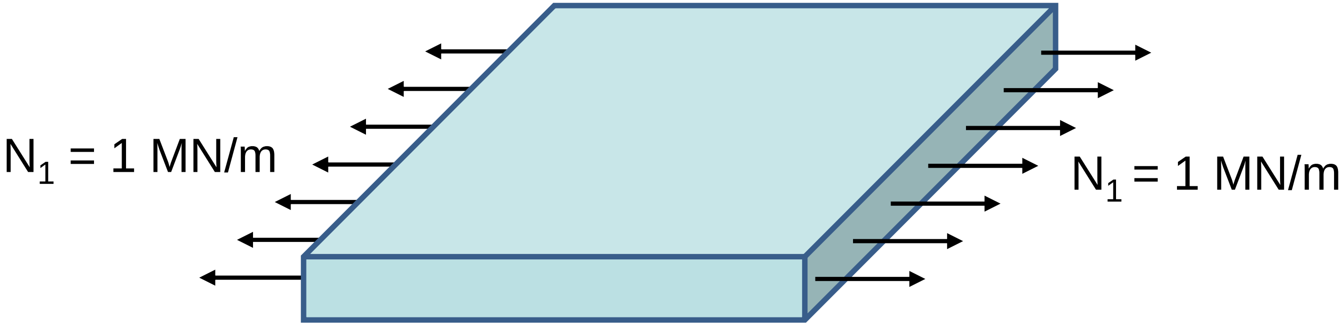


SHOW takes the user to the selected Results Window

EXIT clear this input and returns the user to the Main Window

User should select one of the items: Absolute and Normalized Stiffness and Compliance Matrices, Ply Strain and Stress distributions, Tsai-Wu Strength Ratio for a given Load Case

GENLAM: EXAMPLE 1



Material: T300/5208

Layups: [(0/90)$_r$] (cross-ply) and [(+45/-45)$_r$] (angle-ply)

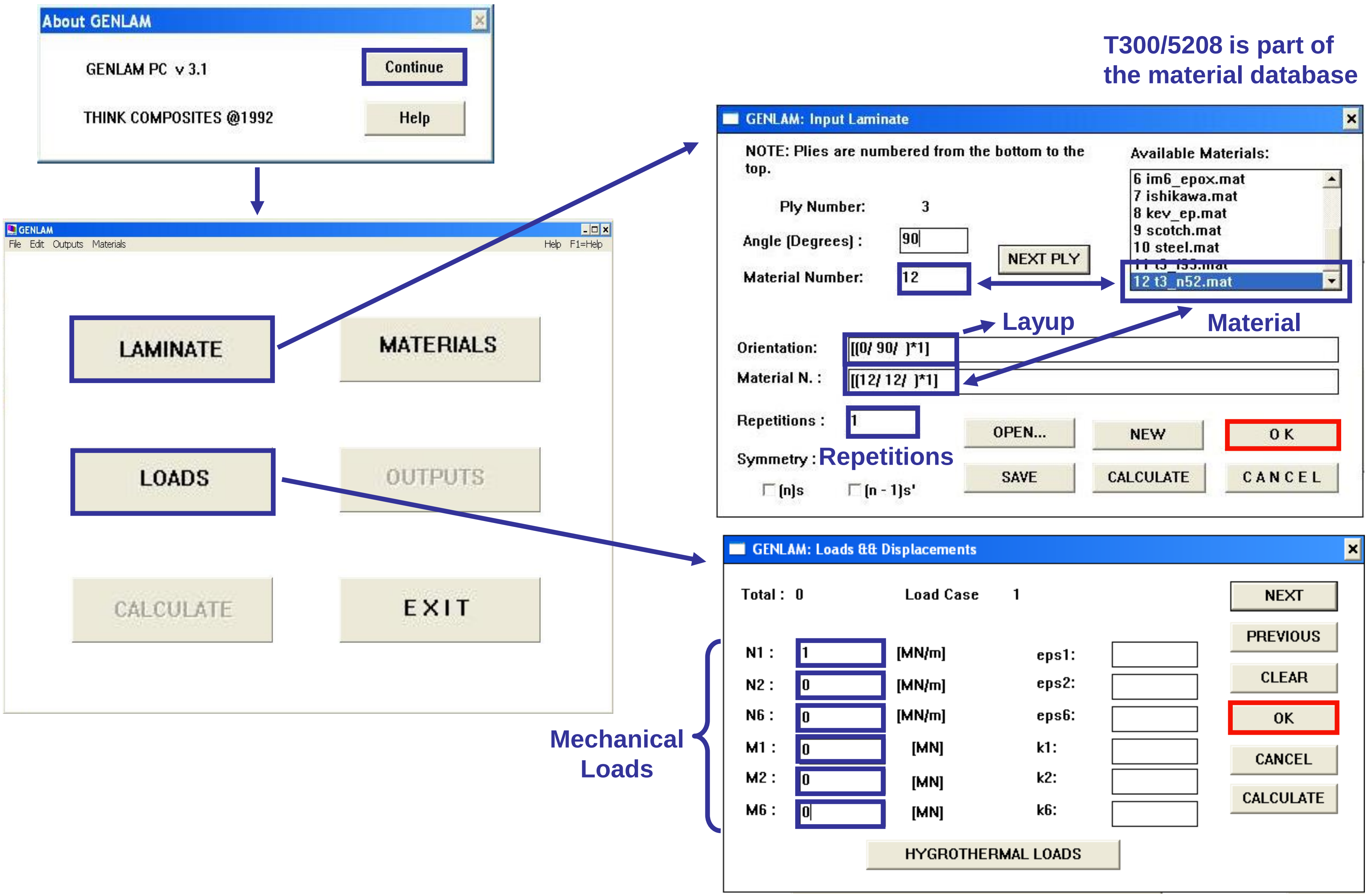
Load vectors: N={1,0,0} [MN/m]; M={0,0,0} [MN]

No hygrothermal effects (ΔT=Δc=0)

Vary repeating index r from 1 to 10

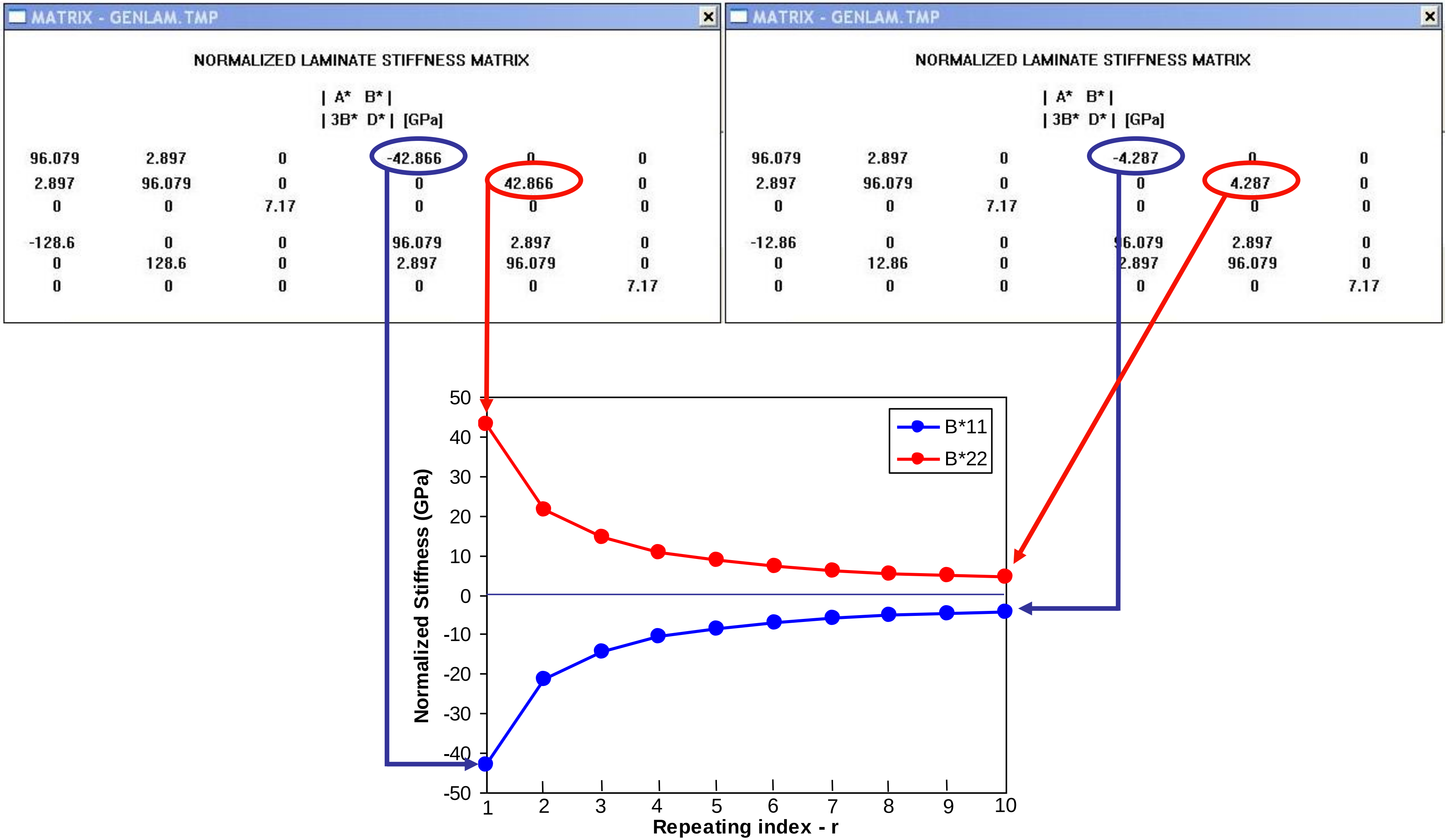
Check coupling B* matrix

GENLAM: EXAMPLE 1 – INPUT [(0/90)$_r$]



GENLAM: EXAMPLE 1 – OUTPUT B* [$(0/90)_r$]

r = 1 … r = 10



r = 1:

96.079	2.897	0	-42.866	0	0
2.897	96.079	0	0	42.866	0
0	0	7.17	0	0	0
-128.6	0	0	96.079	2.897	0
0	128.6	0	2.897	96.079	0
0	0	0	0	0	7.17

r = 10:

96.079	2.897	0	-4.287	0	0
2.897	96.079	0	0	4.287	0
0	0	7.17	0	0	0
-12.86	0	0	96.079	2.897	0
0	12.86	0	2.897	96.079	0
0	0	0	0	0	7.17

GENLAM: EXAMPLE 1 – OUTPUT B* $[(0/90)_r]$

r = 1 … r = 10

MATRIX - GENLAM.TMP (r = 1)

NORMALIZED LAMINATE STIFFNESS MATRIX

| A* B* |
| 3B* D* | [GPa]

96.079	2.897	0	-42.866	0	0
2.897	96.079	0	0	42.866	0
0	0	7.17	0	0	0
-128.6	0	0	96.079	2.897	0
0	128.6	0	2.897	96.079	0
0	0	0	0	0	7.17

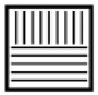
MATRIX - GENLAM.TMP (r = 10)

NORMALIZED LAMINATE STIFFNESS MATRIX

| A* B* |
| 3B* D* | [GPa]

96.079	2.897	0	-4.287	0	0
2.897	96.079	0	0	4.287	0
0	0	7.17	0	0	0
-12.86	0	0	96.079	2.897	0
0	12.86	0	2.897	96.079	0
0	0	0	0	0	7.17

Analysis shows that B^*_{11} and B^*_{22} are inversely proportional to r

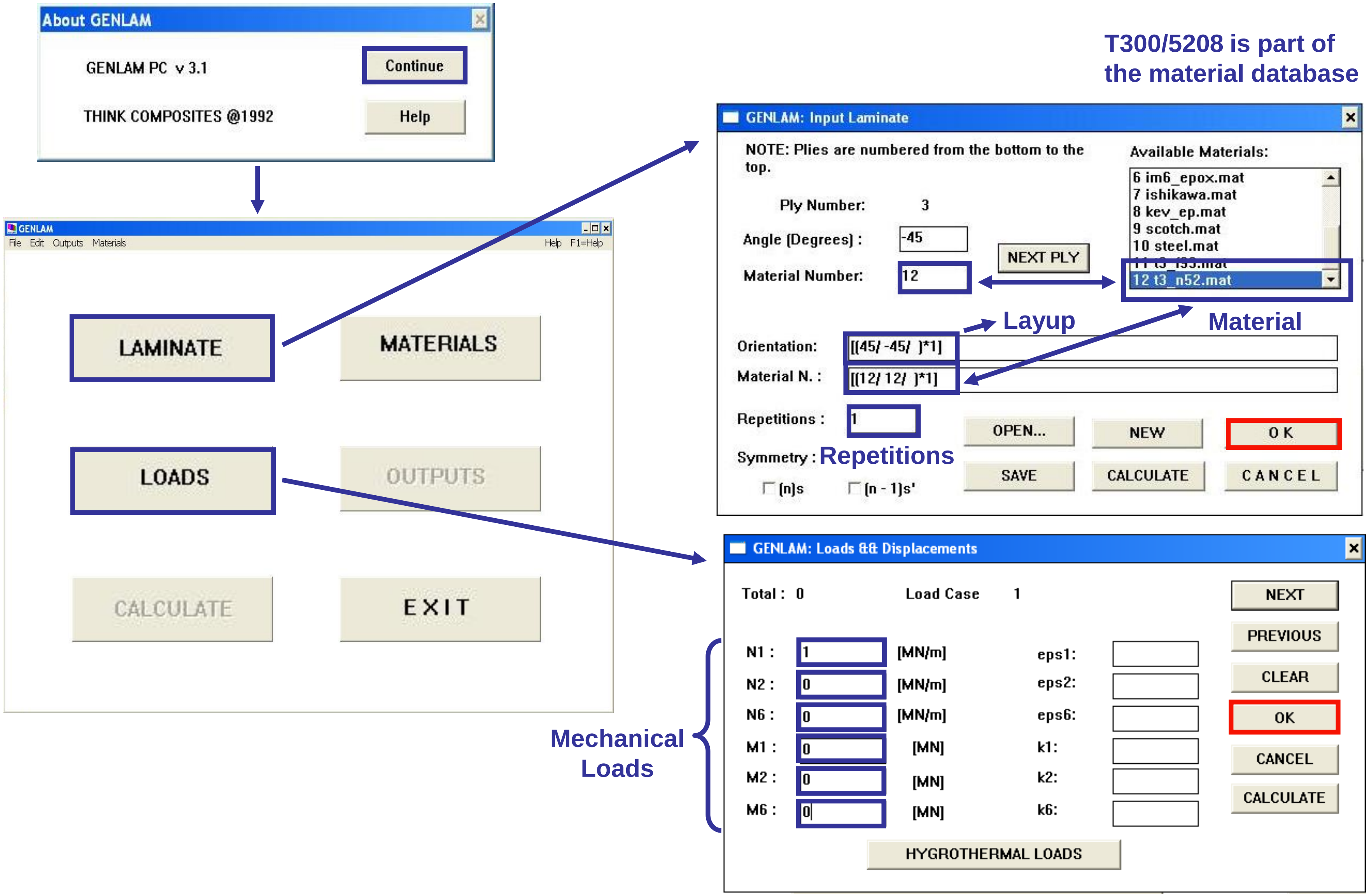


$[0/90]_{rT}$

$$\begin{bmatrix} A^*_{ij} & B^*_{ij} \\ 3B^*_{ij} & D^*_{ij} \end{bmatrix} = \left[\begin{array}{ccc|ccc} 96.0 & 2.9 & 0 & -\frac{42.8}{r} & 0 & 0 \\ 2.9 & 96.0 & 0 & 0 & \frac{42.8}{r} & 0 \\ 0 & 0 & 7.2 & 0 & 0 & 0 \\ \hline -\frac{128.6}{r} & 0 & 0 & 96.0 & 2.9 & 0 \\ 0 & \frac{128.6}{r} & 0 & 2.9 & 96.0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 7.2 \end{array}\right]$$

FIGURE 6.6 NORMALIZED STIFFNESS MATRIX OF A CROSS-PLY LAMINATE, HAVING COUPLING COMPONENTS WHICH DECAY WITH REPEATING INDEX

GENLAM: EXAMPLE 1 – INPUT $[(+45/-45)_r]$



GENLAM: EXAMPLE 1 – OUTPUT B* [(+45/-45)$_r$]

r = 1 … **r = 10**

MATRIX - GENLAM.TMP (r = 1)

NORMALIZED LAMINATE STIFFNESS MATRIX

| A* B* |
| 3B* D* | [GPa]

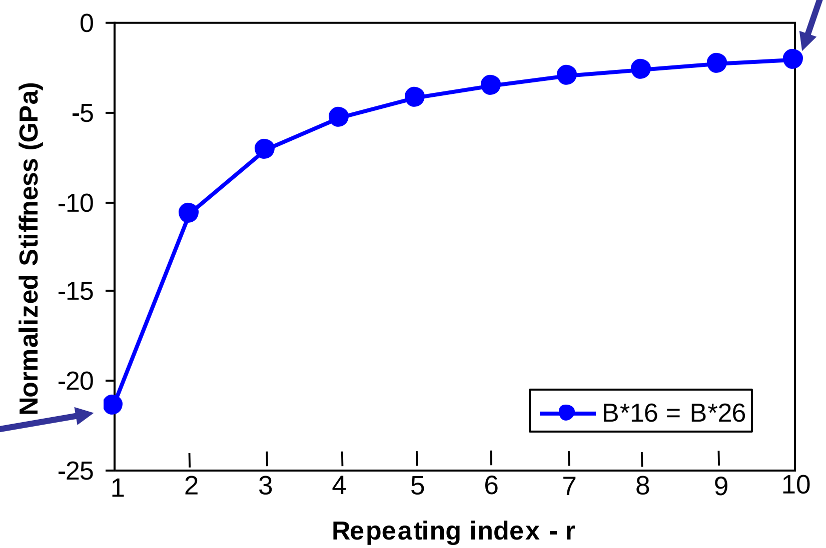
56.658	42.318	0	0	0	-21.433
42.318	56.658	0	0	0	-21.433
0	0	46.591	-21.433	-21.433	0
0	0	-64.299	56.658	42.318	0
0	0	-64.299	42.318	56.658	0
-64.299	-64.299	0	0	0	46.591

MATRIX - GENLAM.TMP (r = 10)

NORMALIZED LAMINATE STIFFNESS MATRIX

| A* B* |
| 3B* D* | [GPa]

56.658	42.318	0	0	0	-2.143
42.318	56.658	0	0	0	-2.143
0	0	46.591	-2.143	-2.143	0
0	0	-6.43	56.658	42.318	0
0	0	-6.43	42.318	56.658	0
-6.43	-6.43	0	0	0	46.591



GENLAM: EXAMPLE 1 – OUTPUT B* [(+45/-45)$_r$]

r = 1 … r = 10

r = 1

MATRIX - GENLAM.TMP

NORMALIZED LAMINATE STIFFNESS MATRIX

| A* B* |
| 3B* D* | [GPa]

56.658	42.318	0	0	0	-21.433
42.318	56.658	0	0	0	-21.433
0	0	46.591	-21.433	-21.433	0
0	0	-64.299	56.658	42.318	0
0	0	-64.299	42.318	56.658	0
-64.299	-64.299	0	0	0	46.591

r = 10

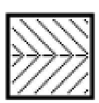
MATRIX - GENLAM.TMP

NORMALIZED LAMINATE STIFFNESS MATRIX

| A* B* |
| 3B* D* | [GPa]

56.658	42.318	0	0	0	-2.143
42.318	56.658	0	0	0	-2.143
0	0	46.591	-2.143	-2.143	0
0	0	-6.43	56.658	42.318	0
0	0	-6.43	42.318	56.658	0
-6.43	-6.43	0	0	0	46.591

Analysis shows that B^*_{16} and B^*_{26} are inversely proportional to r



[45/-45]$_{rT}$

$$\left[\begin{array}{c|c} A^*_{ij} & B^*_{ij} \\ \hline 3B^*_{ij} & D^*_{ij} \end{array}\right] = \left[\begin{array}{ccc|ccc} 56.6 & 42.3 & 0 & 0 & 0 & -\frac{21.4}{r} \\ 42.3 & 56.6 & 0 & 0 & 0 & -\frac{21.4}{r} \\ 0 & 0 & 46.6 & -\frac{21.4}{r} & -\frac{21.4}{r} & 0 \\ \hline 0 & 0 & -\frac{64.3}{r} & 56.6 & 42.3 & 0 \\ 0 & 0 & -\frac{64.3}{r} & 42.3 & 56.6 & 0 \\ -\frac{64.3}{r} & -\frac{64.3}{r} & 0 & 0 & 0 & 46.6 \end{array}\right]$$

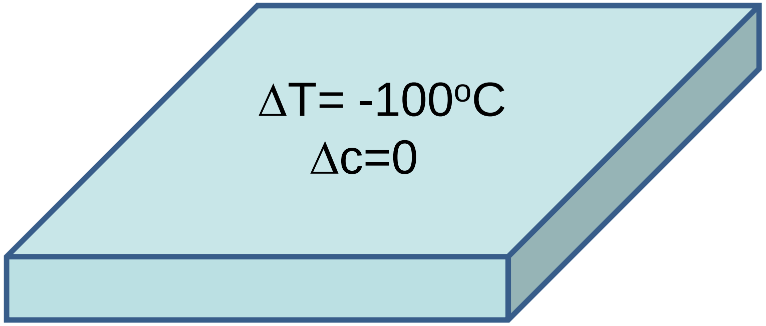
FIGURE 6.14 STIFFNESS MATRIX OF AN UNSYMMETRIC ANGLE-PLY LAMINATE

GENLAM: EXAMPLE 1 - MESSAGE

Terms of coupling B* matrix tend to zero with the increase of the repeating index r

Repeat enough sub-laminates and the resulting non-symmetric laminate behavior will approach to a symmetric laminate

GENLAM: EXAMPLE 2



Material: T300/5208

Layups: $[(0/90)_r]$ (cross-ply) and $[(+45/-45)_r]$ (angle-ply)

No mechanical loading

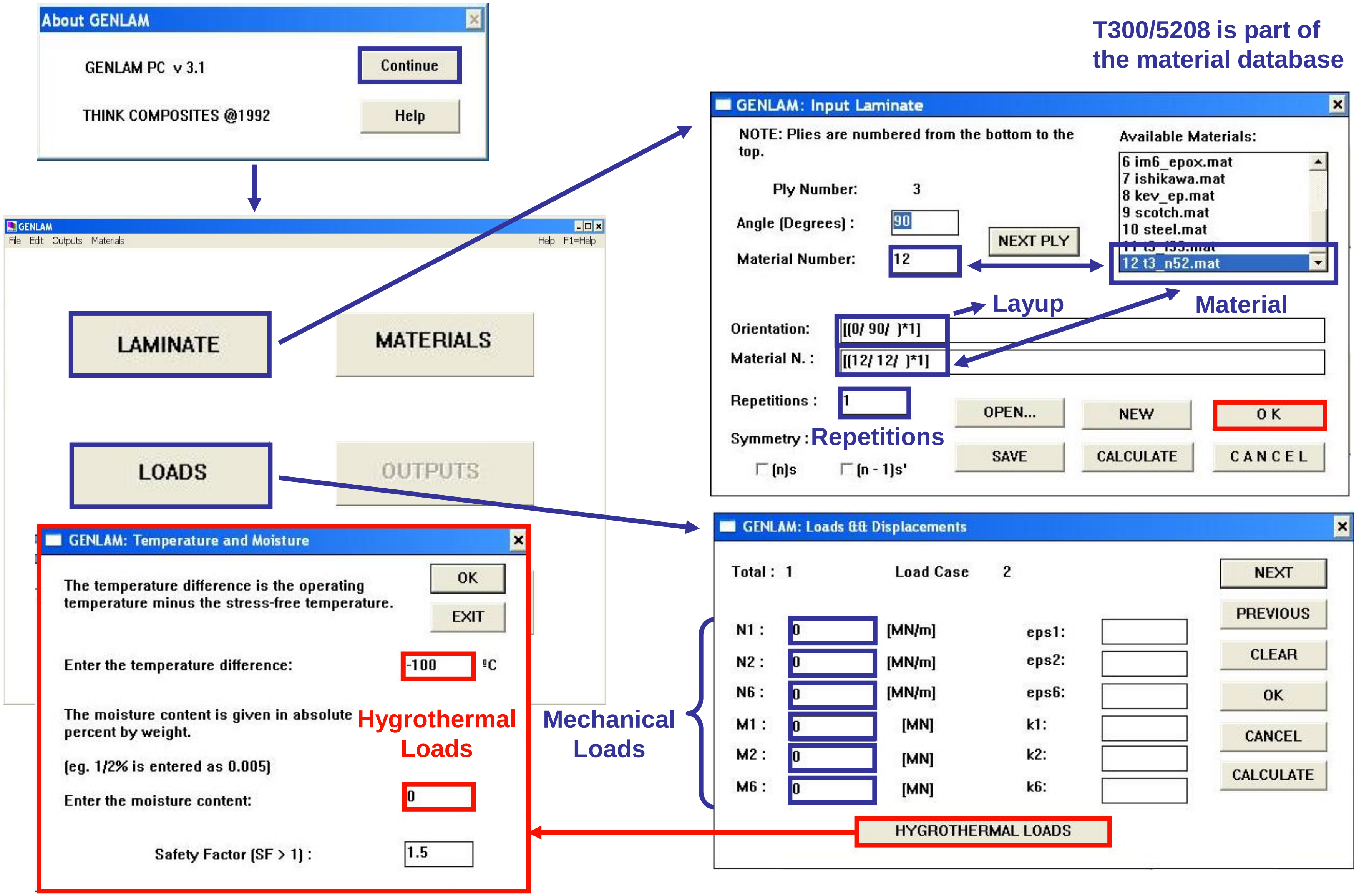
Hygrothermal effects: $\Delta T = -100^oC$; $\Delta c = 0$

Corresponds to laminate getting out of the autoclave

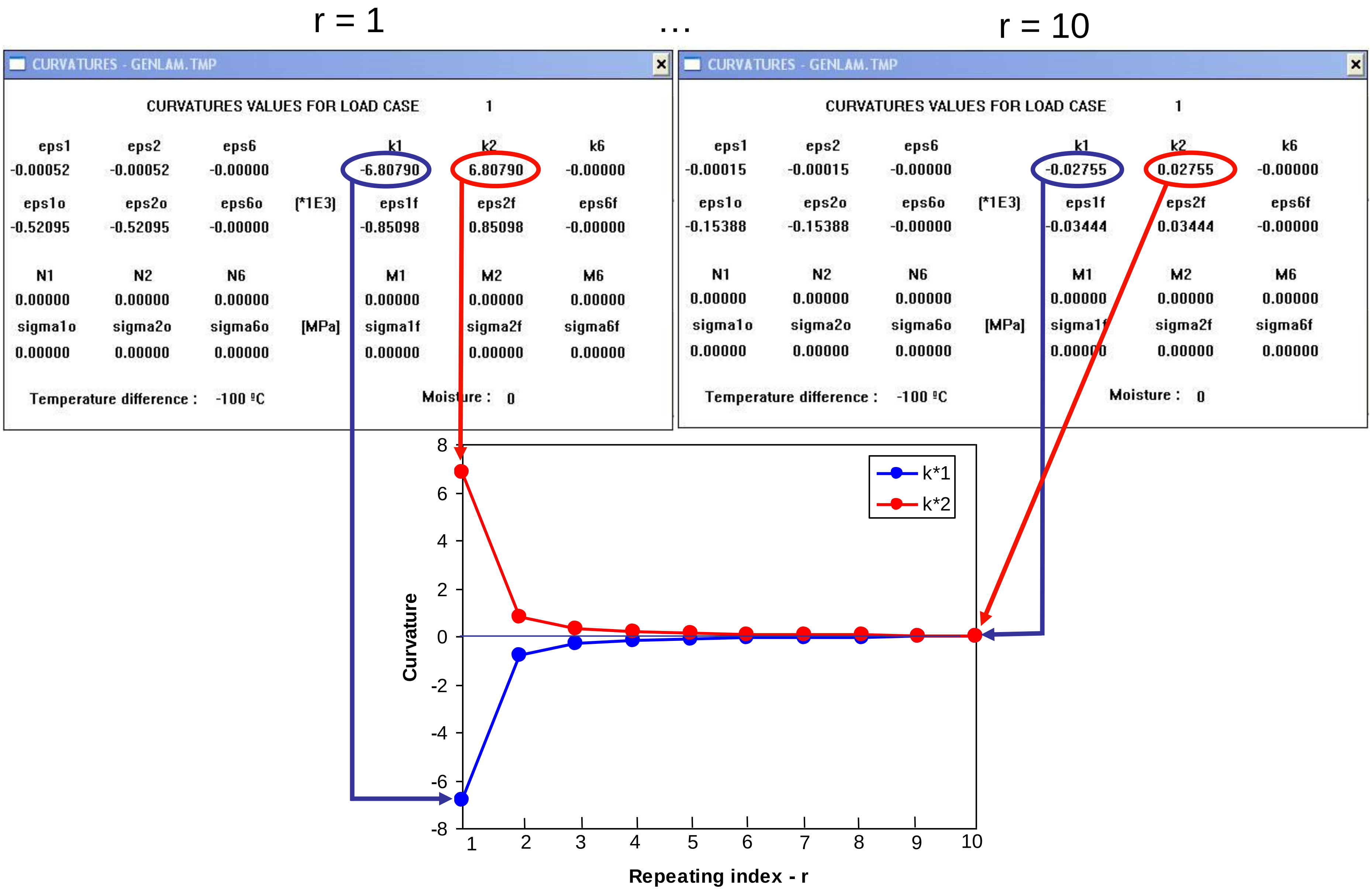
Vary repeating index r from 1 to 10

Check curvature k vector

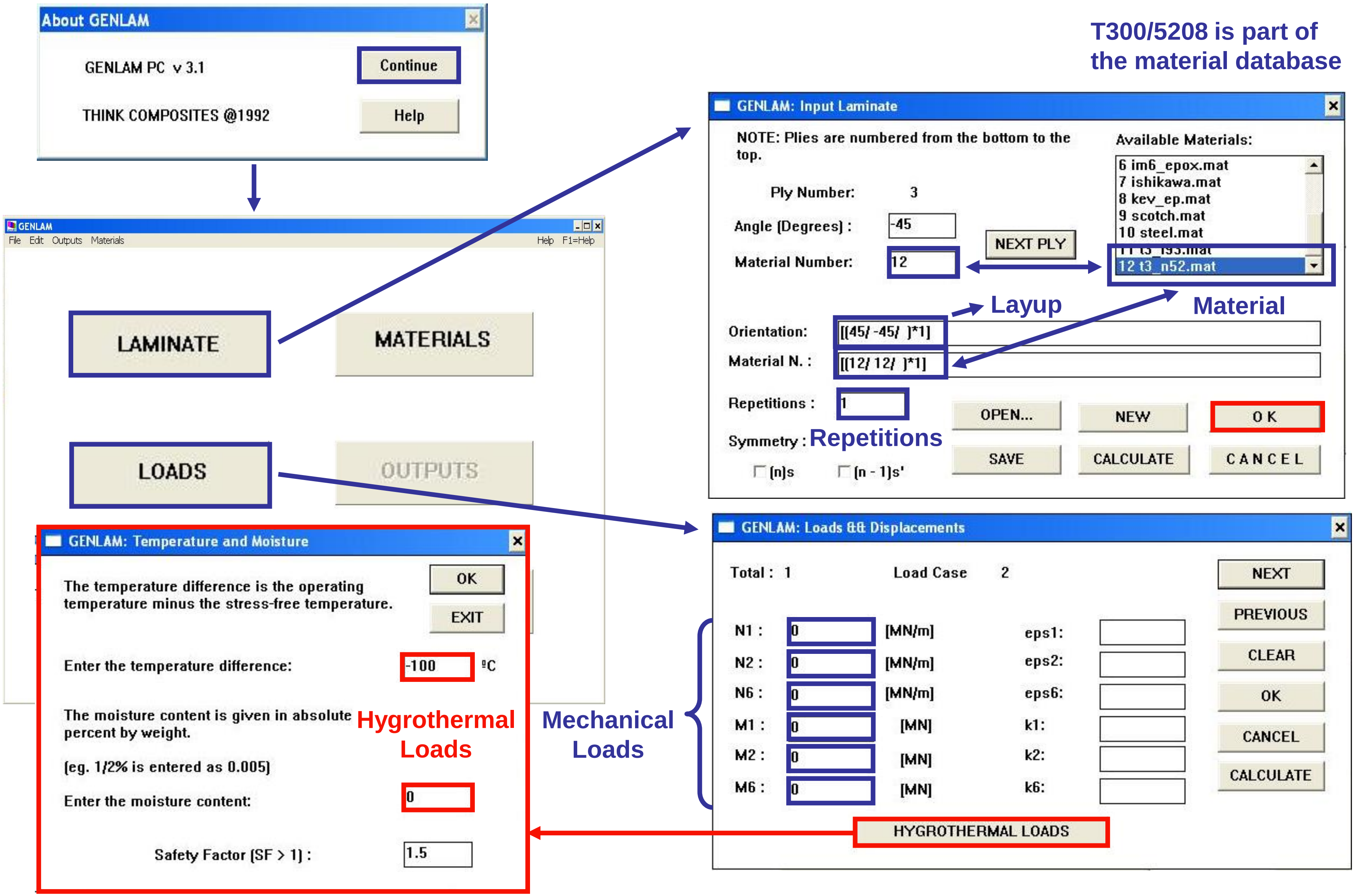
GENLAM: EXAMPLE 2 – INPUT [(0/90)$_r$]



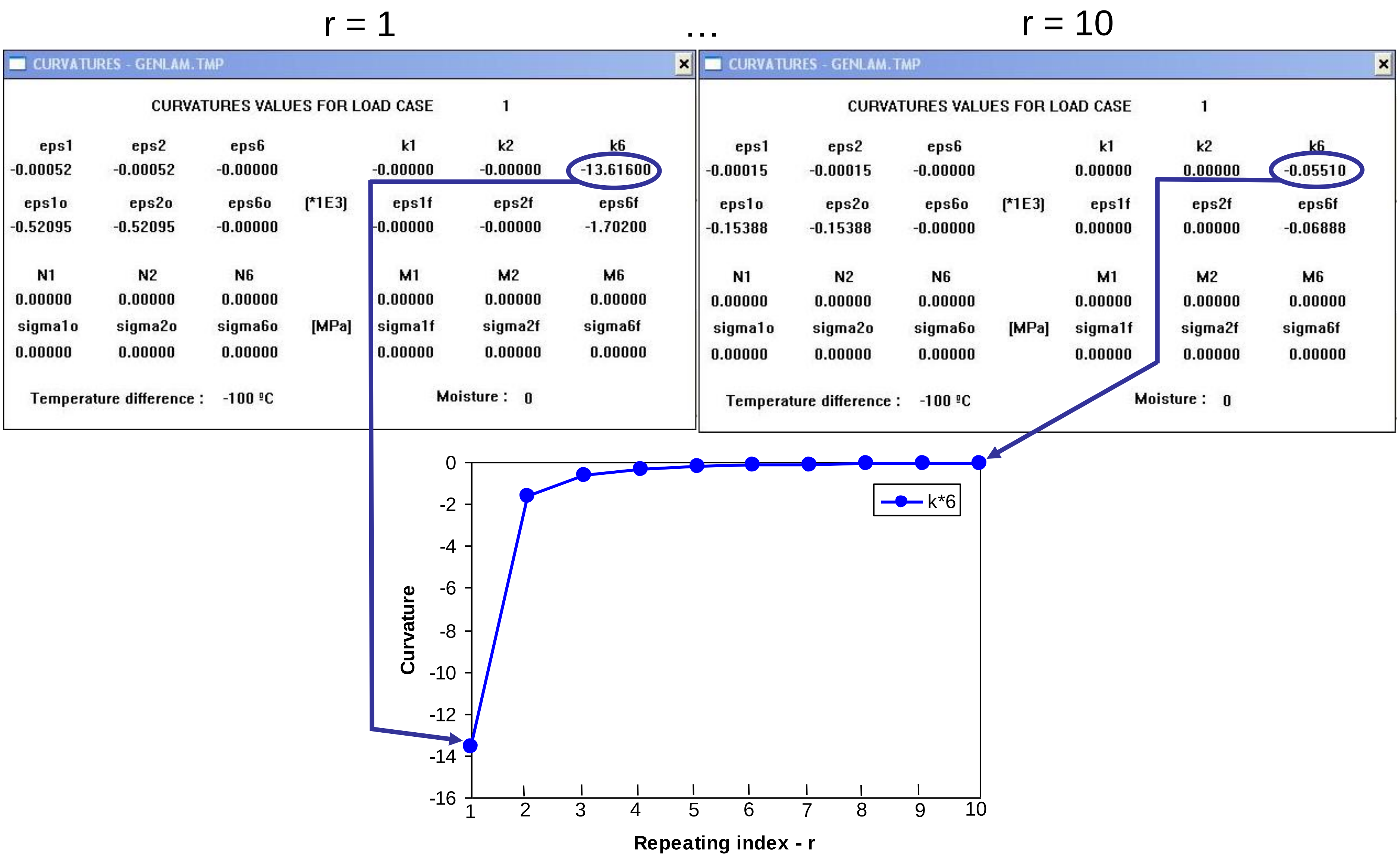
GENLAM: EXAMPLE 2 – OUTPUT k [$(0/90)_r$]



GENLAM: EXAMPLE 2 – INPUT $[(+45/-45)_r]$



GENLAM: EXAMPLE 2 – OUTPUT k $[(+45/-45)_r]$



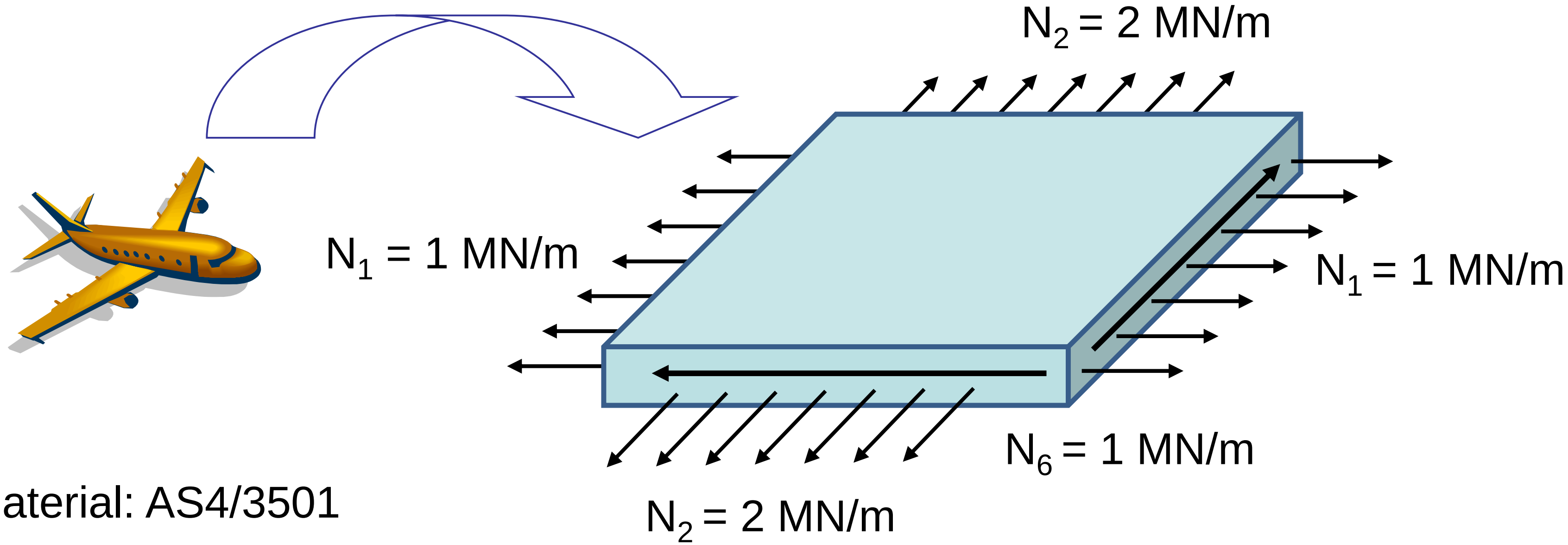
GENLAM: EXAMPLE 2 - MESSAGE

Terms of coupling B* matrix tend to zero with the increase of the repeating index r

Repeat enough sub-laminates and the resulting non-symmetric laminate behavior will approach to a symmetric laminate

No curvature after curing for homogenized laminates

GENLAM: EXAMPLE 3



Material: AS4/3501

Fuselage skin laminate with 60 layers

Layup: [45/-45/90/45/-45/45/-45/0/45/-45/90/45/-45/45/-45/0/45/-45/90/

45/-45/45/-45/0/45/-45/45/-45/45/-45]$_s$ = $[(\pm45/90/\pm45_2/0)_3/\pm45_3]_s$

Load vectors: N={1,2,1} [MN/m]; M={0,0,0} [MN]

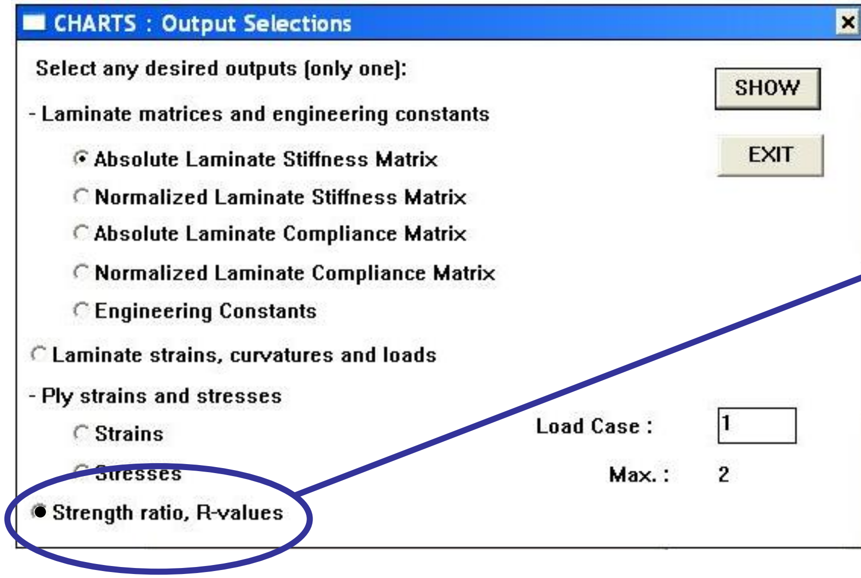
Hygrothermal effects: $\Delta T = -100^oC$; $\Delta c = 0.005$

Find $[(+\varphi\ /\ -\varphi)_{15}]_s$ (same thickness) for better performance

Failure criterion: FPF (First Ply Failure Tsai-Wu)

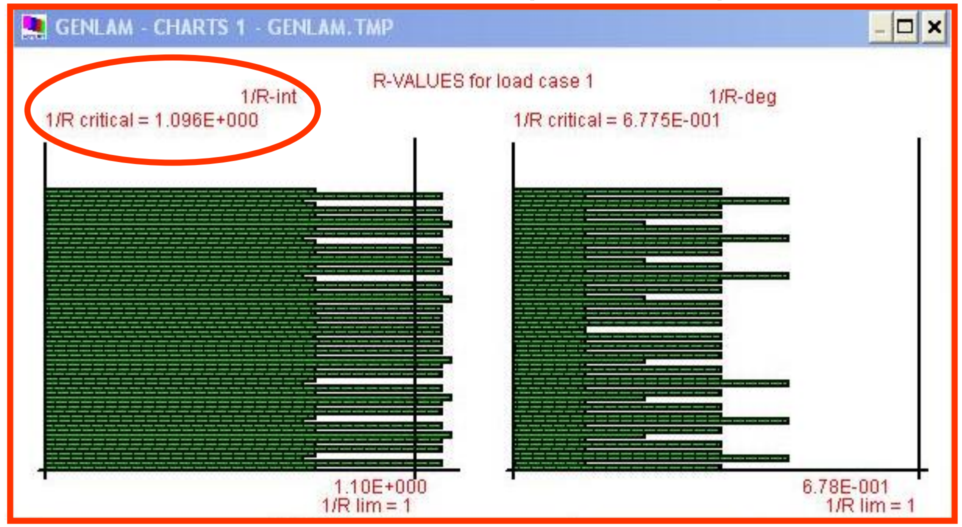
GENLAM: EXAMPLE 3 – FIRST PLY FAILURE

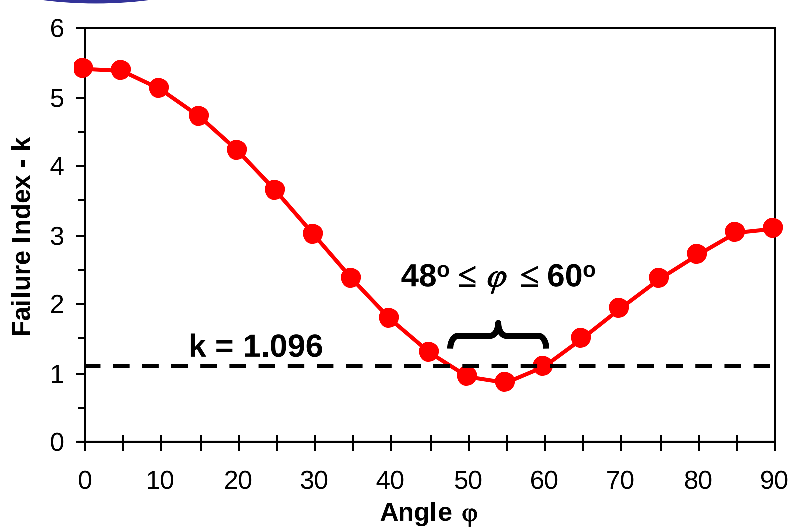
Output: Strength Ratio

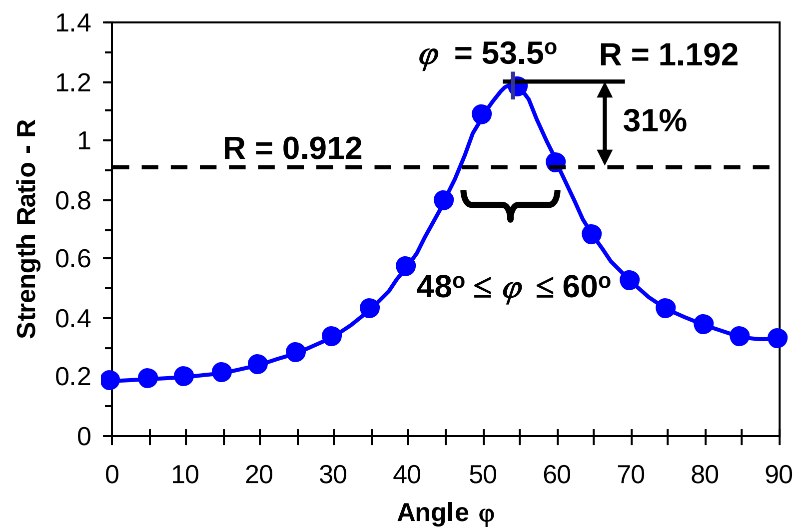


FPF (First Ply Failure) – Tsai-Wu

Failure Index k = 1.096 (R=0.912)







GENLAM: EXAMPLE 3 - MESSAGE

Complicated symmetric layup with four different angles

resulted in Failure Index k = 1.096

(Strength Ratio R=0.912)

⇩

Selected symmetric angle-ply laminates with same thickness

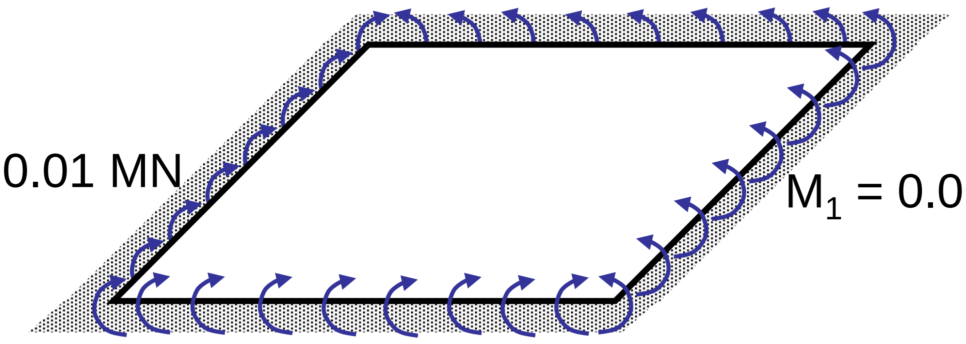
for different angles resulted in better laminates for angles

$48^o \leq \varphi \leq 60^o$ (31% gain for $\varphi = 53.5^o$)

⇩

Less angles can result in better design

GENLAM: EXAMPLE 4



Material/Layup: Top laminate – Kevlar/Epoxy – $[(90/-45/45/0)_2]$

Bottom laminate – E-Glass/Epoxy – [0/45/-45/90]

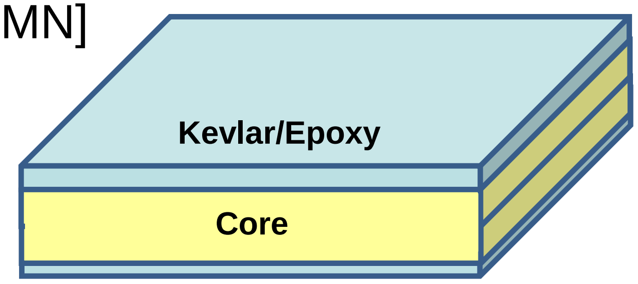
Core – Thickness of 32 material plies

Load vectors: N={0,0,0} [MN/m]; M={0.01, 0.01, 0} [MN]

Displacements: $\varepsilon_1 = \varepsilon_2 = \varepsilon_6 = 0$

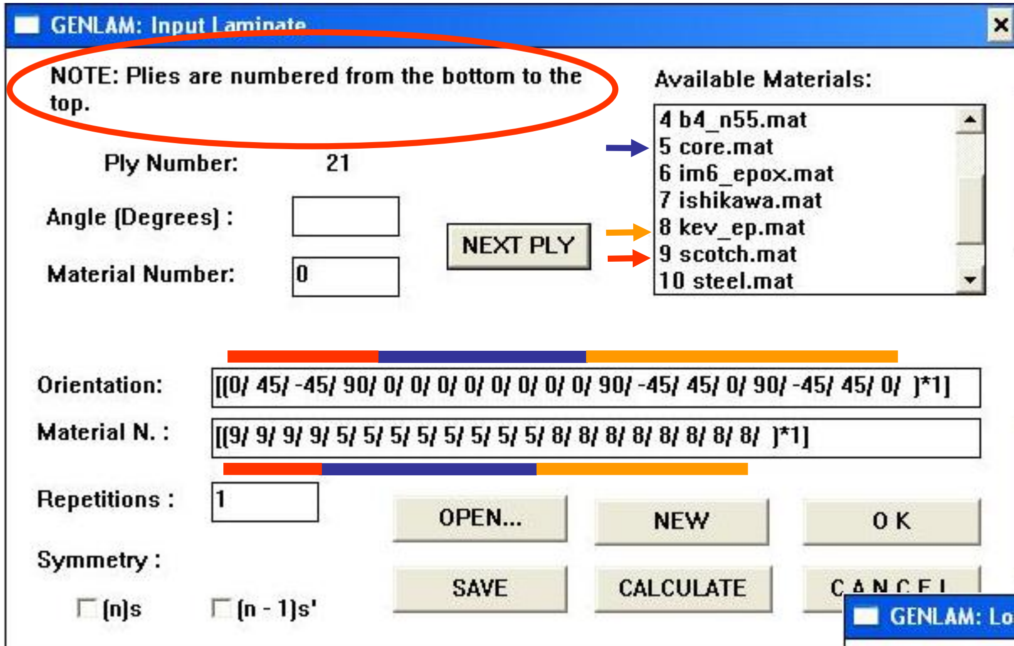
Hygrothermal effects: $\Delta T = -100^{o}C$; $\Delta c = 0.005$

Evaluate FPF (First Ply Failure Tsai-Wu)

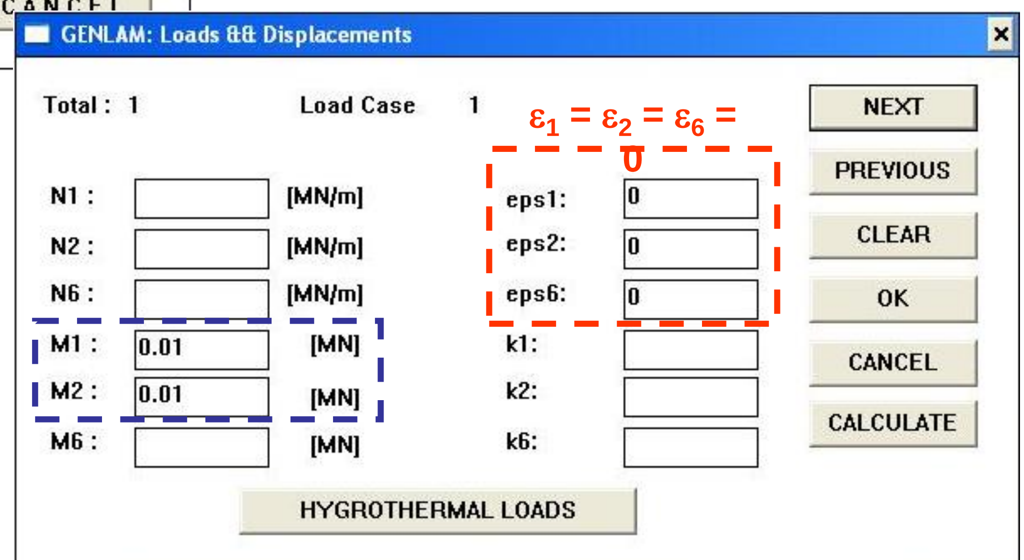


GENLAM: EXAMPLE 4 – INPUT LAMINATE & BC

Laminate input



Loads & displacements (strains) input

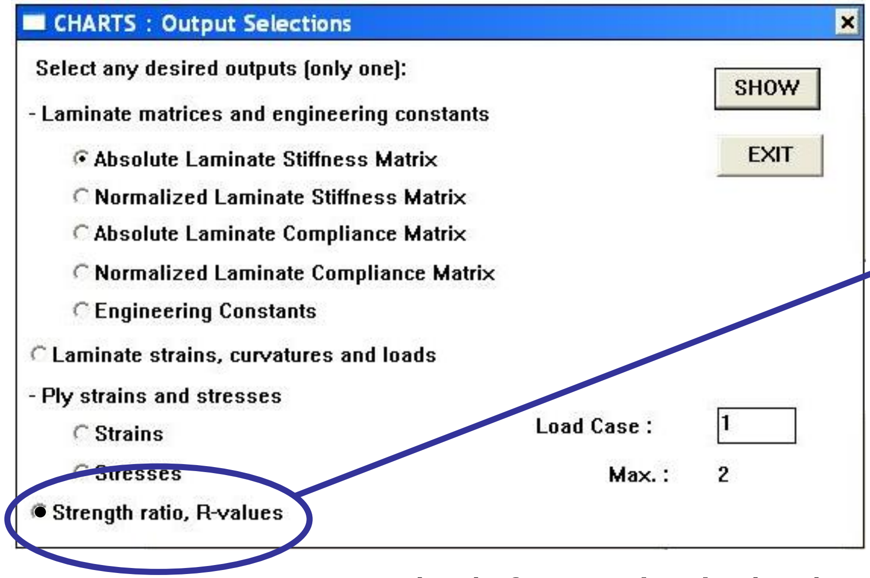


OBS:
Core ply thickness = 0.5 mm
Material ply thickness = 0.125 mm
Each core ply is equivalent to 4 material plies
32 material plies = 8 core plies

$M_1 = M_2 = 0.01$ MN

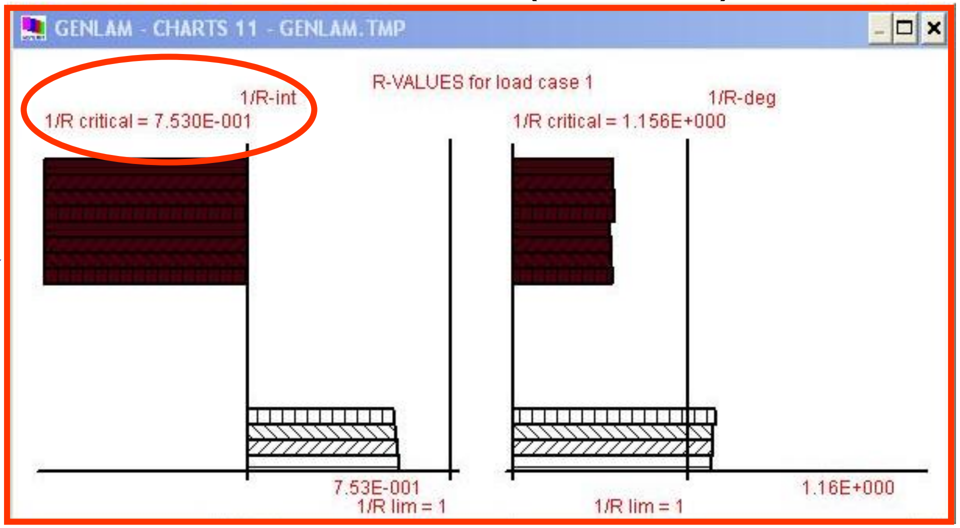
GENLAM: EXAMPLE 4 – FIRST PLY FAILURE

Output: Strength Ratio

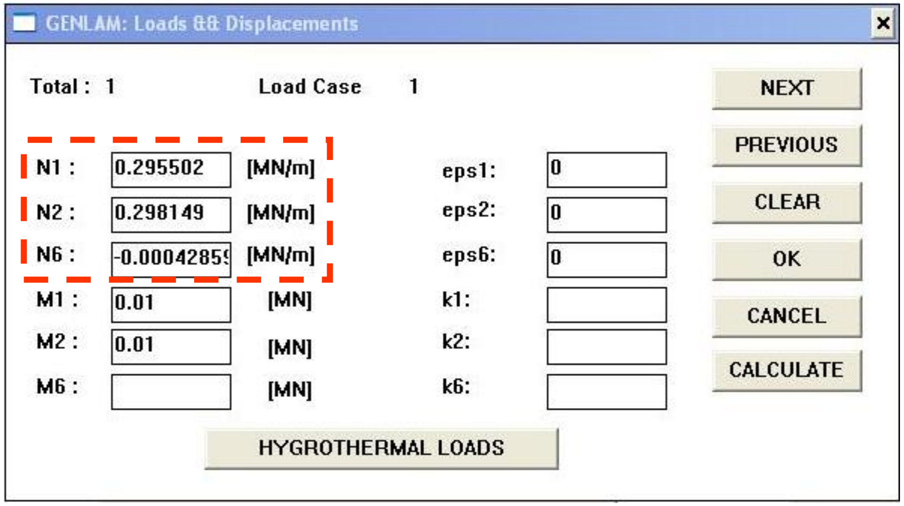


FPF (First Ply Failure) – Tsai-Wu

Failure Index k = 0.753 (R=1.328)



Loads (after calculation)



Internal loads due to the displacement restriction:

N_1 = 0.296 MN/m

N_2 = 0.298 MN/m

N_6 ≈ 0 MN/m

GENLAM: EXAMPLE 4 - MESSAGE

GENLAM flexibility:

Capable to perform analysis for hybrid load / displacement

Capable to perform analysis for sandwich laminates

Top and bottom sub-laminates can be of different materials
as well as non-symmetric

THANK YOU

QUESTIONS ?