Experimental measurements of composite materials from the bearing structure of railway vehicles

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Abstract. Composite materials belong to the category of "new materials", artificially created to meet the demands of science and technology. On the one hand, these are a perfect replacement of ferrous and nonferrous materials, and a perfect solution for a whole series of technical problems in various industrial branches, on the other hand. The composite materials represent fiber arrangements - continuous or not - from a resistant material (reinforcing elements), which are coated with a matrix, the mechanical strength of which is much lower. The Matrix maintains the desired geometrical arrangement of fibers and transmits stresses that the piece is subjected to. The present paper proposes to analyze behavioral patterns during the tests of specimens made of composite materials.

1. Introduction

The composite materials represent a class of engineering materials with special technical and scientific interest. They are not only a perfect replacement of ferrous and nonferrous materials but also the perfect solution for solving a whole series of technical problems in different industrial branches. Some technical problems are difficult or sometimes impossible to solve using traditional materials.

A composite material is a combination of two or more different materials from a chemical point of view, with an interface between them [7].

The constituent materials maintain their separate identity in a composite, though their combination generates all the features and characteristics of the various constituent materials in part. One of the items is called a matrix and is defined as forming a continuous phase.
The other main element called armature is added to the matrix to improve or modify its properties. Reinforcement is a discontinuous phase, equally distributed in the whole volume of the matrix [2].

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The composite materials are part of "new materials" and are specifically created to respond to particular requirements with regard to:
- Mechanical strength and stiffness;
- Resistance to corrosion;
- Resistance to action of chemical agents;
- Low weight;
- Dimensional stability;
- To withstand varying loads, shock and wear;
- Insulating and aesthetic properties [1].

For the construction of railway rolling stock, composite materials were inserted out of the need to reduce masses and to obtain sound and thermal insulation, better braking performance and traction, etc. The main requirements for composite materials are to successfully replace the traditional materials and to make improvements as much as possible.

From the point of view of the masses, the composite materials represent a big plus contributing to a significant reduction of loads and thus leading to improved performance of railway vehicles.

The noise emissions during traffic can be reduced through the use of composite materials with superior insulation properties [8].
For example, the elastomers based thermoplastic polyester offers a successful combination for many parts and components used in isolation railway vehicles.

In the case of rail vehicles, composite materials are used in construction: fuel tanks, fan blades, bodies, frames, chairs, floors, dashboards, radiators, doors, friction pads and brake blocks, cisterns, parts for wagons, elements of decoration and furniture subway trains, thermal and electrical insulation, and so on.

The classification of composite materials is usually done according to a series of criteria among which the most important are:

a) Depending on the nature of the matrix:
   - the metal matrix composite (Al, Cu, Ni, Mg, Al alloys, Cu);
   - organic matrix composites (polymers);
   - ceramics matrix composite (silicon carbide, silicon nitride).

b) After the geometric configuration of the reinforcement material:
   - composites with discontinuous fibers (short fiber, mono or multifilaments);
   - composites with continuous fibers;
   - composites with large particles (graphite, oxides, nitrides, carbides and alloys);
   - composites microparticles (reinforcing material represents 1 ... 15%, and an average particle diameter does not exceed 0.1 μm),
   - lamellars and multi-layers composite

c) After the structure and method of production

Design of composite materials is very different than that of the conventional products of synthetic materials [7].

A „gelcoat” is an in-mold coating used in plastics material reinforced with fibers and molded polymers.

Maxguard gelcoat offers superior performance for critical use in environments with added value of high protection in combination with special cosmetic products and exceptional properties for application in the process.

PAFS assemblies and subassemblies are used for:
- inner cladding of departments and halls of trains and passenger motorcars;
- interior and exterior cladding booths traction of passenger motorcars, interior walls, ceilings, booths traction and passenger wagons, luggage, and so on.

PAFS assemblies and subassemblies must be resistant to environmental conditions, heat, excessive humidity, detergents, influence of solar radiation, and must also be fireproof. They are designed so that the number of wear parts to be minimal, with these arranged to be interchangeable and accessible.

They are designed so that the number of wear/scuffing parts to be minimal, with these arranged to be interchangeable and accessible.

PAFS assemblies and subassemblies of the railway wagons are made from materials such as synthetic resins whose physical-chemical and mechanical properties must meet specific quality and current standards, so the finished product and panels match the characteristics required by European standards.

PAFS are built on the molds of the same material with a high degree for processing active surfaces by laminating manually the successive layers of fiberglass impregnated with polyester resins. The molds are obtained on models made of wood or PVC depending on the technological possibilities of execution.

Products can then be painted with paints that do not affect fireproofing classification.

The products have the role of inner lining and coating or of support mechanisms and various installations.

PAFS assemblies and subassemblies, plated with HPL, must be resistant to environmental conditions, heat, excessive humidity, detergents, influence of solar radiation, and must also be fireproof. They are
designed so that the number of scuffing piece/slice to be minimal, with these arranged to be interchangeable and accessible.

2. Experimental results

Using mechanical tests qualitative data are obtained of the behavior of materials in the corresponding strain conditions during these tests and the values of physical or conventional values called mechanical characteristics, which can be used as quantitative parameters for expressing mechanical properties. The tests were performed at Romanian Railway Authority-Romanian Railway Notified Body- Laboratory department.

2.1. Determination of tensile strength at full load, in the direction parallel and perpendicular to the direction of lamination

In order to highlight the particularities of the mechanically stressed composite material's reinforcements tensile stress was used. The test was conducted in accordance with [3].

Tensile testing was carried out on specimens made of the composite material, having the shape and dimensions according to [5]. For testing 10 rectangular specimens were used, type 2 with dimensions (250 x 25 x 5) mm, 5 taken in the longitudinal direction and 5 taken in the sectional direction of the material lamination. In the case of the specimens the width b and the thickness h were measured. The samples underwent tensile testing, and the speed of displacement of mobile jaw was of 2 mm / min. There was a breaking force F. Maximum tensile stress was calculated using the formula:

\[ \sigma = \frac{F}{bh} \]

The test results for determining the tensile stress at maximum load for resin type Hetron F645 TFE are found in Chart 1 and 2 and test mode samples are shown in fig. no. 3-6:

Figure 3. Test specimens during the tensile test

Figure 4. Test specimens during the tensile test
Figure 5. Test specimens caught in the jaws of the machine during the tensile test

Figure 6. Test specimens caught in the jaws of the machine during the tensile test

Chart 1- Tensile stress Chart on the paralell direction

| Stress (N) | 2012 | 2013 | 2014 | 2015 | 2016 |
|-----------|------|------|------|------|------|
| 70        | 90.7 | 80.96| 107.1| 82.8 | 85.99|
| 80        | 94.5 | 81.03| 107.2| 82.9 | 88.95|
| 90        | 103.6| 82.13| 108  | 84.3 | 93.96|
| 100       | 107.2| 83.04| 113.3| 90.7 | 95.19|
| 110       | 107.3| 84.63| 118.7| 101.1| 97.23|
2.2. Determination of the maximum bending stress conducted on the parallel direction and perpendicular direction of lamination

To highlight the particularities of the composite material, a bending stress test was used. The test was conducted in accordance with [4].

For testing 10 rectangular specimens were used with dimensions (80 x 10 x 4) mm, 5 taken in the longitudinal direction and 5 taken in the sectional direction to the rolling direction of the material. For the test method A was applied (method of 3 points).

For the specimens the width b and the thickness h were measured. The samples were placed one by one on the fixed bearing of the machine and the requested bending test was done with a moving speed of the mobile jaw of 10 mm / minute. The maximum bending force F was checked. The bending stress at maximum load was calculated using the formula:

\[ \sigma_f = \frac{3FL}{2bh^2} \]

where \( L = 16 \times h_{\text{medium}} = 68 \text{mm} \) (represents the distance between the two supports).

The test results for determining the bending stress at maximum load for resin type Hetron F645 TFE are found in Chart 3 and 4 and the test mode samples are shown in fig. no. 7 - 8:
Figure 7. Test specimens caught in the jaws of the machine during the bending test

Chart 3- Bending stress on the parallel direction
2.3. Determination of Charpy impact strength, on samples without notch (on the parallel and perpendicular direction to the rolling direction) and C-notch specimens (on the parallel and perpendicular direction to the direction of lamination)

To highlight the particularities of the composite materials breaking behaviour, a bending impact test was used. The test was conducted in accordance with [5].

For testing, 40 rectangular specimens were used with dimensions (80 x 10 x 4) mm, 20 taken in the longitudinal direction (10 with notch type C and 10 without notch) and 20 taken in the sectional direction (10 with notch type C and 10 without notch) to the rolling direction of the material.

The width \( h \) and the thickness \( b \) for specimens without notch respectively thickness \( b_k \) to notch specimens was measured.

An energy shock for breaking specimens \( A_n \) without notch, respectively \( A_k \) - for notch specimens was recorded.

Charpy impact strength was calculated using the formula:

\[
a_n = \frac{A_n}{hb} \quad \text{sau} \quad a_k = \frac{A_k}{hb_k},
\]

depending on the type of the specimen.

For specimens that were used to determine the Charpy impact strength on specimens with the type C notch, notch execution was carried out at AFER with a broaching machine having the Channel V profile with a depth of 2 mm.

The test results for determining the Charpy impact strength (specimens without notch) for resin type Hetron F645 TFE are found in Chart 5 and 6 and the test mode samples are shown in fig. no. 9 - 10:
Figure 9. Charpy machine and test specimens without notch

Figure 10. Charpy machine and test specimens with notch

Chart 5 - Test specimens without notch on the parallel direction
Chart 6 - Test specimens without notch on the perpendicular direction

The test results for the determining the Charpy impact strength (specimens with C notch) for resin type Hetron F645 TFE are found in Chart 7 and 8:

Chart 7 - Test specimens with notch on the parallel direction
3. Conclusion

The continuously evolving rail transport has led to the development of new technologies that meet market requirements. Thus were created new types of materials with new properties, capable of raising the performance of railway vehicles.

The use of composite materials has an important meaning, firstly by significantly reducing the masses, which leads to lower consumption of energy or fuels and increasing the amount of cargo or number of passengers.

This paper presents an experimental study on composite materials, respectively PAFS assemblies and subassemblies and the testing purpose was the approval / certification of products and framing outcomes within the limits of standards method.

For the verification of the manufacturing technology composite materials, the specimens taken from the composite material were subjected to mechanical tests for certification and underwent real life use.

The products tested were consistent with technical requirements for use in rail vehicles bearing /carrying capacity structure structure.

We can conclude from charts 1 and 2 that during the period of 5 years the results for the tensile stress in both cases of application (the direction perpendicular or parallel to the lamination direction) are very close, the difference being less than 2%. Also, these results are about 25% higher than the minimum required.

We can conclude from charts 3 and 4 that during those five years all breaks were initiated by requesting stretching external fibers. It is noted that the bending stress results in both cases of application (the direction perpendicular or parallel to the lamination direction) are very close, the difference being less than 2.5%. Also, these results are about 40% higher than the minimum required.

In 2015, it was observed that immediately after the start of bending tests on the surface of specimens, small cracks appeared in resin, in the middle of them, even if the test was held in elastic material specimens. As the test continued, the cracks grew in size and number. Meanwhile the loading force of the specimen decreased. After a while, the resin in the middle area of the specimen lost its rigidity being
destroyed by fissures and the specimen was no longer resisting. The application force stabilized. The test specimens did not break, keeping their integrity due to the layered structure of fiberglass.

In conclusion, it was found that the composite material studied can withstand greater demands than those that it will likely have to undergo and can be used with confidence in the support structure of railway vehicles.

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