The study of fix composite panel and steel plates on testing stand

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Abstract. In this paper the practical possibilities of strength verification analysis of composite materials used in the manufacture of selected components of railway wagons are presented. Real laboratory stand for measurements in a scale controlled by PLC controller were made. The study of different types of connections of composite materials with sheet metal is presented. In one of the chapter of this paper principles construction of testing stand with pneumatic cylinder were presented. Mainly checking of displacements and stresses generated on the sheet as a result of pneumatic actuators load for composite boards was carried out. The use of the controller with operating panel allows to easy programming testing cycle. The user can define the force generated by the actuator by change of air pressure in cylinder. Additionally the location of acting cylinders and their jump can be changed by operator. The examination of the volume displacements was done by displacement sensor, and the tensile strain gauge. All parameters are written in CatmanEasy - data acquisition software. This article presents the study of stresses and displacements in the composite plates joined with sheet metal, in summary of this article, the authors compare the obtained results with the computer simulation results in the article: “Simulation of stresses in an innovative combination of composite with sheet”.

1. Introduction
At the Faculty of Mechanical Engineering Technical University of Silesia are conducted research on the analysis and synthesis of mechanical systems and mechatronics [3,12,13,16], concern both theoretical [1,2] considerations how practical industrial tasks [14]. Recent works undertaken relate to research the properties of composite materials [7,9] as components and assemblies railway wagons [5,8,11]. Some of the work is conducted in collaboration with other research centers [10].

Composite materials more and more commonly begin to be used in engineering constructions, especially in the fields such as aviation, automotive or railway industry, construction and medicine. Multi-layered composites, also known as laminates, effectively allow to enhance solidity and rigidity of the construction maintaining a small weight at the same time. In order to model and simulate composite materials, CAx class programmes are used [6,8]. They allow not only to design a product in a parametric or non-parametric way but they also make solid and surface modelling possible. It is advisable to remember that a computer model is made in ‘ideal conditions” and it does not sufficiently reflect the actual composite model. The computer simulation merely allows to predict certain physical
parameters. For this reason, it is important to do the research on factual models and to compare the received results with the computer simulations. The aim of the thesis is to analyse the durability of the sheet metal and glass-epoxy composite blend along with multi-spot pressure application. The assignment adopts the measurement done by a tensometric method and comparing the results of it with the computer simulation findings. The outcomes are presented in the article “Simulation of stresses in an innovative combination of composite with sheet”.

2. Composite panel preparation for tensometric test purposes
A laminate is a composite consisting of several or more layers of two-dimensional mats or plates put on one another and a clay binder which combines the layers into the whole. The particular layers are laid on one another in the direction that provides the greatest durability properties. The layer can also be a fabric made of fibres arranged in a perpendicular manner. A laminate composition can range from 4 to 40 layers. The laminate solidity and rigidity is dependent on the direction of the fibres arrangement. It can be assumed that the fibres conduct compression and stretching forces. The clay binder, however, conducts the shearing forces. A commonly-known laminate is a glass-epoxy composite which shows satisfactory mechanical and electrical properties, has a high bending and compression resistance as well as resistance to higher temperatures.

![Figure 1. Composite plate model](image)

The glass-epoxy composite, necessary to do the research, is a handmade project (Fig.1). It has been established that the composite consists of 4 layers of glass mat and epoxy resin. In order to prepare the samples the glass mat has been cut into 600x500 [mm] sheets. The prepared textolite sheets have been waxed so as to easily separate them later form the composite. LG 700 resin has been applied and it has been mixed with HG 700 hardener in the 100:30 mass proportion. After the last layer was put, a textolite sheet has been applied from the top and the whole has been clamped. After the whole composite has been fully dried, the textolite sheets have been dismantled and the dried-up resin leaks have been trimmed. The sheet has been cropped to a 400x199 [mm] sheet in order to obtain the research object.

3. Construction and operation of endurance test stand
In order to analyse the samples a stand equipped with a pneumatic actuators has been used. The whole stand measures 400x400x600 [mm]. An electrical steering box has been attached to the construction made up of 40x40 [mm] aluminium profiles (Fig.2).
Figure 2. Construction and operation of endurance test stand:
(a) stand view (b) pneumatic actuators view (c) steering desktop view

In the steering box (2c) the following elements have been placed: the air preparation system together with a cut-off valve and, main electricity switch, PLC logical controller by EATON, throttle check valves and reducers, 24VDC voltage-controlled valves with the appropriately set air flow and the power pack. The enumerated elements steer the four double-acting pneumatic actuators. The actuators have been attached to the aluminium profiles in the way that allows to regulate the latter placement of the actuators. In the stand there are two types of actuators installed. They have different piston diameters so that forces such as 754[N] and 1178[N] with operating pressure of 6 bars can be reached
There are pressure regulators with a manometer connected to each actuator so that a force in each actuator can be regulated individually (shown in Fig. 3.)

4. Strain gage

Strain gage system is one of the fields dealing with measurements of construction distortions. Taking into account that strains in terms of pliability are closely connected with relative distortions, it can be stated that strain gauge is an experimental method of determining the strain. In order to measure the strain in the composite plates, rosette-strain gauges by HBM have been used. They have been chosen due to the fact that it is unfeasible to precisely assess the direction of occurring distortions. In order to attach the tensile strain gauge properly, it is essential to keep in mind that the strain gauge fixation surface should be clean and even. The strain gauges have been fixed by means of cyanoacrylate adhesive. The strain gauge endings have been plugged into CANHEAD device which makes archiving and signal volume visualisation possible. A sample has been attached to the prepared stand by means of a slat with fixation holes. Additionally, a tripod with a displacement clock sensor has been attached to the upper bar of the measurement stand. The clock sensor has been fixed in the place that provides the greatest displacement.

In order to estimate precisely what impact the installed composite exerts on the sheet metal, it was necessary to verify how the sheet metal works without a composite. For this reason three cases have been tested:

1) the one with an attached sheet metal with fixation holes
2) the one with an attached sheet metal with fixation holes and blind rivet nuts installed
3) the one with a sheet metal with composite plates attached

Figure 3. Pneumatic scheme of displacement enforcing system
Two programmes have been installed into the device driver of the PLC machine. The first one was meant to make the entire actuators slide out simultaneously with a 3-second delay and to return to the original position. The second one was meant to make the first, second, third and fourth actuator slide out successively with a 3-second delay between every slide-out. Then, all of the actuators were to return to the initial position. Each programme has been designed for three pressure volumes: 2, 4 and 6 [bar]. Every trial was done 11 times in order to average the results out and minimise a measurement error.

5. Analysis of research results

The purpose of the conducted research was to present, in an experimental way, that the fact of fixing a composite plate by means of blind rivet nuts will not diminish its mechanical durability. Testing the unique combination of the steel metal with a glass-epoxy composite with the pressure exerted by pneumatic actuators has been done. Owing to the research a great deal of data has been collected, and which has been shown in tables and in a graphical way. Due to the fact that a substantial amount of results has been gathered, there is one merely informative chart (Fig. 5). The chart presents the strains in a time function, and which have been recorded by a strain gauge no. 2 with the pressure of 2 bars.
In table 1 relative error obtained by comparing the stress measurement by strain gauge and the tension in the simulated NX was shown. The results of computer simulation and modeling of composite given in the article the authors under the title Simulation of stresses stressful in an innovative combination of composite with sheet.

| Pressure [bar] | Research | Tension gauge [MPa] | Displacement [mm] |
|---------------|----------|---------------------|------------------|
|               | MES      | 20.95 32.7 11      | 0.645            |
|               | Factual results | 24.31 34.27 12.66  | 0.63             |
| 2             | Relative results error | 13.82% 4.58% 13.11% | 2.38%           |
| 4             | MES      | 41.81 64.69 26.4   | 1.29             |
|               | Factual results | 52.65 75.24 25.77   | 1.46             |
|               | Relative results error | 20.59% 14.02% 2.44% | 11.64%          |
| 6             | MES      | 63.46 97.1 42      | 1.93             |
|               | Factual results | 72.24 102.23 35.55 | 2.03             |
|               | Relative results error | 12.15% 5.02% 18.14% | 4.93%           |

6. Conclusions
The purpose of the conducted research was to present, in an experimental way, the physical properties of the unique combination of the steel metal with a glass-epoxy composite with the pressure exerted on the combination by pneumatic actuators. The strain gauge test was conducted with the use of a pneumatic actuators stand. In the initial stage of the project a fixation of the sample and actuators placement were established. Also, it was essential to test the metal sheet separately in order to compare and analyse the combination of the sheet metal with the glass-epoxy composite. While analysing the charts presenting different cycles of operating actuators, a gradual growth of the strains has been noticed. It is caused by the fact that the actuators were made to slide out one by one till the complete slide-out of all the actuators. Afterwards, the strains plunge which confirms the actuators’ return to their initial position. A minimal fall can be observed before every following strain growth. It is due to the fact that the valve opening during the actuator’s slide-out, closes the airflow. Consequently, the air present in the actuator’s piston is pressed.
While scrutinising the strain course for the three previously enumerated cases, it can be observed that the strain decreases when blind rivet nuts are used. However, when an additional laminate is used, the strain in sensor no. 2 with the pressure of 4 MPa falls by 50%.

Tables 1 and 2 present maximum strain volumes for all examined cases. The greatest strain volumes ought to be theoretically identical while executing programme no. 1 and 2. Nevertheless, a slight difference can be noticed, and which is classified as a measurement error.

Tables 1 and 2 show the comparison of the results received owing to the strain gauge measurement and MES simulation. There are certain discrepancies observed. The biggest discrepancy in terms of the strains and displacements occurs when the pressure of 4 bars is exerted. The results and the estimated measurement error (the one resulting from the strain gauge test and MES simulation) confirm the experiment correctness. There was also a test conducted for 2000, 5000 and 10000 cycles with the aim of monitoring what pressure is exerted on the composite. After 2000 cycles no considerable changes were observed in the composite. After 5000 cycles slight dents and fractures on the composite surface in the pneumatic actuator pressure spot were detected. After more than 1000 cycles the pneumatic actuator pressure spot was clearly noticeable. The force exerted by the pneumatic actuators on the sample causes a crack between a sheet metal and the laminate to occur.

The crack is an impediment due to the fact that water, pieces of dirt or other substance may get into the crack, and which may have a detrimental effect on the durability of the blend. In order to prevent the blend from harmful external factors interference, a filling material can be applied in the place of the sheet metal and the laminate seam.

In conclusion, the application of the innovative combination of a sheet metal with a glass-epoxy composite provides a better durability than the application of a sheet metal only. Nonetheless, it is advisable to take into account that the use of a composite additionally increases a total object mass and its cost.

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