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STUDY OF THE INFLUENCE OF VARIOUS LASER SOURCES ON NON-METALLIC MATERIALS USED IN UAV STRUCTURAL COMPONENTS

ДОСЛІДЖЕННЯ ВПЛИВУ РІЗНИХ ЛАЗЕРНИХ ДЖЕРЕЛ НА НЕМЕТАЛЕВІ МАТЕРІАЛИ, ЩО ВИКОРИСТОВУЮТЬСЯ В КОНСТРУКЦІЙНИХ КОМПОНЕНТАХ БПЛА

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The investigation of how different laser radiation sources interact with non-metallic materials commonly used in the production of unmanned aerial vehicles (UAVs) represents a highly relevant and important research direction in both fundamental science and applied engineering. Among these materials, carbon composites, fiberglass-reinforced plastics (FRP), phenolic paper laminates (Getinax), and various polymer-based compounds occupy a leading position due to their unique combination of properties. These materials feature low density, high specific strength, excellent dielectric characteristics, corrosion resistance, and relatively low manufacturing costs. Such properties make them ideal for modern UAV construction, covering a wide range of applications – from lightweight reconnaissance drones to heavy combat platforms.

However, their interaction with laser radiation involves complex physical and chemical processes. The response of these materials is highly dependent on multiple factors, including the wavelength and spectral range of the laser beam, its power level, generation mode, scanning speed, and exposure time. Laser radiation can induce both thermal effects, such as melting, burning, and surface carbonization, and photochemical effects that lead to molecular and structural changes within the polymer matrix. These processes manifest as ablation of the surface layers, microcrack formation, internal stress

buildup, delamination of layered composites, and, under certain conditions, complete destruction of the material.

The study of these mechanisms is of dual importance. From the perspective of defense technology, the research enables the identification of critical operating regimes of laser systems that ensure the most efficient destruction of UAV components while minimizing energy consumption. Such knowledge plays a key role in the development of advanced counter-UAV systems that use directed-energy weapons for precise and rapid neutralization of hostile drones.

On the other hand, the findings are equally valuable for civilian and industrial applications. They allow for the optimization of laser processing techniques such as precision cutting, drilling, engraving, and micro-machining of non-metallic composites in aerospace engineering, electronics manufacturing, and advanced prototyping. Improved process control leads to higher product quality, reduced material waste, and increased manufacturing efficiency.

The research also includes a comparative analysis of different types of laser sources, such as fiber, solid-state, gas, and diode lasers. This approach makes it possible to identify the most effective configuration for specific material compositions and structural thicknesses. The results bridge multiple scientific domains, integrating laser physics, materials science, military engineering, and industrial design.

The study was conducted within the framework of project No. 2023.04/0166, “Study of the effect of a laser beam on the materials of UAV parts and substantiation of the technical parameters of the laser equipment of the mobile complex to combat them,” funded by the National Research Foundation of Ukraine (contract No. 8/0166 dated March 3, 2025). During the 2025 project stage, new high-power laser equipment was acquired, which enabled the design and assembly of a prototype experimental laser module. The prototype includes: a MAX MFSC-6000M fiber laser manufactured by Maxphotonics (China) with a maximum output power of up to 6.0 kW; a water-based cooling system for stable operation; a precision optical head with advanced focusing optics; a mechanical positioning and fixation system for the optical head; specialized fixtures for test specimens imitating UAV structural elements, made of carbon composites, fiberglass, Getinax, and polymers.

A series of experiments was carried out using the prototype to refine and validate the methodological approaches developed during the initial project stage. Particular attention was given to studying the effect of varying the distance between the laser source and the target material on the efficiency of damage processes. The obtained experimental data were compared with results from earlier tests conducted using a solid-state Nd:YAG DY044 laser

manufactured by Rofin-Sinar (Germany), with a maximum output power of 4.4 kW.

Based on these comparative experiments, the methodology for assessing the impact of laser parameters on the destruction of UAV-relevant materials was significantly improved and corrected. This advancement establishes a robust scientific foundation for the development of mobile high-energy laser systems capable of neutralizing drones under field conditions. Furthermore, the research contributes to the broader field of precision laser material processing, offering valuable insights for future technological innovations in both defense and industry.