Fatigue test of a fiberglass based composite panel. Increasing the lifetime of freight wagon

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Abstract. In the XXI century transportation of goods plays a key role in the economy. Due to a good logistics the economy is able to grow fluently. Although land transportation is carried out mainly through trucks for the last several years there has been noted an increase in the percentage share of rail transport in the freight transport. The main goods transported by railways are mineral fuels, mining and quarrying products. They constitute the greater part of 70% of total transported goods. Transportation of material of such high weight, high hardness and with different shapes involves increased and accelerated wear and tear of the cargo space of the wagon. This process is also magnified by substances used to prevent overheating or goods theft. Usually they are in the form of chemical compounds powder, eg. Calcium. A very large impact on the wear of the freight wagons hull is made because of mechanical damage. Their source comes mostly from loading cargo with impetus and using heavy machines during unloading. A large number of cycles of loading and unloading during the working period causes abrasion of body and as a result after several years a wagon car qualifies for a major maintenance. Possibility of application composite panels in the process of renovating the wagons body could reduce the weight of whole train and prolong the service life between mandatory technical inspection. The Paper "Fatigue test of a fiberglass based composite panel. Increasing the lifetime of freight wagon" presents the research process and the results of the endurance test of the composite panel samples fixed to a metal plate. As a fixing method a stainless steel rivet nut and a stainless steel button head socket screws were chosen. Cyclic and multiple load were applied to test samples using a pneumatic cylinder. Such a methodology simulated the forces resulting from loading and unloading of the wagon and movement of the cargo during transport. In the study a dedicated stand equipped with a pneumatic cylinder and a strain gauge sensors was used. A logic controller to control pneumatic valves was used. Tests were carried out for different number of cycles. The paper contains the results and conclusions which will be useful for the actual application of composite panels on the hull of a freight wagon.

1. Introduction
Composite materials are increasingly being used in modern construction engineering, in particular in areas such as aviation, astronautics, the automotive industry, railway industry, construction, sports equipment and medicine. Intensive development of these materials can be observed from the 60s of the twentieth century. Multi-layer composites, commonly referred to laminates, allow effectively increase the durability and rigidity of many structures, while maintaining low weight. The mechanical properties of the eventual composite element mainly depend on the components combined together.
and carried out mechanical strength calculations and tests. It would not be possible without modern engineering tools. Many of them are using Finite Element Method (FEM). Computer modelling and FEM simulation allow to produce theoretically unlimited number of combinations of a new composite material. It should be noted that the computer model is an idealized representation and does not reflect in one hundred percent true model of the composite. Difficulty of creating the perfect real model is due to imperfections which are hard to avoid in the manufacturing process, and due to the heterogeneity of composite structure. Computer simulation allows, however, with a close approximation to predict the behaviour of the material. For this reason, it is very important to carry out research on real models and compare the results with computer simulations. The basic physical quantities, which shall be subject of the research are displacement and deformation. One of the methods for measuring displacement or deformation of the test material can be a method involving the strain gauges. From their use, very valuable information can be obtained, which is mandatory during a process of producing much reliable materials. [1, 2, 4, 5, 6]

The aim of the study was to analyse the strength of the combination of metal panels and glass-epoxy composite during a multi-point pressure test. The study was conducted on a test stand equipped with 4 pneumatic actuators and the PLC driver as shown on figure 1. During the test the same sample was successively checked. Firstly bare metal panel was tested, then on a panel with fitted rivets nuts a composite panel was fixed. To determine the changes between the samples a strain gauges and distance amplifying instrument were used. Two programs were written and uploaded to the PLC. Each of the programs were executed with three values of the forces generated by pneumatic actuators. [3, 9, 10, 11]

![Figure 1. Pneumatic test stand with embedded PLC driver.](image-url)
2. Laboratory research part

In the laboratory research a dedicated test stand equipped with pneumatic actuators was used. The dimensions whole test stand is 400x400x600 [mm] and it is made with an aluminium profiles with a square 40x40 [mm] cross-section. A dedicated distribution board was attached to the test stand. The distribution board:

- an air preparation system with shut-off valve and the quick release valves,
- main circuit breaker,
- an EATON PLC controller,
- check-choke valves and reducers (4 pieces)
- Individual valves (4 pieces) controlled 24VDC with adapted flow,
- 24V DC power supply

Figure 2. Four pneumatic cylinders mounted to the aluminium profiles.
These elements were controlling the four double-acting pneumatic actuators attached to aluminium profiles and fixed with dedicated brackets and M8 screws as shown on figure 2. Thanks to the grooves in aluminium profiles a cylinder can be set anywhere along the profile. For the study, actuators were spread at 130 [mm] distance.

Two types of pneumatic actuators were used in the test stand, respectively, 754 [N] and 1178 [N] at 6 Bar. Every actuator was equipped with a pressure regulator with a manometer (Fig. 8). Thanks to this solution it was possible to individually adjust the strength of each cylinder. The dimensions of the test stand are a limitation to the dimensions of samples which were set at 400x400 [mm]. The samples are clamped using special bars with holes and fixed to the profiles with an M8 screw.

The glass-epoxy composite necessary to perform the test is shown on figure 3. It was made by hand method. It was assumed that the composite will consist of four layers of glass fabric and epoxy resin. To prepare the samples a 500g/m2 glass fabric was used. As the matrix of the composite a LG700 resins and HG 700 hardener were used mixed in a weight ratio of 100: 30. The individual layers are applied on a textolite panel, which had previously been coated with a liquid release agent. The appropriate number of layers were pressed one onto another with another panel and additionally loaded with weights in order to achieve a uniform thickness of the sample. The resulting composite panel was cut into samples with dimensions of 400x199 [mm]. To obtain a stresses value occurring in the steel plate, a HBM type delta strain gauges were used. [5, 7, 8, 13].

To register stress value CATMANEASY software was used. Delta type rosettes were connected to the computer via CANHEAD amplifier. Data from all sensors were saved to a .XML file after each test. In total, 18 cases were examined with different force. For each case also the displacement value was read and saved. In addition the gap formed between composite panels was measured for three different values of pressure force. [14]
3. Results and discussions

The studies were aimed to provide in an experimental way physical properties of a unique combination of metal panel and glass-epoxy composite. Formed composite had a slightly vary in thickness over the entire surface. The thickness deviation was in the range of 1 mm. The surface of the composite also had imperfections in the shape. It was covered with pores which were results of a manual method of lamination of the composite. These areas are more sensitive to the loads during fatigue test. In result it can effect with a degradation of properties of the composite in the above mentioned places.

When analysing the charts a non-linear course of the stress value can be indicated. This is caused by non-synchronous retraction of the actuators. At the return of the actuators the tension value returns to the initial state. This allows to determine that the metal sheet was strained elastically, which proves that the composite material stiffened the metal plate. Prior to any subsequent increase in tension on the chart, a minimal decline is noticeable. This is because the valve that opens when the actuator was pushed out closes the air flow inside. As a result, the air, which is located in the piston cylinder, is being compressed.

While analysing the stress in any case, a decrease in occurring strain value is clearly visible. Using the laminate plate, 50% decreases of the tension on strain gauge 2 at a pressure of 4 MPa is noticeable (Figure 5).

Analysing the other graphs on figures 6 and 7 an advantage of using a combination of a composite panel with a metal plate is clearly visible.

4. Conclusions

After analysing the results it can certainly be said that, despite some differences in the results the researches were carried out successfully. The composite in combination with a metal plate, can significantly strengthen the entire structure. The use of composite inserts, eg. in the regeneration
process of a freight wagons will help to extend the time intervals between maintenance. The effect of such a change would minimize the expenses associated with necessary repairs of railway transport.

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