Self-Sensing Behavior of Laser-Processed sCFRP Based on Electrical Resistance Change

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This study proposes a self-sensing approach for laser-processed short carbon fiber reinforced plastic (sCFRP) based on electrical resistance change. In recent years, lightweight and highly formable sCFRP has been increasingly used in automotive components and complex-shaped parts. However, internal microdamage is difficult to detect from the surface, which may reduce structural safety. Therefore, the development of a self-sensing technique that enables the material itself to detect damage and strain without external sensors is required. In this study, local electrical conductivity is introduced into originally insulating sCFRP by laser processing [1]. The objective is to investigate the possibility of using the material itself as a strain sensor by utilizing changes in electrical resistance associated with mechanical strain.

The effects of processing conditions on the electrical properties are investigated by characterizing the processed surfaces. Scanning electron microscopy (SEM) observations show that carbon fiber accumulation in the laser-processed region strongly influences conductive path formation. In regions with greater fiber accumulation, increased fiber-to-fiber contact forms a continuous conductive network, resulting in electrical conductivity. Surface roughness measurements using a laser microscope further show that the smoothest processing condition gives the lowest initial resistance. On smoother surfaces, electric current flows more directly, whereas on rougher surfaces, the current path becomes more tortuous, leading to higher resistance. These results indicate that both carbon fiber accumulation and surface morphology affect the electrical properties.

The relationship between electrical resistance and strain is examined under tensile loading. Laser processing is performed at different scanning speeds to compare the conductive paths formed under each condition. Strain is measured using a strain gauge, and electrical resistance is simultaneously recorded using a radio-frequency identification (RFID) tag, enabling correlation between mechanical deformation and electrical response. At low laser scanning speeds, longer irradiation promotes carbon fiber accumulation, resulting in low initial resistance and a small resistance change rate. The resistance changes linearly with strain and shows stable, reproducible behavior. In contrast, at high laser scanning speeds, insufficient laser energy hinders conductive path formation. As a result, the initial resistance is high, and even small strain causes large changes in fiber-to-fiber distance, leading to a high resistance change rate. The response is nonlinear, variable, and unstable. Cyclic tensile tests further show that electrical resistance increases during loading and decreases during unloading. These results demonstrate the potential of laser-processed sCFRP as a self-sensing material.

REFERENCES

[1] M. Enomoto and A. Todoroki, Electrical resistance welding of 3D-printed short carbon fiber/PA-6 using laser surface treatmen, 70(6), 30-35, 2024.