Development and characteristics of Metal-Polymer Laminates

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Over the past two decades, extensive research has focused on impact-resistant polymeric materials, a pressing modern scientific challenge. Notably, Metal-Polymer laminates stand out as hybrid composites, combining traditional fiber-reinforced plastics with metal elements like foils or mesh. While the primary application of these laminates has historically been in aircraft structures, their use has extended to the construction industry. Ongoing research aims to enhance the mechanical properties of these materials, paving the way for diverse applications. Scientists at the Grigol Tsulukidze Mining Institute have achieved significant breakthroughs in creating these innovative materials. By leveraging advances in polymer chemistry, they've managed to engineer composites with targeted properties, capable of withstanding dynamic loads and diverse conditions. One of the standout advantages of this technology is its cost-effectiveness. It boasts reduced electricity expenses by 30-40%, facilitates the production of larger components, and slashes labor costs by 40-50% compared to alternatives.

Keywords: Hybrid composites, Shock Resistance Materials, Mechanical Properties

Introduction

For two decades, there has been significant progress in the production of shock-resistant composites, especially in the military field. These materials include metal-polymer laminates that contain both organic and inorganic fibers. The metal-polymer laminates presented here belong to a broader category of composites. They consist of thin metal layers and fabrics connected using a polymer matrix (adhesive) as the bonding material for the intermediate layers (Fig. 1).

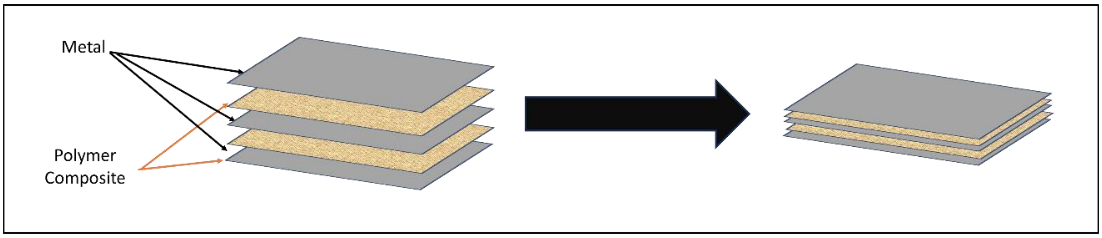

Fig. 1. Schematic presentation of Metal-Polymer laminates

Metal-polymer laminates offer several notable advantages over traditional metal structures. Firstly, they possess all the inherent properties of ordinary metal, including high strength and stiffness. Additionally, they exhibit several additional positive characteristics. For instance, the inclusion of polymer layers provides enhanced corrosion resistance, safeguarding the underlying metal layers from degradation caused by environmental factors. Metal-polymer laminates deliver significant weight savings compared to solid metal counterparts. By utilizing thin metal layers supported by polymer materials, these laminates achieve lighter structures without compromising strength. This reduction in weight is particularly valuable in industries such as aerospace and automotive, where improved fuel efficiency and performance are essential - . Furthermore, the design flexibility of metal-polymer laminates allows for optimization based on specific performance requirements. Through careful engineering of the thickness, composition, and arrangement of the metal and polymer layers, these laminates can be tailored to meet desired specifications and standards. Additionally, they possess special characteristics related to metal fatigue strength, further enhancing their durability and longevity. In summary, the intensive development of metal-polymer laminates over the last two decades has resulted in a composite material that combines the strengths of metal with additional benefits like corrosion resistance, weight reduction, optimization, and improved metal fatigue properties - . These advancements have opened new possibilities for applications in various industries seeking high-performance, lightweight, and durable materials.

Sample preparations:

One of the methods to manufacture Metal - polymer laminates is to stack the main component (metal, fabric) and infuse resin into it. RFI (Resin Film Infusion) method and direct pressing (load - 10 kg) were implemented to make cube-shaped composites of three different compositions (types). Aramid, Glass, and Basalt fibers were used (fig 2). Epoxy resin was used because of its cost-effectiveness and high mechanical properties. RFI method provides an edge through its ability to thoroughly impregnate the resultant material with polymer, leading to exceptional homogeneity (fig 3).

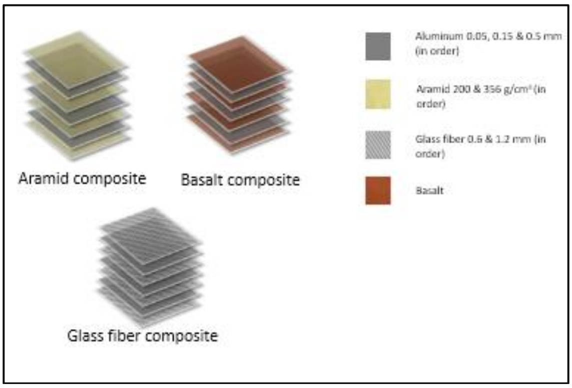

Fig. 2. Individual component of metal-polymer laminate composite samples

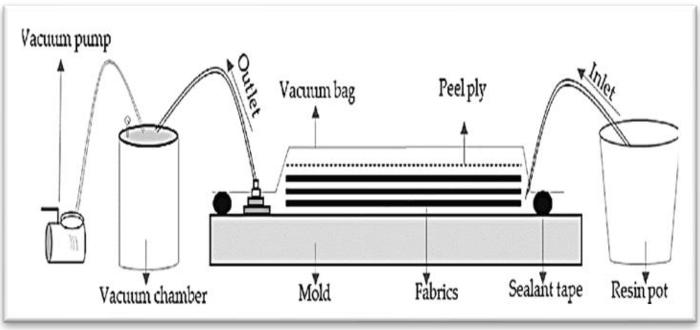

Fig. 3. General Structure of Resin Film Infusion (RFI) Technology

Blast Testing:

The requirement for incorporating hybrid reinforcements emerges from the inherent strengths unique to each fabric type. It's worth noting that factory-produced aramid fabric, as applicable in our context, is made available in two distinct surface densities (measuring 200 g/m² and 350 g/m² respectively). Conversely, in the instance of the glass fabric, a choice was made to utilize two varying fabric thicknesses (measuring 0.6 mm and 1.2 mm respectively). This deliberate selection of diverse fabric attributes underscores the quest for optimizing performance through a synergistic blend of materials.

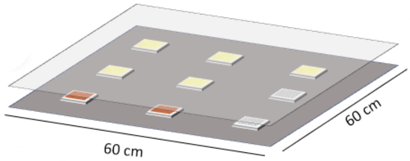

Fig. 4. Picture and diagram of test sample plate (thickness of Steel plate - 2 mm)

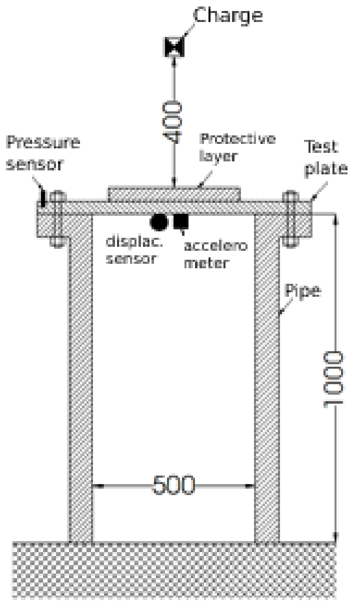

Fig. 5. Stands for dynamic loading testing

Result and discussion

The technology for manufacturing metal-polymer laminates in laboratory conditions has been studied and modified. This epoxy polymeric matrix was used. It provides optimal means for bonding the composite layers (metal and textile) of the laminate. Both the chemical characteristics and physical-mechanical properties of the polymer have been thoroughly investigated. The graph (fig 6) displays the results of an experiment on blast wave loads (pressure and acceleration) applied to the sample, which were recorded by the oscilloscope (Tektronix DPO 2024B)

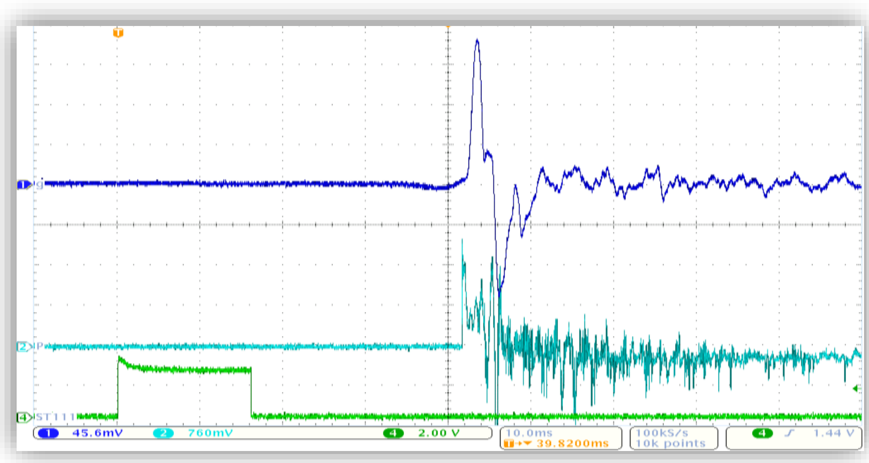

Fig. 6. The oscillograph recorded the results obtained during the blast testing on materials.

Conclusion:

In the manufacturing process, a variety of fabrics and aluminum plates with different thicknesses were utilized. RFI technology is employed to create metal-polymer laminates, ensuring a significant impregnation of resin. The key parameters for producing the composite have been identified: the pressure is set at 1 atm, temperature ranges from 24 to 28°C, and the resin curing time is 48 hours. The material underwent explosion testing, during which data on acceleration and pressure were gathered.

Further investigations are necessary to evaluate the properties of the current materials. As previously discussed in the preceding sections of this report, a series of samples has been meticulously crafted for the express purpose of conducting comprehensive studies focused on evaluating their resistance to explosive forces. These samples, meticulously fabricated under controlled laboratory conditions, represent a critical component of our research efforts aimed at enhancing our understanding of blast resistance in various materials and structures. The data gathered from these samples will play a pivotal role in informing future design considerations and safety protocols, particularly in scenarios where resilience to explosive events is of paramount importance.

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