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PULSATING TENSION TESTS ON GLASS FIBER REINFORCED PLASTICS

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Abstract: *Fatigue tests were carried out in pulsating tension tests on glass fiber reinforced plastics, different in fiber form. To classify the materials a correlation between the stress amplitude and the ultimate tensile strength was established. The objective of the tests is to find the mechanical properties of selected fiber glass composites and to classify them for using them in the construction of special vehicles.*
Key words: *GRP, fiberglass, pulsating, tension, S-N-curve*

1. INTRODUCTION

The shortages regarding the development time for the realization of high performance and at the same time economical cars require reliable knowledge about the properties of the used materials. The continuing trend towards premium performance of modern cars has a significant increase in the mechanical and thermal load of components.

The assurance and maintenance of the safety and integrity of structures is one of the most important tasks in engineering. Numerous catastrophic failures that have occurred in the past have proved that this demand has to be given higher priority. Even till today and with enormous input and carefulness failures cannot be avoided.

The rapidly increasing use of glass fibre reinforced plastics (GRP) in recent years has brought about the need for greater knowledge of their behaviour under load.

Glass fiber reinforced plastics are generally more sensitive to fatigue loading than are composites based on high modulus fibers (Mandell, 1982).

3. EXPERIMENTAL METHODS

The investigations relate to five different glass fiber reinforced plastics. Our project partner, the vehicle manufacturer, Binz selected the materials and the company PB Composite produced them. The materials differ mainly in the arrangement of the fibers: amorphous, +/- 45° tissue, unidirectional 45°, unidirectional 0° and unidirectional 90°. (figure 1)

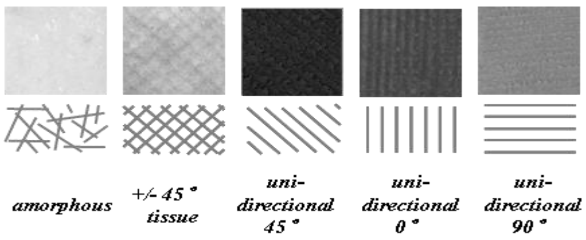

Fig. 1. Tested glass fiber reinforced plastics

The material used for the tension fatigue study was in the form of laminated plates. The samples have a top and bottom layer of 600 g/cm ² and a resin system 285 of the firm Lange and Ritter. The shape and dimensions of the specimens used for the experiments are shown in figure 2. The specimens have a original thickness of 5 mm, a wide of 30 mm and a shaft of 90 mm. Unnotched specimens (K_t = 1.0) were tested.

The fatigue tests were carried out load controlled, with constant load amplitude ("S-N-curve experiments") at room temperature. The S-N-curve is since decades the fundamental diagram for the fatigue design. The curve is valid for constant amplitude load cycles but is as well used to characterize the resistance for the damage accumulation theories under variable amplitude loading.

A 100-kN resonance testing machine, SincoTec, type Power Swing, was used. A special clamping facility was build for the fatigue tests, see figure 2. The test frequency was about 37 Hz. To prevent excessive heating of the specimens, an air cooling was achieved with a nozzle body, see figure 3.

The analysis of the experiments is based on nominal stresses. These are calculated at tension and compression as following:

$$\sigma = F/A \quad (1)$$

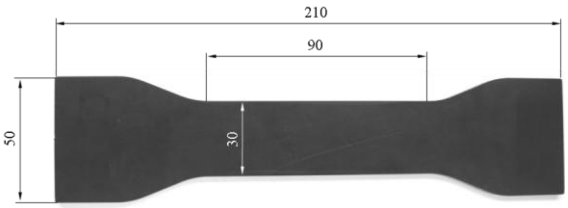

Fig. 2. Geometry of specimens

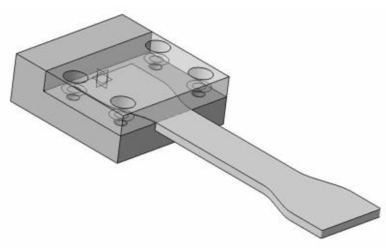

Fig. 3. Clamping facility for fatigue tests

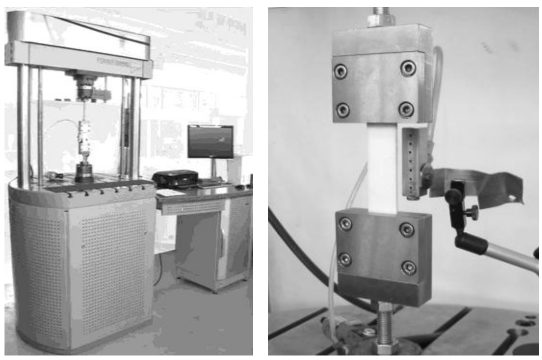

Fig. 4. Test setup for pulsating tension tests

3. RESULTS

The S-N-curves of the pulsating tension tests on the five different glass fiber reinforced plastics are plotted in figure 5.

The results of the pulsating tension tests are shown in table 1. The failure of the specimens is mostly parallel to the plies of fiber glass, see figure 6.

To classify the materials a correlation between the stress amplitude and the ultimate tensile strength was established. The materials A, B and C have an average ratio of stress amplitude fatigue strength and tensile strength of 0.15 (amorphous) to 0.25 (unidirectional 0°), see figure 7.

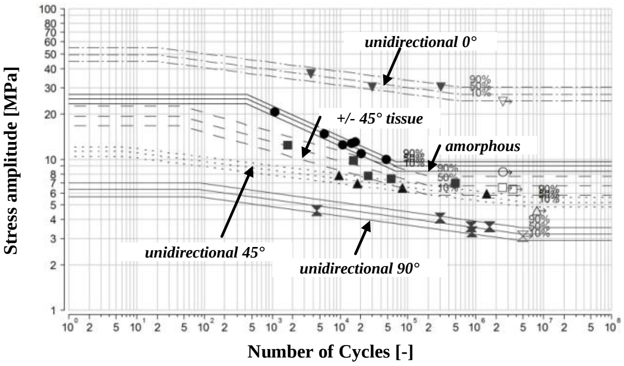

Fig. 5. Comparison of the S-N-curves of the pulsating tension tests on different GRP

Protocol pulsating tension						
Material	*Stress ratio R*	N_G	*Nominal stress amplitude* σ_{An} *[MPa]*		*Slope k*	*Scatter range* T_N
			$P_A = 50\%$	$P_A = 10\%$		
amorphous	0,1	$6{,}7 \cdot 10^5$	9,0	8,4	4,94	2,02
+/-45° tissue		$2{,}2 \cdot 10^5$	6,7	5,8	7,95	10,80
unidirectional 45°		$6{,}7 \cdot 10^6$	5,2	4,9	17,83	12,73
unidirectional 0°		$6{,}5 \cdot 10^5$	27,1	24,4	16,98	34,34
unidirectional 90°		$4{,}8 \cdot 10^6$	3,2	2,9	16,18	28,02

Table. 1. Results of pulsating tension tests

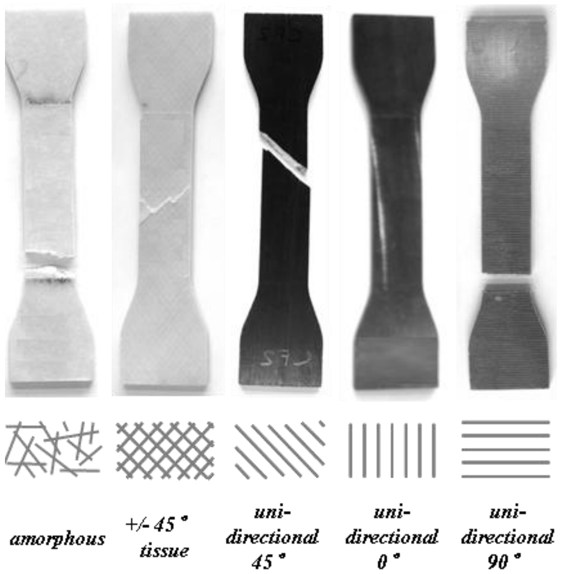

Fig. 6. Failure of specimens in pulsating tension test

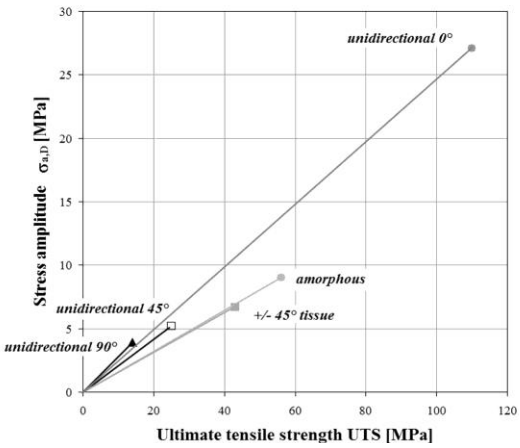

Fig. 7. Correlation between the ultimate tensile strength and the nominal stress amplitude of the tested GRP

4. CONCLUSION

The experimental results indicate a hierarchy in relation to the fiber direction: unidirectional 0°, amorphous, +/- 45° tissue, unidirectional 45°, unidirectional 90°.

The absolutely best fatigue behavior suggests itself, therefore, for the unidirectional material with 0 ° fiber direction with tolerable amplitude fatigue strength of 27 MPa, followed by the materials amorphous, +/- 45° tissue and unidirectional 45° with fatigue strength of 5-9 MPa.

By laying multiple layers of fiber on top of one another, with each layer oriented in various preferred directions, the stiffness and strength properties of the overall material can be controlled in an efficient manner.

A notable result of the investigation are the good static and dynamic properties of the amorphous glass fiber reinforced plastics, which is much cheaper than composites with unidirectional plies or tissues.

6. FURTHER RESEARCH

Further fatigue tests are planed with a stress ratio of R = -1. The influence of notches and of the testing frequency will also be examined. Exemplary experiments under humidity and radiation are prepared and carried out on selected materials. Long-term experiments, including creep tests, are also planned.

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