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Thermal Diffusivity Analysis of Carbon-Ceramic Brake Discs Using Lock-In Thermography

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Carbon-ceramic brake discs are widely used in high-performance and safety-critical applications due to their excellent thermal resistance, durability and braking efficiency. A crucial characteristic for high-performance brake discs is their ability to withstand the extreme temperatures generated during braking. Since braking converts kinetic energy into heat, understanding how this heat propagates through the disc is essential. Efficient heat dissipation prevents thermal stress, material degradation, and performance loss, ensuring durability and consistent braking efficiency. This study investigates the local thermal diffusivity of brake-discs using lock-in thermography, with the objective of analyzing the heat propagation along its thickness when subjected to laser heating. The experiment has been conducted at two locations: one on a rib and the other on a cooling channel, and three separate directions have been considered for the analysis to capture the anisotropic thermal behavior of the brake disc. The first direction is parallel to the carbon fibers, the second direction is perpendicular to the fibers, and the third direction is set at a 45° angle to provide information on intermediate heat propagation characteristics. This approach allow a comprehensive evaluation of how the orientation of the material fibers affects thermal diffusivity and heat transfer efficiency. Post-processing has involved the application of a 1D fast Fourier transform (FFT) algorithm to extract amplitude and phase maps. The phase maps show variations in thermal diffusivity, influenced by the material's anisotropy and structural differences (rib vs. cooling channel). The propagation of the thermal wave along the thickness varies with the selected measurement points, confirming that the local geometry affects the heat transfer characteristics. The analysis of thermal diffusivity across different fiber orientations reveal a pronounced anisotropy in heat propagation. The measured diffusivity is significantly higher in the direction parallel to the carbon fibers, where heat conduction is more efficient, while it is considerably lower in the perpendicular direction due to the obstructive effect of fiber-matrix interfaces. The intermediate measurement at 45° exhibited a smooth transition in thermal behavior and show the greatest variability depending on structural differences at the measurement points (rib vs. cooling channel). These findings underscore the critical influence of fiber orientation on thermal management and demonstrate that thermography can serve as a valuable tool for advanced quality control in brake disc manufacturing.

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