6.14 Example N: Plain Weave Composite

<u>Sample Input File for Plain Weave Composite:</u> Step 1 - Determine Yarn Properties

<u>Problem Summary</u>

Load Type:	Mechanical
Load Component:	33-direction (transverse to fiber)
Load History:	Monotonic
Load Control:	Strain
Load History Data:	$\dot{\varepsilon}$ =1.0x10^{-4}/sec, ε_{max}=0.018, ε_{min}=0. Δt_{mech} = 4. sec.
Micromechanics Model:	Double Periodicity
Fiber Packing Arrangement:	Square Pack, R = 1., 65% fiber volume ratio
Repeating Unit Cell:	26x26 circular fiber cross-section approx.
Integration Algorithm:	Forward Euler
Constituent Material Model:	Fiber: Elastic, transversely isotropic Matrix: Elastic, isotropic
Constituents:	Fiber: AS-4 Graphite Fiber (properties input manually) Matrix: PMR-15 Epoxy (properties input manually)

☞ **Note:** Step 1 of analyzing a woven composite with **MAC/GMC** involves determining the effective properties of the fiber/matrix yarns which reinforce the woven composites. For the elastic example shown, this is quite simple and involves determining only the five transversely isotropic elastic properties and the two transversely isotropic CTEs for the unidirectional fiber/matrix yarn. These effective properties will then be employed in step 2 (using ncmd = 9, transversely isotropic model) to analyze the actual woven composite unit cell. Inelastic analysis of woven composites is possible with **MAC/GMC**, but the inelastic characterization of the unidirectional fiber/matrix yarns (for implementation with one of the transversely isotropic inelastic constitutive models) becomes more complex. Future versions of **MAC/GMC** may include automated routines to aid in the analysis of thermo-inelastic woven composites.

```
analysis of a graphite/epoxy yarn
*PRINT
 NPL=3 %
*LOAD
 LCON=2 LOP=3 LSS=1 %
*MECH
 NPTW=2 TI=0.,108. LO=0.,0.018  %
*MODEL
 MOD=1  %
*SOLVER
 NTF=1 NPTS=2 TIM=0.,108. STP=4. %
*FIBER
 NFIBS=1
 NF=1 MF=6 NDPT=1 MAT=U IFM=1&
 EL=31.E6,2.E6,0.2,0.25,2.E6,-0.55E-6,5.6E-6 %
*MATRIX
 NMATX=1
 NM=1 MM=6 NDPT=1 MAT=U IFM=1 &
 EL=0.5E6,0.5E6,0.41,0.41,0.1773E6,57.E-6,57.E-6 %
*MRVE
 IDP=13 VF=0.65 R=1.0
*CURVE
 NP=1 %
*MACRO
 NT=1
 NC=1 X=3 Y=9 NAM=YARN
*END
--------------------------------------------------------------------------------------------------------
                      Results for fiber/matrix yarn:

                   EFFECTIVE ENGINEERING MODULI
                         E11S=   .203E+08
                         N12S=   .272E+00
                         E22S=   .134E+07
                         N23S=   .432E+00
                         E33S=   .134E+07
                         G23S=   .359E+06
                         G13S=   .596E+06
                         G12S=   .596E+06

              EFFECTIVE THERMAL EXPANSION COEFFICIENTS
                    .493E-07     .310E-04     .310E-04
```

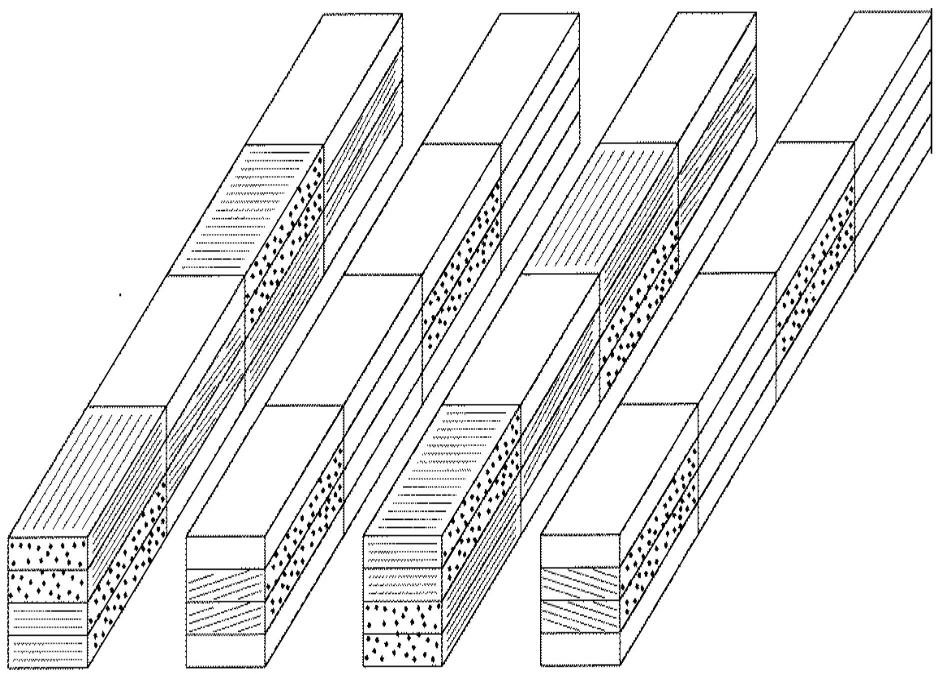
Sample Input File for Plain Weave Composite: Step 2 - Composite Behavior

Problem Summary

Load Type:	Mechanical	
Load Component:	33-direction (in the plane of the woven reinforcement)	
Load History:	Monotonic	
Load Control:	Strain	
Load History Data:	$\dot{\varepsilon}$ =1.0x10^{-4}/sec , ε_{max}=0.018, ε_{min}=0. Δt_{mech} = 4. sec.	
Micromechanics Model:	Triple Periodicity	
Repeating Unit Cell:	Input manually - approximates a plain weave reinforced composite	
Integration Algorithm:	Forward Euler	
Constituent Material Model:	Fiber/Matrix Yarns:	Elastic, locally transversely isotropic
	Pure Matrix:	Elastic, isotropic
Constituents:	Fibers 1 - 4:	V_f = 65% AS-4/PMR-15 yarns with different fiber orientations (properties input manually)
	Matrix 1:	PMR-15 Epoxy (properties input manually)
	Matrix 2, 3:	V_f = 65% AS-4/PMR-15 yarns with different fiber orientations (properties input manually)

☞ **Note**: **MAC/GMC** currently limits the number of fiber and matrix constituents to 4 each.

☞ **Note:** Step 2 of analyzing a woven composite with **MAC/GMC** involves assembling a repeating unit cell that represents the woven composite using the effective fiber/matrix yarn properties determined in step 1. The repeating unit cell employed for a plain weave composite in this example is shown in the figure below. The heterogeneous subcells in this figure are represented by effective fiber/matrix yarn properties, while the local fiber direction of these subcells is accounted for by the D vector in the locally transversely isotropic constitutive model.



User defined IDP for woven architecture (not drawn to scale)

```
plain weave reinforced composite
*PRINT
  NPL= 3%
*LOAD
  LCON=2 LOP=3 LSS=1 %
*MECH
  NPTW=2 TI=0.,108. LO=0.,0.018  %
*THERM
  NPTT=2 TI=0.,108. TE=23.,23.
*MODEL
  MOD=2  %
*SOLVER
  NTF=1 NPTS=2 TIM=0.,108. STP=4. %
*FIBER
  NFIBS=4
  NF=1 MF=9 NDPT=1 MAT=U IFM=1 &
  EL=20.3E6,1.34E6,0.272,0.432,0.596E6,0.0493E-6,31.E-6 D=0.,0.,1. %
  NF=2 MF=9 NDPT=1 MAT=U IFM=1&
  EL=20.3E6,1.34E6,0.272,0.432,0.596E6,0.0493E-6,31.E-6 D=0.,1.,0. %
  NF=3 MF=9 NDPT=1 MAT=U IFM=1&
  EL=20.3E6,1.34E6,0.272,0.432,0.596E6,0.0493E-6,31.E-6 D=0.25,1.,0. %
  NF=4 MF=9 NDPT=1 MAT=U IFM=1&
  EL=20.3E6,1.34E6,0.272,0.432,0.596E6,0.0493E-6,31.E-6 D=-0.25,1.,0. %
*MATRIX
  NMATX=3
  NM=1 MM=6 NDPT=1 MAT=U IFM=1 &
  EL=0.5E6,0.5E6,0.41,0.41,0.1773E6,57.E-6,57.E-6 %
  NM=2 MM=9 NDPT=1 MAT=U IFM=1 &
  EL=20.3E6,1.34E6,0.272,0.432,0.596E6,0.0493E-6,31.E-6 D=0.25,0.,1. %
  NM=3 MM=9 NDPT=1 MAT=U IFM=1 &
  EL=20.3E6,1.34E6,0.272,0.432,0.596E6,0.0493E-6,31.E-6 D=-0.25,0.,1. %
*MRVE
  IDP=99
  NA=4 NB=4 NG=4
  D=0.25,0.25,0.25,0.25
  H=1.,1.,1.,1.
  L=1.,1.,1.,1.
  CM=F1,M1,F2,M1
  CM=F1,F3,F2,F4
  CM=F2,F3,F1,F4
  CM=F2,M1,F1,M1
  CM=M1,M1,M1,M1
  CM=M3,M1,M2,M1
  CM=M3,M1,M2,M1
  CM=M1,M1,M1,M1
  CM=F2,M1,F1,M1
```

```
  CM=F2,F4,F1,F3
  CM=F1,F4,F2,F3
  CM=F1,M1,F2,M1
  CM=M1,M1,M1,M1
  CM=M2,M1,M3,M1
  CM=M2,M1,M3,M1
  CM=M1,M1,M1,M1
*CURVE
  NP=1 %
*MACRO
  NT=1
  NC=1 X=3 Y=9 NAM=WEAVE
*END
```

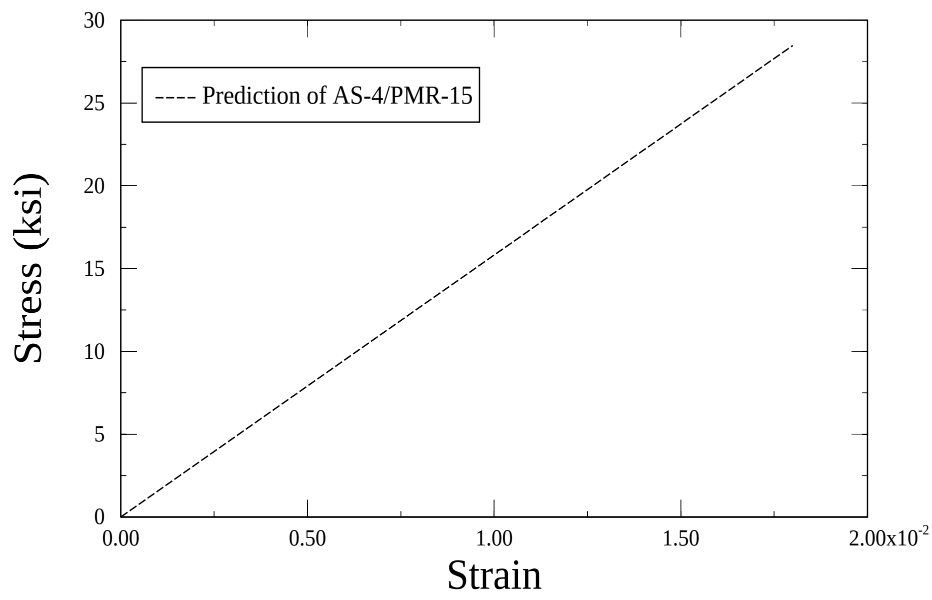
Results for woven composite:

EFFECTIVE ENGINEERING MODULI

E11S= .920E+06
N12S= .288E+00
E22S= .158E+07
N23S= .151E+00
E33S= .158E+07
G23S= .357E+06
G13S= .351E+06
G12S= .351E+06

EFFECTIVE THERMAL EXPANSION COEFFICIENTS

.548E-04 .261E-04 .261E-04
.000E+00 .318E-22 -.567E-23



☞ **Note**: The overall volume fraction is 32.5% while that of the yarn itself is 65%.