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Study of a New Composite Material Rt800 Reinforced with Polyte 440-M888 in Endurance Conditions

Arina Modrea[a,]*, Vasile Gheorghe[b], Venetia Sandu[c], Horatiu Teodorescu-Draghicescu[c], Mircea Mihalcica[c], Maria Luminita Scutaru[c]

[a]*Petru Maior University, Targu Mures, Romania*
[b]*SC INAR SA, 5 Poenelor, 500419, Brasov, Romania;* [c]*Transilvania University of Brasov, 29 Eroilor Blvd, 500036, Brasov, Romania*

Abstract

This paper aim to determine the analytical form of the Wöhler function F which is associated with the behavior of the composite material made of polyester resin reinforced with 5 layers of glass fiber fabric, RT800, with the specific mass of 845g /m^2, reinforced with Polyte 440-M888.

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Keywords: endurance stress testing; composite materials; Wöhler function; glass fiber fabric.

1. Introduction

The study of the composite laminate is presented in many paper (i.e. [1]-[8]) and the properties of such materials are calculated. The mechanical identification of these materials are presented in the papers [9]-[13]. A long series of papers studies the mechanical properties of the materials (i.e. [14]-[37]). The durability problem for a mechanical component can be no longer approached without knowledge of operating data, along with the knowledge of the behavior of the component's material from an endurance point of view. Considering the fact that both the stresses and the materials strengths have, in almost all the cases, a random particularity, the analytical approach regarding

* Corresponding author. Tel.: +40-265-233212.
E-mail address: arina.modrea@ing.upm.ro

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fatigue and wear can only be made from a probabilistic point of view, by knowing the probability P which is associated to a pair of values (σ, N) of the Wöhler function:

$$P=F(\sigma, N) \quad (1)$$

where σ represents the stress and N represents the number of cycles until the material tears.

In order to determine the analytical form of the function F, we need to perform a series of endurance tests, on a sufficiently high number of specimens, at different levels of amplitudes of the stresses, with a constant asymmetry of cycle's coefficient. In this paper, we will analyze (using the approach described above) the behavior of a RT800 composite material in endurance testing and we will find the continuous Wöhler function F associated with this material. Finding the analytical form of the Wöhler function is very important in estimating the life of mechanical components, using damage accumulation hypothesis like Miner, Corten-Dolan etc.

2. Material and method

The specimens which were used for endurance testing were obtained from a composite material board made of polyester resin reinforced with 5 layers of glass fiber fabric, RT800, with the specific mass of 845g /m^2. The specimens have the following physical characteristics:

- the length of the specimen (A) is 100mm;
- the width of the specimen (B) is 10mm;
- the thickness of the specimen (C) is 4.5mm.

The endurance testing was developed for bending stresses. The specimens were designed as in the Fig. 1.

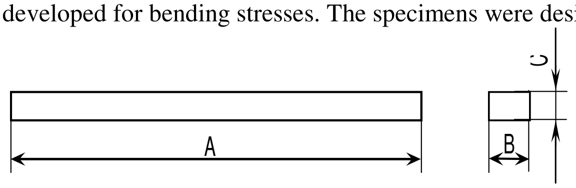

Fig. 1. The shape of the specimens which were used in endurance testing

For endurance testing, we used the following setup and method: The specimen is placed on two supports, as a lever, and is forced into alternating symmetric bending, until tearing. The method can be easily understood from Fig. 2. The distance between the fixed pairs of cylindrical supports is 80mm, and the force F is applied in the middle of the specimen, in an alternating manner.

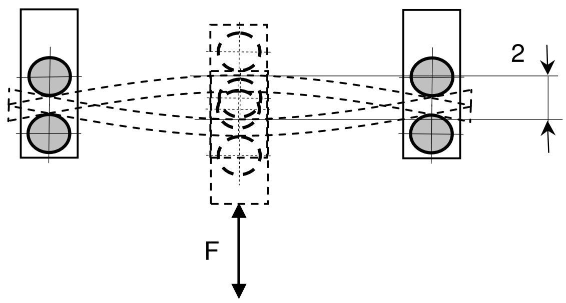

Fig. 2. The bending process in three points

The fly-wheel of the testing bench is operated by an electrical motor of constant speed (90 rpm's). The testing bench is provided with a force sensor (for reading the active force), a displacement sensor (for reading the displacement of the specimen) and a mechanical counter which records the number of cycles until tearing for each tested specimen. The device offers support on both ends and on both sides using a pair of metallic cylinders.

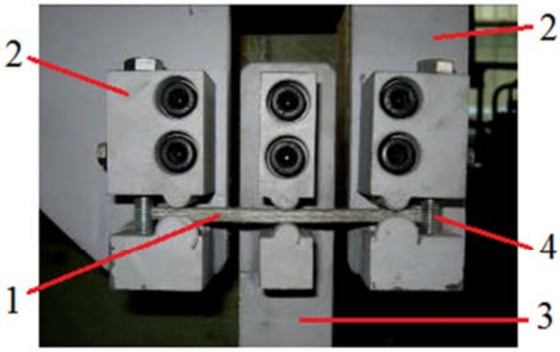

Fig. 3. The specimen, fixed on the testing bench. 1 Specimen, 2 Fixed support, 3 Mobile support, 4 Fixing screw

The force will be applied also using a pair of metallic, but this time mobile, cylinders. Both cylinders of both pairs can be set up to be all times tangent to the superior and inferior sides of the specimen, so that „pure" bending stress is obtained. This can be seen in Fig. 3.

3. Experimental results and analysis

For the experiment, we used 10 specimens obtained from the same board, with the same physical dimensions (as described above). The specimens were forced into alternating symmetric bending, until tearing, for 5 displacement arrows: 3.5mm, 3mm, 2.5mm, 2mm, 1.5 and 1mm. Our main interest was to determine the number of cycles until tearing occurs for each specimen. The experimental data can be observed in Table 1.

Table 1. The displacement arrow (on Y axis) vs. the number of cycles until tearing (on X axis)

Arrow (mm)	The number of cycles until tearing, measured on the testing bench									
	Spec. 1	Spec. 2	Spec. 3	Spec. 4	Spec. 5	Spec. 6	Spec. 7	Spec. 8	Spec. 9	Spec.10
3.5	26737	35900	34778	42875	37895	47850	31560	33998	34673	33181
3	51549	62890	53123	53377	52986	54391	54389	52317	49873	45662
2.5	69980	78315	69718	70231	72538	68319	71248	70039	65421	65858
2	83530	116831	65441	83308	87600	87273	86490	89613	88942	83747
1.5	168935	174322	174219	173249	175693	176417	172996	173926	169932	188942
1	285049	267843	274591	244381	261399	263762	261975	259680	262439	243368

The distribution for the number of cycles until tearing, for each displacement arrow, can be easily observed in the Fig. 4. Using the means for each set of values, we determined the average number of cycles until tearing for each displacement arrow. We then used MATLAB to determine a shape function for these average points.

This continuous function defines the behavior of the RT800 composite material for bending stress, and has the following expression:

$$f(x) = p1\,x^2 + p2\,x + p3 \tag{2}$$

with the coefficients being: p1 = 5.837e-011; p2 = -2.735e-005; p3 = 4.237.

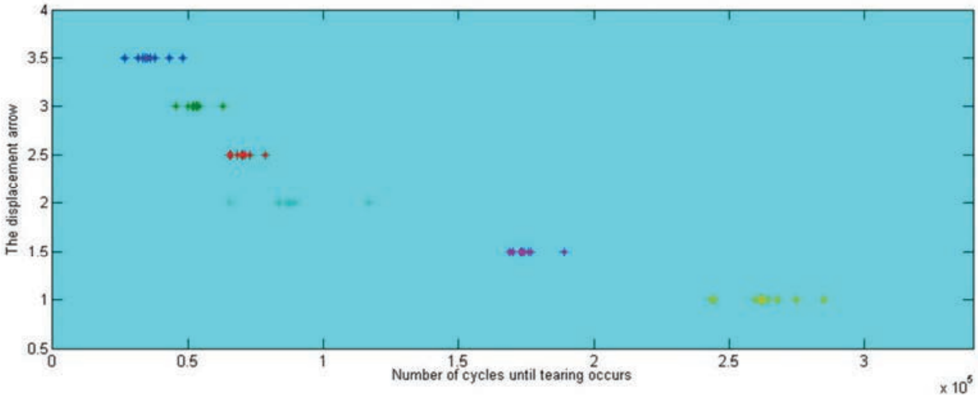

Fig. 4. The distribution for the number of cycles until tearing, on different displacement arrow levels

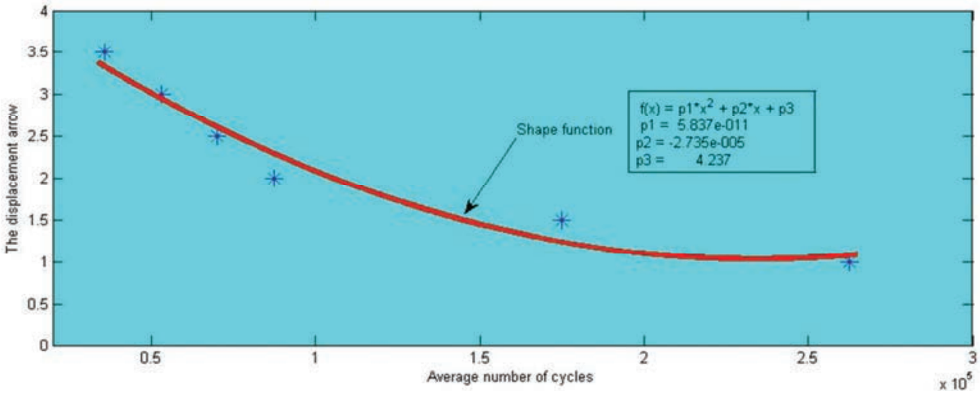

Fig. 5. The shape (Wöhler) function which defines the behavior of the RT800 composite material for bending stress

4. Conclusion

In this article, we managed to determine the analytical form of the Wöhler function F which is associated with the behavior of the composite material made of polyester resin reinforced with 5 layers of glass fiber fabric, RT800, with the specific mass of 845g /m^2. If we compare the Wöhler function's shape for this material with the Wöhler function's shape for common steel, a key difference can be noted: while, for steel, the function has a "steps" shape, for this material, the function is a simple curve, which denotes a more uniform behavior for this kind of material regarding endurance stress in operation. Also, during the testing, we observed a significantly high variance for the number of cycles at where specimens tear (obviously, considering each displacement arrow separately). This happens because of the complexity of this kind of material compared to common steel, and it implies that the testing should be done on a sufficient enough number of specimens in order to obtain good results.

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