A METHOD FOR MEASURING BIAXIAL IMPACT PROPERTIES OF SHORT FIBRE COMPOSITE

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ABSTRACT

Standard impact test like pendulum testing is not perfect for inhomogeneous materials like SMC. The damage zone is smaller the texture of the material. A method to increase the damage zone has been developed to evaluate impact properties on standard and toughened SMC. Compared to pendulum testing the biaxial method generates a larger damage zone in the material. The test was performed in a tensile tester were a striker hit the test specimen at a defined speed. During the impact, the striker penetrates through the material and absorbed energy. Defects such as first crack/max stress can also be detected from the load/displacement curve.

1. INTRODUCTION

Sheet Moulding Compound (SMC) usually consists of unsaturated polyester or vinyl ester resins, glass fibre reinforcements and fillers. The fibres are responsible for the strength and stiffness and the fillers for the compression strength as well as the dimensional stability and low thermal expansion. The length of the glass fibres is between 12 to 50 mm and the fibre fraction is between 25 to 60% by weight. Components like cure initiators, thickeners, fire protection and additives for processing are often added too. The exact amount of the ingredients varies depending on the application and the process ability. During moulding of SMC the charge is stacked and assembled into a charge pattern to optimise the filling of the mould cavity. The mould temperature is generally between 130 to 170°C and typical mould pressures are between 5 to 10 MPa. High fibre content gives good mechanical properties but has negative effect on the surface.

SMC is generally considered as a fairly brittle material and in some applications this can be an important drawback. If the toughness properties can be improved in SMC the material has great potential, especially in the automotive industry where they want tougher material in front ends and coachwork components.

The energy absorption in the damage zone can be increased, addition of plasticizer and the addition of a softer phase (low modulus). Generally, the plasticizers reduce the brittleness of the polymer, but at the same time other properties as yield stress and thermal properties are deteriorated. The additions of softer materials cause phase changes and may significantly improve the fracture toughness. The fracture behaviour of toughened thermoset is the dominant by shear yielding [1, 2, 3, 4].

Addition of a softer phase in SMC has therefore the potential to improve toughness.

Toughing agent has been added in the SMC and compared whit not toughened SMC. The materials have tested mechanically by using biaxial impact test and measure force and calculate energy absorption during the penetration of the striker.

2 EXPERIMENTAL

2.1 Materials

The experimental set up is shown in Table 1. The variables in the test were:

- Using toughing agents as an additive, two levels (1=no and 2=high).
- Type of Low Profile-additive, two types (1 and 2)
- Impact testing point, at edge or in middle of the plate, sees Figure 2.
- Processing direction of SMC-machine, in Longitudinal or Transverse direction (1=L or 2=T), see Figure 2.
- Impact testing speed, fast or slow.

Table 1 Experimental set-up

Receipt NR.	B1LM	B1LE	B1TM	B1TE	B3LM	B3lE	B3TM	B3TE	B7LM	B7lE	B7TM	B7LE
LP 1	X	X	X	X					X	X	X	X
LP 2					X	X	X	X				
Toughing 1 (no)	X	X	X	X	X	X	X	X				
Toughing 2 (high)									X	X	X	X
Orientation 1 (0°)	X	X			X	X			X	X		
Orientation 2 (90°)			X	X			X	X			X	X
Test in middle	X		X		X		X		X		X	
Test at edge		X		X		X		X		X		X

2.2 Processing of Impact specimen

During processing of the SMC material, the not moulded raw material was cut to a squared shape, 25 by 300 mm. To each moulding six layers of SMC were used. The material was put on top of each other and then inserted in the tool. The mould has the size 350 by 450 mm.

Table 2 shows the experimental set-up for the tensile test specimens.

Table 2 Processing parameters for tensile test specimens

Processing parameter	Value	Unit
Mould temperature	180	°C
Closing speed	20	mm/s
Mould pressure	10	MPa
Moulding time	150	s

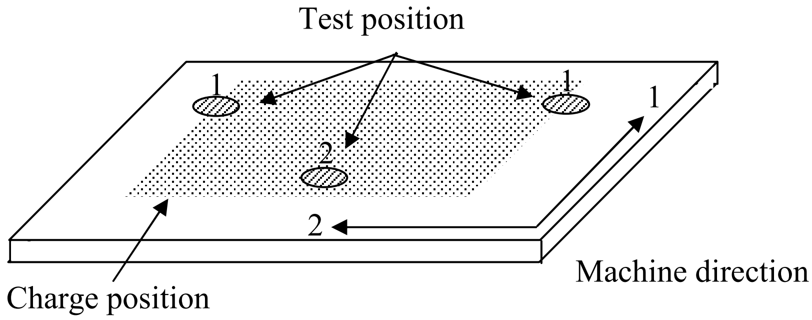

Figure 1 Impact test position on the molded plate

2.3 Biaxial impact testing

The biaxial impact test was performed at room temperature in an Instron 8501/H0162 test machine with a 100 kN load cell. Figure 2 describe the biaxial impact testing method were the striker penetrates the material. The striker has a spherical tip with a diameter of 12.3 mm. To minimize bending the specimen clamped by together by two bolted steel rings, inside ∅ 77 mm. During penetration load and displacement are recorded to detect cracks and maximum load. Absorbed energy is calculated by were *E* is absorbed energy; *F* is force and *u* displacement:

$$E = \sum_{t=0}^{t_u} F_t u_t$$

To evaluate the effect of viscoelasticity the he impact test were performed at two speeds, 0.1 and 17 m/minute.

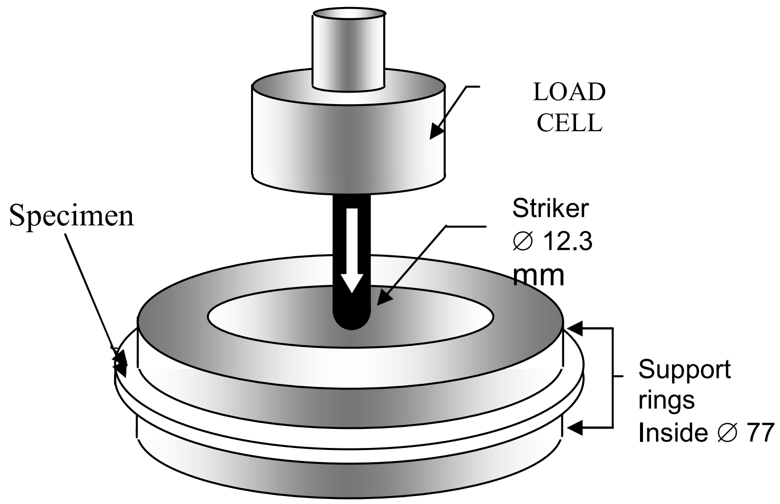

Figure 2 Test configuration at slow biaxial Impact testing

2.4 Optical study

The damage zone of Material 1 and 7 has been studied on by a stereo microscope. The image was captured by a CCD-camera (SANYO VCB-3512P).

3 RESULTS AND DISCUSSION

3.1 Impact test

Figure 3 show a typical load versus displacement curve for a SMC specimen tested at a rate of 0.1 m/minute. In Figure 3 there is a clear drop in the load versus displacement curve between 1 kN and 2 kN when the striker starts to penetrate the specimen. This occasion is named *First crack*. Next occasion occur when the load start to decrease, named *Maximum load*.

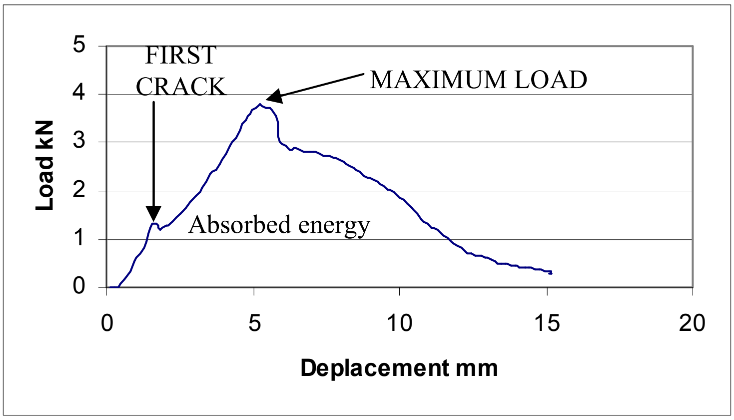

Figure 3 Typical Load / Displacement curve during biaxial impact test

3.2 Impact results Multifunctional ANOVA test

To evaluate effects of speed, molding direction and impact test position a multifunctional ANOVA test were performed. Figure 4 and Figure 5 show the ANOVA test of the effect of testing speed (1=0.1 and 2=17m/minute). The results show the effect of speed is not statically significant in the case of *load at fist crack* but significant for *maximum load* as expected.

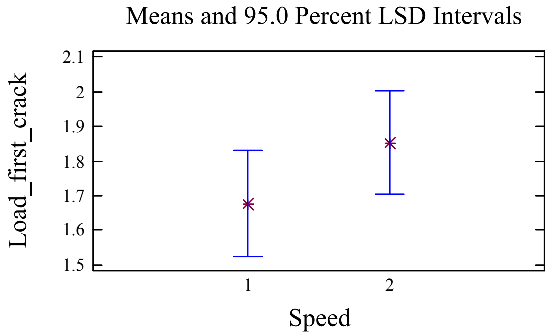

Figure 4 Influence of the testing speed on the load at first crack

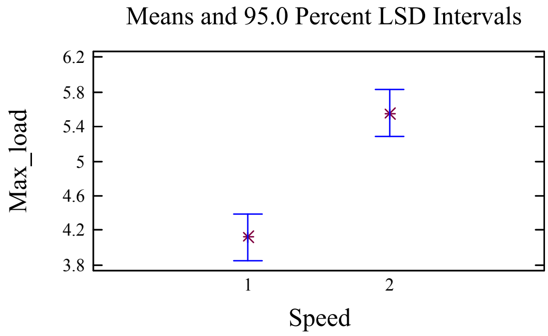

Figure 5 Influence of the testing speed on the maximum load

Figure 6 show that the specimen thickness was depending in material type (1=B1, 2=B3 and 3=B7).

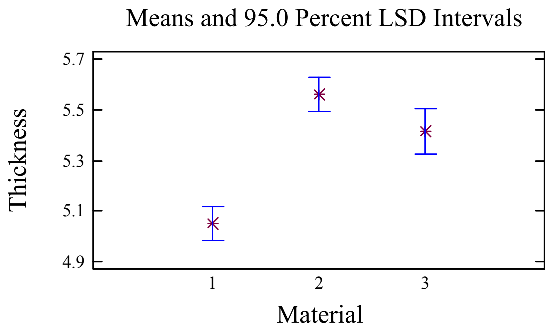

Figure 6 Influence of the material type on the specimen thickness

Figure 7 and Figure 8 show that in an ANOVA test the additives material don't effect the load at first crack or maximum load.

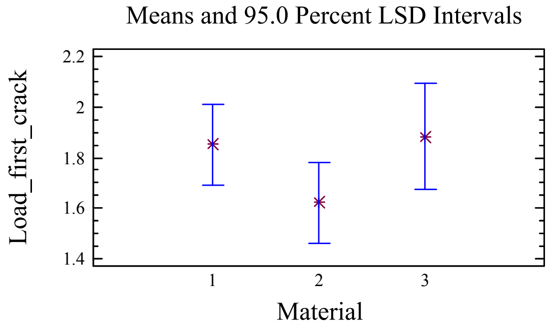

Figure 7 Influence of the material type on the load at first crack

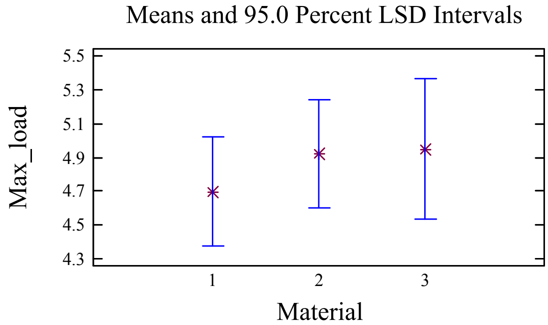

Figure 8 Influence of the material type on the maximum load

3.3 Absorbed energy during impact

Figure 9 show that the material B3 (LP2, no Toughing) absorb more energy during biaxial impact then the material B1 LP1, no Toughing) does during impact of 0.1 m/minute.

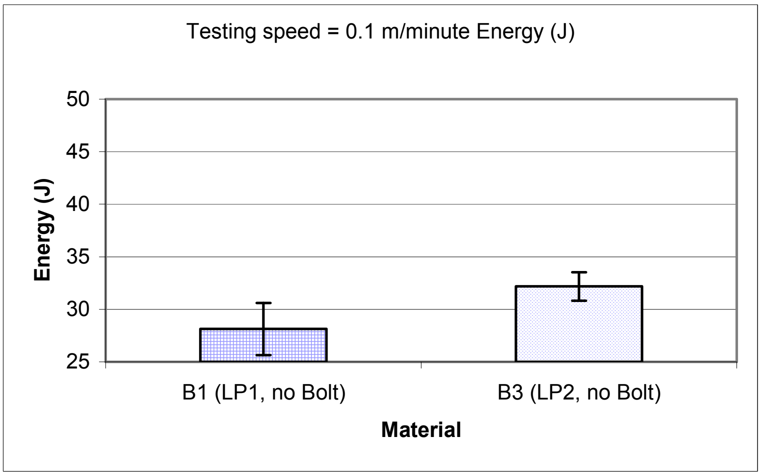

Figure 9 Absorbed energy for B1 and B3 at 0.1 m/minute

Similar thing can be seen in Figure 10 were the material B7 (LP1, high Toughing) absorb significantly more energy than the standard SMC B1 does during impact at same speed.

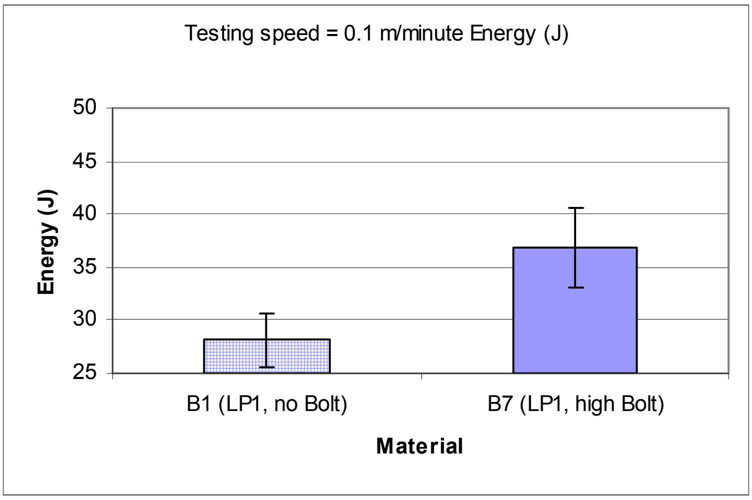

Figure 10 Absorbed energy for B1 and B7 at 0.1 m/minute

Figure 5 show the absorbed energy at a testing speed of 17m/minute for B1 and B3. The materials behave in the same manner as in the lower testing speed in Figure 9 even if the average level is higher.

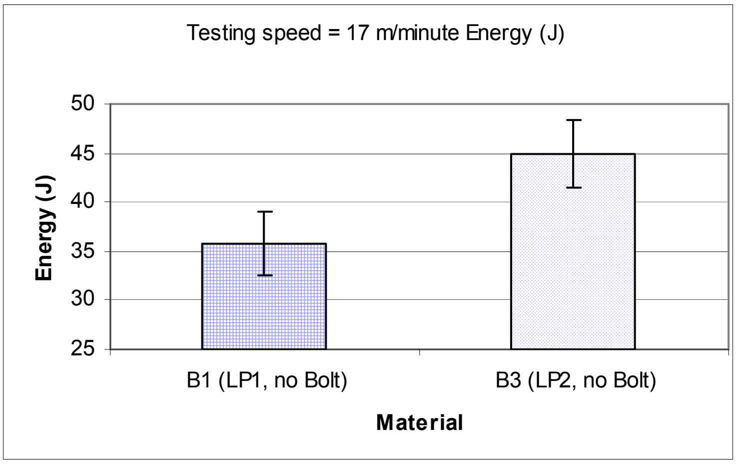

Figure 11 Absorbed energy for B1 and B3 at 17 m/minute

Almost as much energy is consumed when B7 is compared to B1 in Figure 12.

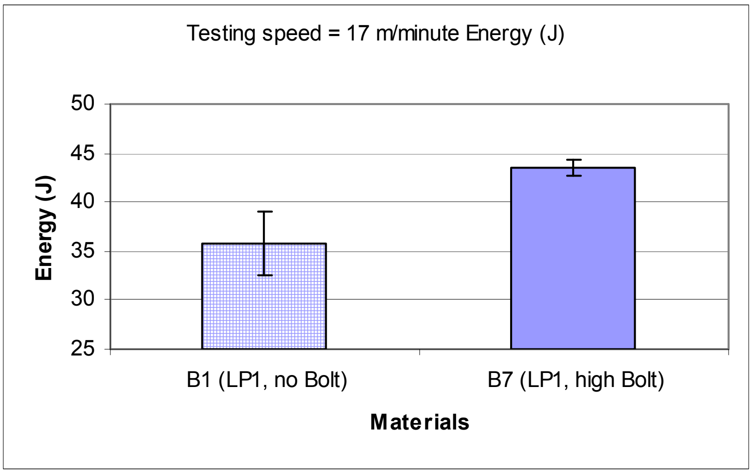

Figure 12 Absorbed energy for B1 and B7 at 17 m/minute

3.4 Optical study

Figure 13 shows the damage zone after the impact test for the not toughened material. In the damage zone the fibre bundles have been ripped off. That is in contrast to Toughing 7 material in Figure 14 where the material has delaminated between the layers and where the fibre bundled has debonded out of the matrix.

Figure 13 Damage zone in the not toughened material (B1)

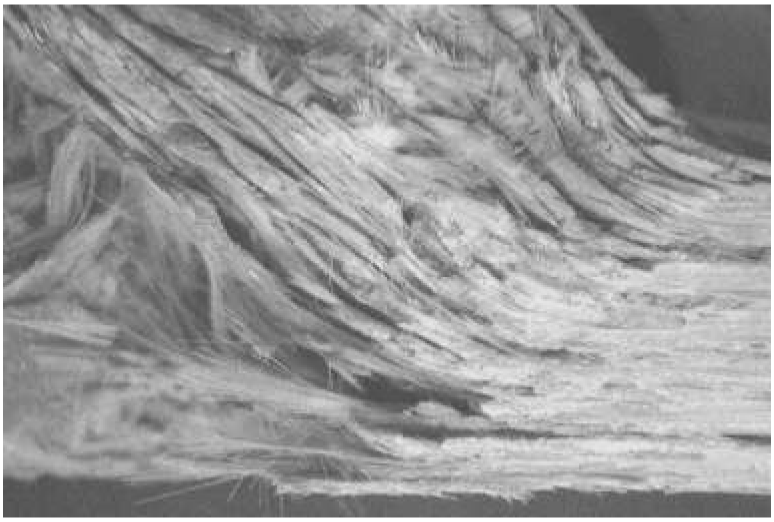

Figure 14 Large damage zone in the toughened material (B7)

4 CONCLUSIONS

The method for biaxial impact testing worked well. The reason is the method generates a large damage zone in the material that's suits inhomogeneous materials like SMC.

All materials behaved in similar manner according to load at first crack and maximum load. For the material with LP2 additive and the toughened material the breakage occurred over a wider displacement range and as a results of that consumed more energy. It is also interesting to notice that the material B3 is more affected by the testing speed then the other materials.

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