# **Electronic Annex to: Test Validation of Extension-Twisting coupled Laminates with Matched Orthotropic Stiffness.**

Table A1: Geometry for each of the four samples, corresponding to the three laminate designs of Table 2 of the above article.

1. – Laminate 1

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | Specimen thickness |  | Specimen width |
| Position: | Top | 2.43 | 2.62 | 2.59 | 2.58 |  | 24.05 | 24.09 | 24.08 | 24.05 |
| Middle | 2.56 | 2.62 | 2.63 | 2.63 |  | 24.07 | 24.06 | 24.15 | 24.16 |
| Bottom | 2.60 | 2.66 | 2.70 | 2.64 |  | 24.02 | 24.09 | 24.12 | 24.10 |
| Laminate: | Average *H* | 2.53 | 2.63 | 2.64 | 2.62 |  | 24.05 | 24.08 | 24.11667 | 24.10 |
| Ply: | Average *t* | 0.158 | 0.165 | 0.165 | 0.164 |  |  |  |  |  |

1. – Laminate 2

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | Specimen thickness |  | Specimen thickness |
| Position: | Top | 2.53 | 2.57 | 2.62 | 2.66 |  | 24.05 | 24.09 | 24.08 | 24.05 |
| Middle | 2.61 | 2.65 | 2.69 | 2.66 |  | 24.07 | 24.06 | 24.15 | 24.16 |
| Bottom | 2.61 | 2.67 | 2.70 | 2.70 |  | 24.02 | 24.09 | 24.12 | 24.10 |
| Laminate: | Average *H* | 2.58 | 2.63 | 2.67 | 2.67 |  | 24.05 | 24.08 | 24.12 | 24.10 |
| Ply: | Average *t* | 0.161 | 0.164 | 0.167 | 0.167 |  |  |  |  |  |

1. – Laminate 3

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | Specimen thickness |  | Specimen thickness |
| Position: | Top | 2.61 | 2.69 | 2.64 | 2.7 |  | 23.64 | 23.8 | 23.86 | 23.57 |
| Middle | 2.64 | 2.66 | 2.63 | 2.67 |  | 23.57 | 23.83 | 23.59 | 23.49 |
| Bottom | 2.66 | 2.66 | 2.62 | 2.68 |  | 23.67 | 23.82 | 23.74 | 23.64 |
| Laminate: | Average *H* | 2.64 | 2.67 | 2.63 | 2.68 |  | 23.63 | 23.82 | 23.73 | 23.57 |
| Ply: | Average *t* | 0.165 | 0.167 | 0.164 | 0.168 |  |  |  |  |  |

Figure A1 – Gauge length measurement confirmed from indentations on test specimens from bevel edged serrated grips.

|  |  |
| --- | --- |
|  |  |

ABAQUS Input Files:

LAMINATE 1

\*HEADING

EXTENSION-TWISTING TEST SPECIMEN

\*NODE

1001,0,0,0

1025,24.07,0,0

201001,0,189,0

201025,24.07,189,0

300000,12,199,0

\*NSET,NSET=RNODE

300000

\*NGEN,NSET=TOP

201001,201025

\*NGEN,NSET=BOTTOM

1001,1025

\*NFILL,NSET=ALL

BOTTOM,TOP,200,1000

\*ELEMENT,TYPE=S4R

1001,1001,1002,2002,2001

\*ELGEN,ELSET=PLATE

1001,24,1,1,200,1000,1000

\*RIGID BODY, REF=RNODE,TIENSET=TOP

\*MATERIAL,NAME=CFRP

\*ELASTIC,TYPE=LAMINA

131E3,8.2E3,0.38,4.3E3,4.3E3,2.2E3

\*SHELL SECTION,ELSET=PLATE,COMPOSITE

\*\*Laminate 1

0.152,3,CFRP,-22.5,PLY\_1

0.152,3,CFRP,-22.5,PLY\_2

0.152,3,CFRP,67.5,PLY\_3

0.152,3,CFRP,67.5,PLY\_4

0.152,3,CFRP,22.5,PLY\_5

0.152,3,CFRP,67.5,PLY\_6

0.152,3,CFRP,-22.5,PLY\_7

0.152,3,CFRP,-67.5,PLY\_8

0.152,3,CFRP,67.5,PLY\_9

0.152,3,CFRP,22.5,PLY\_10

0.152,3,CFRP,-67.5,PLY\_11

0.152,3,CFRP,-22.5,PLY\_12

0.152,3,CFRP,-67.5,PLY\_13

0.152,3,CFRP,-67.5,PLY\_14

0.152,3,CFRP,22.5,PLY\_15

0.152,3,CFRP,22.5,PLY\_16

\*BOUNDARY

BOTTOM,ENCASTRE

RNODE,1

RNODE,3,4

RNODE,6

\*STEP, INC=7500, NLGEOM

\*STATIC,RIKS

0.01, 1., 1.E-5, 0.01, 1

\*CLOAD

RNODE,2,5000

\*RESTART,WRITE,FREQUENCY=0

\*OUTPUT,FIELD,VARIABLE=PRESELECT

\*OUTPUT,HISTORY

\*NODE OUTPUT,NSET=RNODE

CF2,UR2

\*END STEP

LAMINATE 2

Change only the nodal data and laminate description from the above input file, as follows:

\*NODE

1001,0,0,0

1025,24.11,0,0

201001,0,189,0

201025,24,189,0

300000,12,199,0

\*\*Laminate 2

0.159,3,CFRP,-22.5,PLY\_1

0.159,3,CFRP,22.5,PLY\_2

0.159,3,CFRP,67.5,PLY\_3

0.159,3,CFRP,67.5,PLY\_4

0.159,3,CFRP,67.5,PLY\_5

0.159,3,CFRP,-22.5,PLY\_6

0.159,3,CFRP,-22.5,PLY\_7

0.159,3,CFRP,-22.5,PLY\_8

0.159,3,CFRP,-67.5,PLY\_9

0.159,3,CFRP,67.5,PLY\_10

0.159,3,CFRP,-67.5,PLY\_11

0.159,3,CFRP,-67.5,PLY\_12

0.159,3,CFRP,22.5,PLY\_13

0.159,3,CFRP,-67.5,PLY\_14

0.159,3,CFRP,22.5,PLY\_15

0.159,3,CFRP,22.5,PLY\_16

LAMINATE 3:

Change only the nodal data and laminate description from the above input file, as follows:

\*NODE

1001,0,0,0

1025,23.72,0,0

201001,0,189,0

201025,23.69,189,0

300000,12,189,0

\*\*Laminate 3

0.163,3,CFRP,-22.5,PLY\_1

0.163,3,CFRP,67.5,PLY\_2

0.163,3,CFRP,67.5,PLY\_3

0.163,3,CFRP,-22.5,PLY\_4

0.163,3,CFRP,22.5,PLY\_5

0.163,3,CFRP,22.5,PLY\_6

0.163,3,CFRP,22.5,PLY\_7

0.163,3,CFRP,-67.5,PLY\_8

0.163,3,CFRP,-67.5,PLY\_9

0.163,3,CFRP,-67.5,PLY\_10

0.163,3,CFRP,-67.5,PLY\_11

0.163,3,CFRP,-67.5,PLY\_12

0.163,3,CFRP,-67.5,PLY\_13

0.163,3,CFRP,22.5,PLY\_14

0.163,3,CFRP,22.5,PLY\_15

0.163,3,CFRP,22.5,PLY\_16