Fibre Composite Residual Strength after Impact

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Introduction

At CSM Materialteknik AB, long term behaviour of carbon fibre composites has been studied with financial support from the Swedish Defence Material Administration. Among others, the influence of low-velocity impact damage has been investigated and non-destructive inspection methods for these small damages has been developed. In this work a simple method for residual strength testing was used, based on a standardized method for 4-point bending test, which means that it's a method with low costs for performance and material. The results were compared to compression after impact. In addition, the effect of moisture on low-velocity damaged laminates, conditioned after impact, was investigated.

CSM Materialteknik AB

CSM perform consultation and testing services within materials and process technology. CSM is 100 % owned by Saab AB and a partner to Saab Aerostructures.

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Residual Strength after Impact
A modified 4-point bending test

Testing

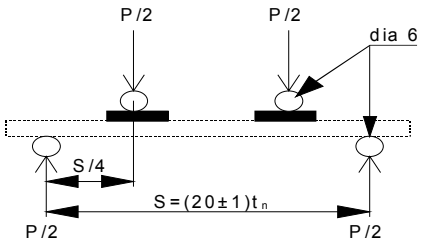
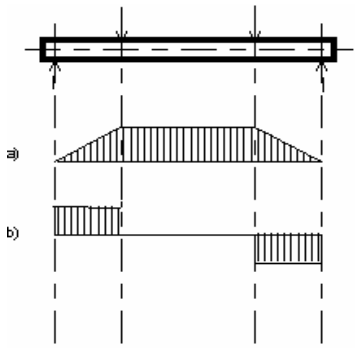
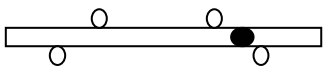


Figure showing 4-point bending test according to Saab STD 3023



In the figure the distribution of stresses that occurs during 4-point is shown
a) bending stress and b) shear stress

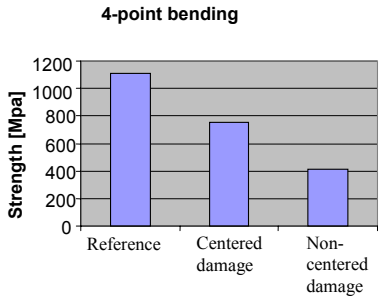
By placing the damaged area between inner and outer supports as in the figure below the damage zone is loaded in constant shear stress.



Initial step: 3 mm thick quasi-isotropic laminates were impacted and specimens were cut out. The damage area was appr. 100mm^2.

The diagram shows the results from 4-point bending test of reference, sample with centered damage and sample with a non-centered damage.

The modified testing method was more sensitive.



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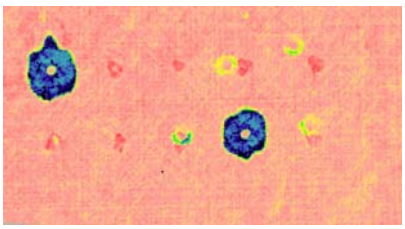
Step 2: 2mm thick quasi-isotropic laminates were damaged and examined by ultrasonic testing. Damage areas with preferred sizes were picked and the specimens were cut out for 4-point bending test (80x20 mm) with non-centered damage and for compression testing (178x254 mm). Some specimens were moisturized after damage and cutting.

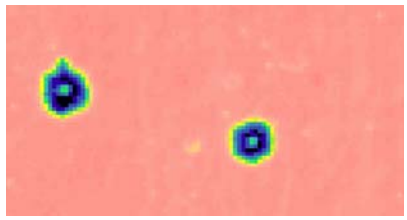
The weight of the impactor was 4,55 kg with a 10 mm hemispherical steel tip. Energies in the range of 5-10 J were applied. In all cases damages of the same sizes were compared, independent of energy level.

It was supposed that a damage, although barely visible, would enhance the effect of moisture on residual strength.

Results from ultrasonic inspection
of damaged laminates



C-scan of the same laminate: 75 MHz transducer,
" barely visible" damages can be observed
Area size appr. 15mm^2



C-scan: 5 MHz transducer
Two visible damages, also visible with the naked eye.
Area size appr. 100mm^2

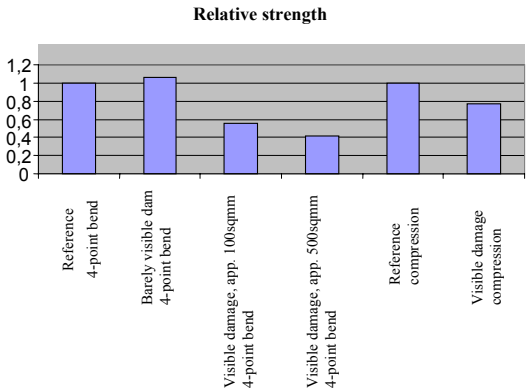
Results

Residual strength after impact			
4-point bending [Mpa]			Compression [Mpa]
Damage size	Non conditioned	Specimen moisturized after impact*	Non conditionend
Reference	1218	956	544
Barely visible damage, 13-17mm^2	1289	1095	
Visible damage, 90-150 mm^2	673	570	420
Visible damage, 450 mm^2	516	424	

*Conditioning in 85%RH, 70°C until 0,8% moisture content, tested in RT

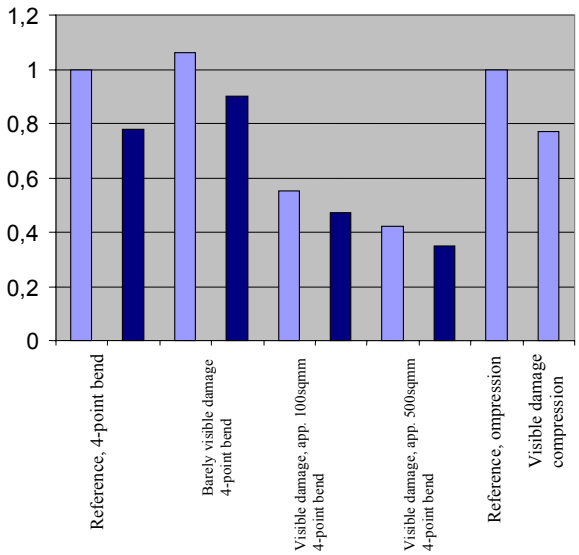
Barely invisible damages did not reduce the strength as measured by 4-point bending and the effect of moisture was not enhanced by the presence of a small damage.

Results



The figure shows the relative strength of modified 4-point bending test and compression for different damage sizes.

Effect of moisture
dark blue staples, moisturized specimens



Conclusions

•The residual strength as measured by the non-centered 4-point bending test was reduced twice as much as residual compression strength.

•The residual strength was not reduced by the unvisible damages

• The effect of moisture was not enhanced by the presence of a small/unvisible damage.

•The non-centered damage 4-point bending test is useful for comparative or screening studies since it is based on standardized methods, with low costs for performance and material.

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