Proposals for new geometries of cruciform specimens

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OPTIMAT BLADES

TG 2

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1. Introduction

Biaxial testing of fibre-reinforced polymer material using cruciform test specimen is considered to be successful when the ultimate failure occurs in or around the gage section and a large uniform stress/strain distribution in the gage section is obtained. For most of the specimens tested with geometry 0 (basis geometry, see report 2), failure started at one of the intersections between two arms and therefore the test results could not be considered as real biaxial test results. New proposals for the specimen geometry should be made. Certainly the end-tap design should be reconsidered since early debonding of the end-taps occurred for all tested specimens.

2. Proposals for new geometry

All new specimens will have the same width of 25 mm in both directions of the arms instead of a width of 20 mm in the direction of the UD fibres and a width of 25 mm in the perpendicular direction. Since no problems were encountered to load the specimens up to failure, only values of +/- 50kN were necessary to obtain failure, the use of smaller width in the direction of the UD fibres is not necessary. The values of the failure load will probably be higher when failure occurs in the test zone and not near one of the corners (stress concentration) or in one of the arms due to debonding of the end-taps. However, loads of more than 100kN (the capacity of the biaxial test bench) will not be necessary.

A radius of curvature R=20 mm will be used for the new specimen's geometry 1 till 4 since this radius gave less stress concentrations in the intersection zone than R=10 mm. Also higher failure values were obtained. First the original duralumin taps will be tapered to introduce the load more gradually into the specimen. In the next step, the taps will be made of glass fibre epoxy to avoid early debonding. Probably, the mismatch between the Poisson coefficient of the MD-material (ν=0.7) and of the duralumin taps (ν=0.3) results in high interlaminar stresses and consequently in early debonding. The taps will also be placed further away from the test zone to avoid huge load transfer from one direction to the perpendicular direction due to the +/-45° fibres in the curved area between the arms. The third step is not to use end-taps anymore but to mill material away in the test zone. Two cases will be investigated: one with a square test zone and one with a circular one. For geometry 5 and further the radius of curvature will be chosen different, such that the width of the arms near the test zone will be decreased.

2.1 Geometry 1

On the first geometry tapered end-taps of 15° in duralumin with 2.5mm thickness will be glued. Tapering will introduce the loads more gradually into the test zone and will avoid early debonding of the end-taps. Total length of the end-taps is the same as for the original specimen. The MD material consists of 3 UD layers and 4 +/-45° layers with $([\pm 45°, 0°]_3, [\pm 45°])$ lay-up.

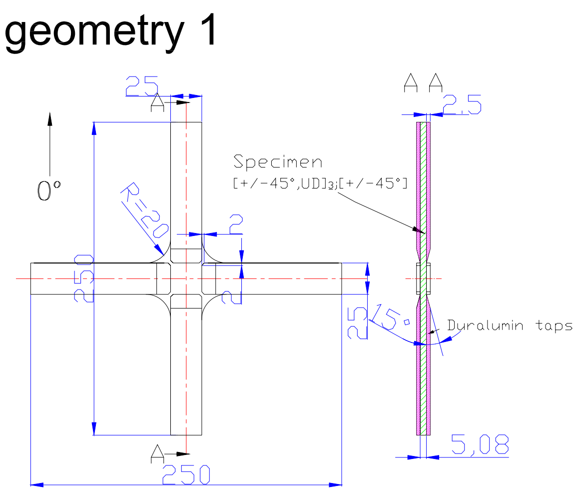

Figure 1: New geometry 1.

2.2 Geometry 2

2.2.a Geometry 2a

The second geometry contains tapered end-taps of standard glass fibre material with a thickness equal to 2.5 mm. Tapering is done with an angle of 15°. Total length of the end-taps is the same as for the duralumin taps. The use of the same material for the end-taps as for the specimen will avoid early debonding of end-taps due to differences in Poisson coefficient of the two materials. The +/-45° fibres want to reorient their selves in the direction of the loads and are responsible for the high Poisson values.

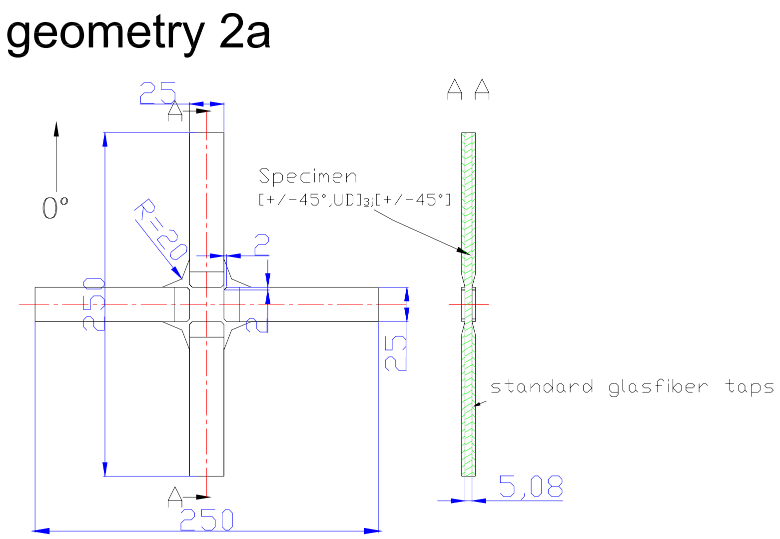

Figure 2a: New geometry 2a.

2.2.b Geometry 2b

This geometry will be the same as geometry 2a but with total length of the end-taps equal to 85 mm. The end-taps do not go beyond the beginning of the curved area in the measurement zone. This is to avoid huge load transfer from one direction to the perpendicular direction due to the +/-45° fibres in the curved zone between to arms.

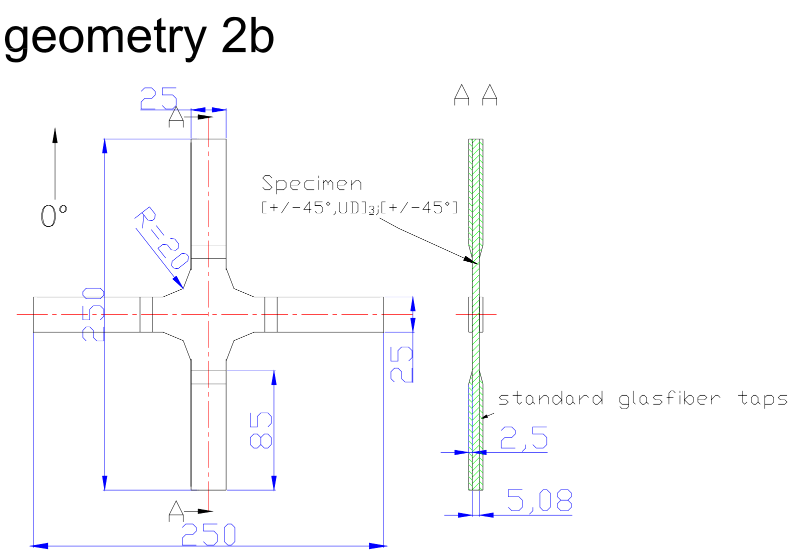

Figure 2b: New geometry 2b.

2.3 Geometry 3

For the next specimens no end-taps will be used but material will be milled away in the test zone. To be sure only the desired layers are milled away and no damage is introduced in other layers this milling has to be done very carefully and with a very precise CNC milling machine. The geometry of the milled test zone is circular with an inner diameter of 25mm. MD material consists of 4 UD layers and 5 +/-45° layers with $([\pm 45°,0°]_4,[\pm 45°])$ lay-up. In the test zone at each side of the specimen one layer [+/-45°, 0°] is milled away. The milled zone will show a tapering of 15°.

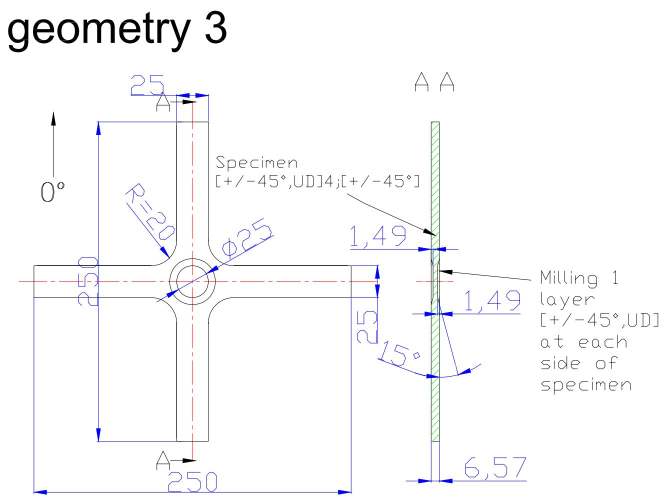

Figure 3: New geometry 3.

2.4 Geometry 4

In this case the geometry of the milled test zone is square with rounded edges. Rounding at the edges is circular with radius 6mm. MD material consists of 4 UD layers and 5 +/-45° layers with $([\pm 45°,0°]_4,[\pm 45°])$ lay-up. In the test zone at each side of the specimen 1 layer [+/-45°, 0°] is milled away. The milled zone will show a tapering of 15°.

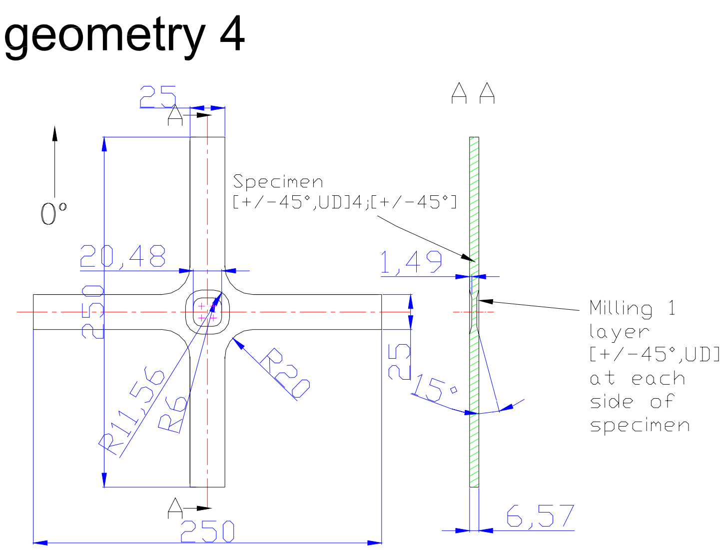

Figure 4: New geometry 4.

2.5 Geometry 5

For suggested geometries 5, 6 and 7 the radius of curvature between two arms, will be different than for the specimens mentioned before. In fact the proposed curvature will decrease the width of the arms. At the smallest point the width is 21.1 mm. The radius of curvature at the intersection of two arms has a diameter of 12.5 mm and it's position is such that it is tangential to a circle with diameter 25mm (the original width of the arms) at 100 mm from the end of the specimen arm. A smooth decrease of the width of the arms is obtained. Since less +/-45° fibres take load directly from one arm to the perpendicular one, load is introduced more directly in the specimen test zone. The geometries will all have a square test zone with rounded edges of 6mm radius. MD material consists of 4 UD layers and 5 +/-45° layers with $([\pm 45°,0°]_4,[\pm 45°])$ lay-up. In the test zone at each side of the specimen 1 layer [+/45°,0°] is milled away. The milled zone will show a tapering of 15°. The difference between geometries 5, 6 and 7 is the size of the milled test zone. For geometry 5 this test zone is the smallest one (Figure 5), for geometry 6 it is tangential to the radius of curvature (Figure 6) and for geometry 7 milling starts at the smallest point of the width of the arms (figure 7).

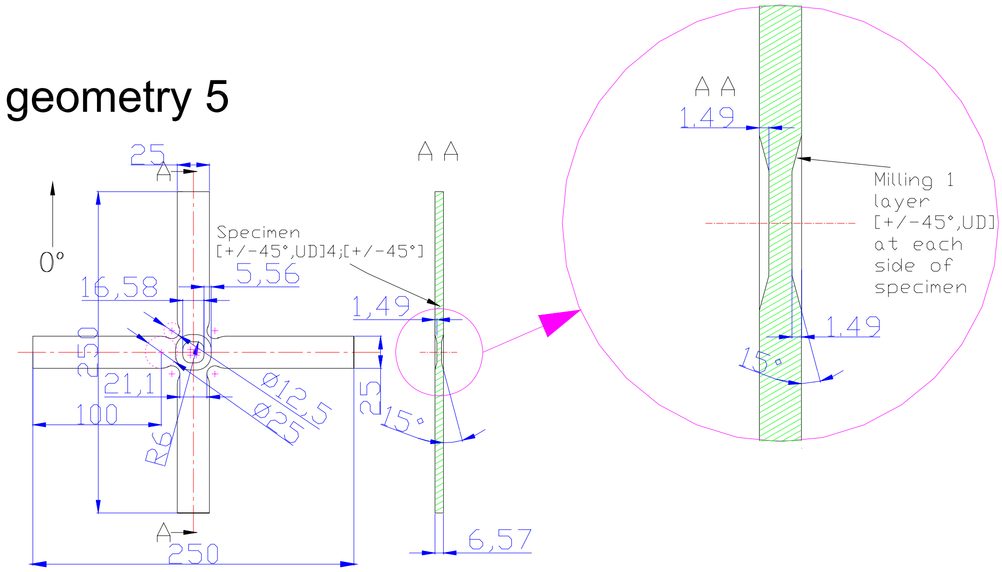

Figure 5: New geometry 5.

2.6 Geometry 6

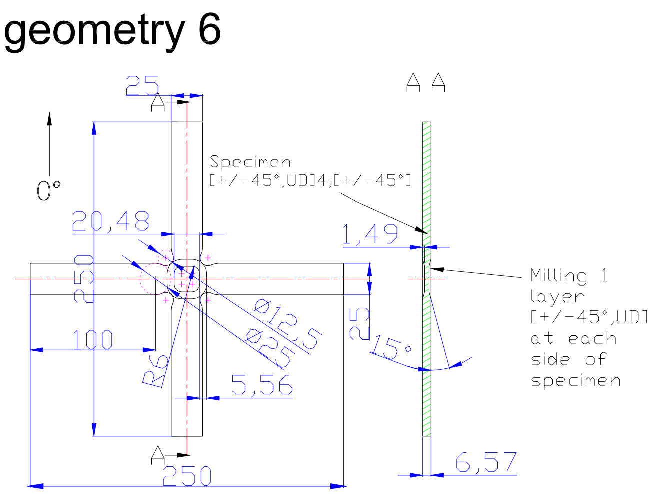

Figure 6: New geometry 6.

2.7 Geometry 7

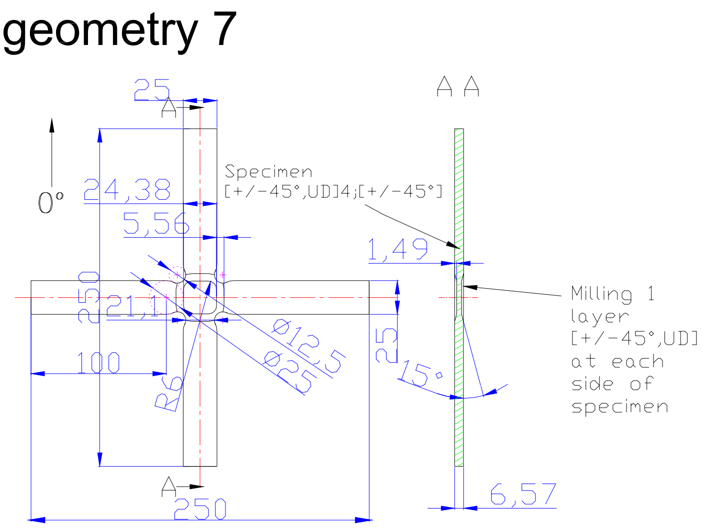

Figure 7: New geometry 7.

2.8 Geometry 8

In the last geometry a radius of curvature of +/- 25 mm diameter (24.2 mm) at the arms of the specimen will be used. This circle is tangential to a circle drawn in the specimen with diameter of 25 mm at 92.5 mm from the end of the specimen. This way, a smooth reduction of specimen width is obtained. The smallest width of the arms is 20.76mm. The test zone is square with rounded edges of 6 mm radius. MD material consists of 4 UD layers and 5 +/-45° layers with $([\pm 45°, 0°]_4, [\pm 45°])$ lay-up. In the test zone at each side of the specimen 1 layer [+/-45°, 0°] is milled away. The milled zone will show a tapering of 15°.

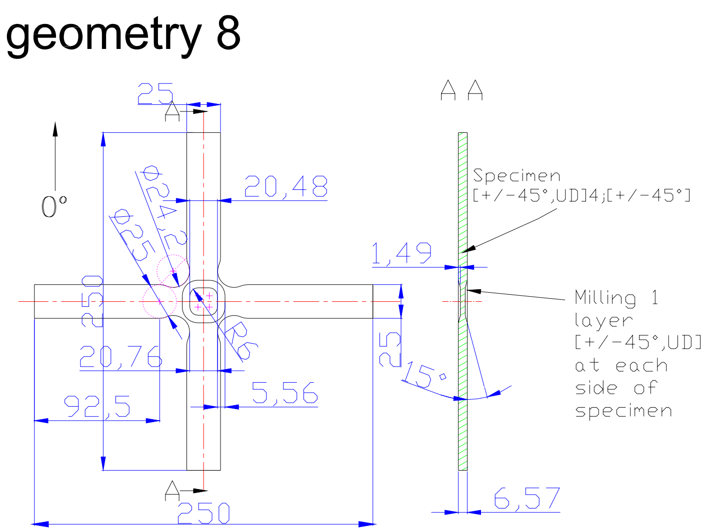

Figure 8: New geometry 8.