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Analysis of mechanical properties of layered composites with polyester-glass recyclate

Abstract

Various types of composite materials, in particular polyester-glass laminates, are widely used in industry. They constitute an important structural element of vessels (hulls, superstructures, bulkheads, compartments, cabins), airplanes, cars, cisterns, motorcycles or bicycles. It is also used in civil engineering as elements of bridges and reinforcing rods. The ter materials are characterized by high resistance and relatively good strength properties obtained at relatively low manufacturing costs. The widespread use of this material gives rise to a discourse about its utilization. In Poland, over 80,000 tons of elements containing this laminate are produced each year (around 845 production plants). This generates the creation of about 2,000 tons of post-production waste generated next to finished products in the production process. For example, in 2011, a company from the vicinity of the Tri-City, producing floating units made of laminate, produced over 10 tons of waste. In a natural way, after a period of use, the products of this company (similarly to other production companies) are sent to landfills. Empirical data say that there are more than 20,000 tonnes of waste in Poland each year.

There is no doubt that a large amount of waste and their adverse impact on the environment motivates to specific interventions. Currently, there are many methods of processing these wastes into full-value products. Technological advances in recycling have meant that there are currently large opportunities to use recycled waste for different types of composites, which in the recent past were treated as unnecessary materials.

The literature on the subject shows that today there are many ways to recover glass fibers from waste, which can be - with great success - used in the production of a fully-fledged component. It may be in the form of: 1) powdered as evenly crushed and short fibers; 2) elongated particles used in the production of specific products.

Prudent modeling and management of waste materials, understood as so-called high recycling rates, can significantly reduce the costs of storage and processing. First of all, it would help reduce transport costs and reduce greenhouse gas emissions. As you know, plastics are almost always a product created from the processing of crude oil (statistically it is 8% of world oil production, of which 4% is used as a raw material and 3-4% as a source of energy necessary for industrial production). The results of scientific research prove that the recycling of plastics and other wastes has a major impact on reducing the effects of climate change, as well as

reducing the need for so-called abiotic resources and a significant reduction in the toxicity of both small sea basins and oceans. Modern technologies make it possible to reduce the energy consumption of transport of raw materials necessary for composite production and transport of finished construction materials, which in turn reduces greenhouse gas emissions.

The main objective of the research was to determine the mechanical properties (including strength, hardness, resistance to impact loads) of this composite, as well as the development of technology for the production, use, storage and recycling of this new material. The purpose of the research formulated in this way was achieved through the implementation of the following milestones (detailed): 1) Evaluation of the quality of polyester and glass waste coming from hulls and superstructures of vessels (eg ships, ships, sailing ships, yachts, lifeboats, etc.) and from construction elements of vehicles mechanical, parts of machines and devices, as well as household appliances, clothing, packaging and the like, 2) Development of technology for recycling polyester-glass waste, 3) Determination of the impact of polyester-glass granules on the mechanical properties of the new composite (its content% and granulation) , 4) Verification of the possibility of using traditional technologies for the production of plastics in the process of producing a composite with polyester-glass regranulate, 5) Determination of mechanical parameters, based on research, in particular strength, corrosion and structural, 6) O working on applications and proposals for further improvement of the production and use of polyester-glass recycled composite.

An attempt was made to formulate the following general hypothesis:

"The polyester-glass recycled composite has the mechanical properties of a fully-fledged product and can be a building material or material used in the construction of machines, devices, etc.".

The supposition outlined above was the basis for concretization and creation of the following partial (specific) hypotheses: 1) Polyester-glass waste has a high material, financial and utility value, 2) Polyester-glass waste should be subjected to the material recycling process and, as a last resort, energy and raw material recycling , 3) The glass-polyester recyclate determines the mechanical properties of the composite containing this particulate product, 4) The composite with polyester-glass regranulate can be produced in rendering plants that have machines and devices to crush and segregate plastic waste, 5) Modern technologies of composite production with polyester-glass granules allow to obtain this product, characterized by good mechanical properties, 6) Application of Kolmogorov-Sinaia metric entropy allows to determine the transition stage of the composite from the phase of Unused the plastic phase, the material-specific, 7) is a need to develop and improve research on the process for producing a

composite with the recycle polyester-glass and using it in an efficient, profitable, and not causing controversy.

This doctoral dissertation, consisting of the theoretical and research part, contains verification of the assumed goals, as well as the general hypothesis and partial hypotheses. **The theoretical part** is the result of in-depth studies on the literature of the subject. It contains a brief description of composite materials as well as their components, including structural composites, resins, granular fillers and reinforcing fibers, resin modifiers. It discusses the mechanical and corrosion properties of various composites (including polyester-glass). He synthesizes opinions on polymer waste and their impact on the natural environment and the health condition of the population. Describes methods of processing this waste, referred to as energy recovery, raw material recycling and material recycling. It contains a discourse on composite recycling both in our country and in neighboring countries. It shows the possibilities of using this waste in industrial and specialist production.

The research part of the dissertation is the result of research on layered composites containing polyester-glass recyclate. The beginning of this part of the dissertation concerns the methodology and contains the following elements of the structure of the research process: research goals, research problems, research hypotheses, research methods and results of own research. In the course of the work, research materials obtained by means of the technology of obtaining polyester and glass recyclate and the technology of composites production were characterized by manual lamination and the vacuum bag method. Static tensile testing of polyester-glass recycled composites was performed to determine mechanical properties on stretching. The results were used to determine the plastic boundary of composite materials by the Kolmogorov-Sinai metric entropy method. Methodology and test results are presented, such as: impact strength (and associated kinetics of damage), three-point bending, hardness, aging of composites. The issues of microscopic examination with the use of stereoscopic and optical microscope were also taken.

The conducted research, obtained results and their analysis allowed to formulate the following conclusions: 1) There are large possibilities for full management of polyester and glass waste that eliminates pollution and reduce the amount of this waste and its destructive impact on the natural environment; 2) Processed polyester-glass waste can be completely used for the production of new construction materials; 3) The content of polyester-glass recyclate in the composite affects its mechanical properties and determines its application to structural elements; 4) Recycled content up to 15% in the composite, allows it to be used in structures subjected to high loads; 5) Composites made by vacuum bag containing up to 15% of recyclate,

show higher mechanical properties than materials with similar recyclate content, but obtained by manual lamination; 6) The use of Kolmogorov - Sinaia metric entropy method allowed to determine the yield strength of composites.