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SIZE EFFECT AND FRACTURE CHARACTERISTICS OF FIBRE COMPOSITES
STANOVENÍ ROZMĚROVÉHO EFEKTU A LOMOVÝCH CHARAKTERISTIK VLÁKNOVÝCH KOMPOZITŮ

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Effect of the characteristic dimension of the structure on the nominal strength i.e. size effect is evaluated experimentally. The studied composite was multilayered fibre composite from vinyl ester matrix and glass fibre fabrics. Two sets of specimens were tested: with matrix of bisphenol and novolac types. Each set of specimens consisted of four notched specimens of same thickness and different size, geometrically similar. Results of tests can be used for determining of fracture energy.

Keywords
composites, damage, fracture

1 Introduction

An important parameter of damage process is effect of the characteristic dimension of the structure on the nominal strength σ_N i.e. size effect. Aim of the present study is to asses such an effect on vinyl ester composites reinforced by glass fabrics.
The size effect has been studied for concrete, ceramics and also for some composites [1], but the effect for composites fabricated from vinyl ester resins has been studied recently [2].

2 Fracture Tests on Composites

The material used was multilayered composite from vinyl ester resin Derakane 411-45 (bisphenol A) and Derakane 470-36 (novolac) reinforced by glass fibre fabric V1313-500-706 (Vertex). Orthotropic laminate was prepared by the hand lay up method so that the warp a weft direction of each fabric were parallel.

Two sets of specimens were prepared for the fracture tests: from Derakane 411-45 and Derakane 470-36. Each set consisted of four rectangular specimens of the same thickness but different size, geometrically similar. The width and gage length were following: 5x25, 10x50, 20x100 and 40x200 mm. The thickness of the specimen was 4 mm and size ratios 1:2:4:8.
Single edge notch of length D/5 was machined in the specimens, where D is specimen width. The notch was machined by specialized equipment Notchvis (CEAST), with the knife with angle 45^0

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and 0,2 mm radius. The notched composite specimens were tested under uniaxial tension in testing machine Instron 100 kN. The tests were conducted at a constant crosshead rate so that for the different size specimens the same average strain rate 0,5%.min^{-1} was achieved. Fig.1 shows typical size of the notched specimens of various sizes.

The test results for the notched specimens are summarized in Table 1, where the nominal strength is defined as the average stress at failure on the unnotched cross section.

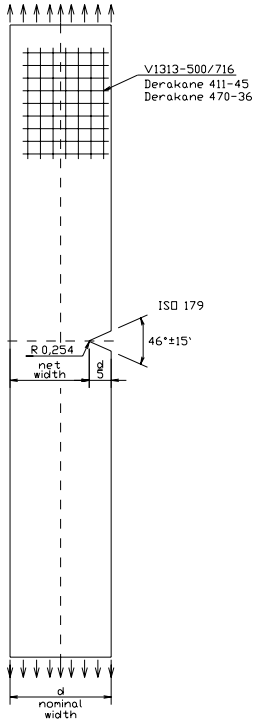

Fig.1 Geometry of Test Specimen

Tab.1. Results of tests in tension Derakane 411-45

SIZE EFFECT Derakane 411-45				
Specimen length	Specimen width	Max. load	Nominal strength	Net strength
[mm]	[mm]	[N]	[MPa]	[MPa]
25	5	3919,50	176,56	217,96
50	10	6786,5	159,20	198,02
100	20	11276,33	127,98	159,60
200	40	19495	111,56	139,31

Tab.2. Results of tests in tension Derakane 470-36

SIZE EFFECT Derakane 470-36				
Specimen length	Specimen width	Max. load	Nominal strength	Net strength
[mm]	[mm]	[N]	[MPa]	[MPa]
25	5	3570,1	163,24	202,32
50	10	6999,07	156,80	194,41
100	20	11419,67	133,90	166,84
200	40	20609,67	119,08	148,35

3 Size Effect

Size effect on the nominal strength of geometrically similar quasi-brittle structures can be approximately described by the following size effect law:

$$\sigma_N = Bf_u(1+\frac{D}{D_0})^{-\frac{1}{2}}$$

where σ_N is a nominal strength

D is characteristic dimension of structure

B is constant characterizing the solution according to plastic limit analysis

D_0 is constant depending on fracture process zone size

f_u is a reference strength of the material.

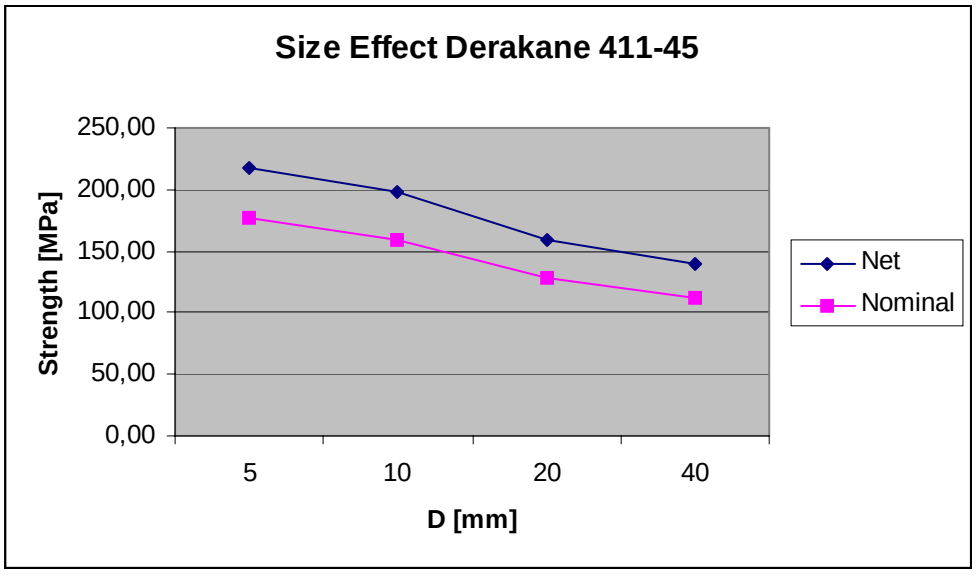

Fig.2 Size Effect of Composite Based on Derakane 411-45 Resin

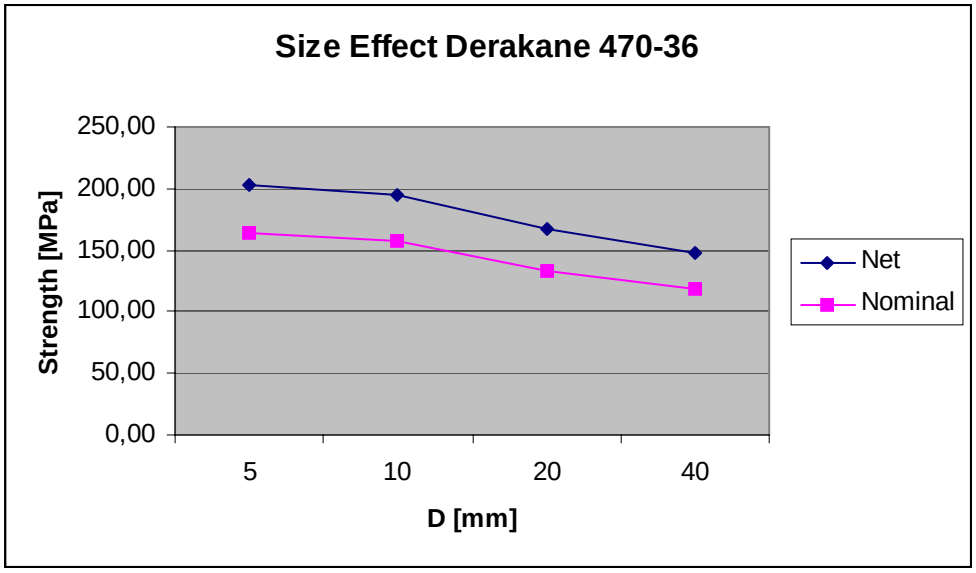

Fig.3 Size Effect of Composite Based on Derakane 470-36 Resin

To determine the parameters of the size effect law, the tested data can be plotted in a diagram σ_N^{-2} versus D (width of the specimen). After linear regression analysis we obtain

Derakane 411-45
y=1.39x + 27
Bf_u= 0.192
D_0=19.42

Derakane 470-36
y=0.968x + 32
Bf_u= 0.176
D_0=33.05

After substitution to the size effect law we obtain the folowing size effect relationships (D in mm, σ_N in GPa):

Derakane 411-45

$$\sigma_N = 0.192.(1+\frac{D}{19.42})^{-\frac{1}{2}}$$

Derakane 470-36

$$\sigma_N = 0.176.(1+\frac{D}{33.05})^{-\frac{1}{2}}$$

4 Fracture characteristics

By matching of size effect law the following expression for a fracture energy can be found [1]:

$$G_f = \frac{(Bf_u)^2}{E} D_0 g(\alpha_0)$$

where E is modulus of elasticity

$g(\alpha_0)$ is dimensionless energy release rate which can be calculated by linear elastic fracture mechanics

5 Conclusions

The results of tests show that the nominal strength for the notched specimens exhibits a significant size effect. The nominal strength of Derakane 411-45 is decreasing more significantly than of Derakane 470-36 (36% vers. 26%).

The measured values can be used for determining the fracture energy of the composites.

Acknowledgment

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References

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