Experimental Time-Domain Analysis of Dynamic and Damping Properties of CFRP, GFRP, and Advanced Composite Materials

Prof. Ing. Zuzana Murcinkova
Technical University of Kosice, Košice, Slovakia

Abstract

This study focuses on the time-domain analysis of free damped vibration of selected viscoelastic polymer composites reinforced with long carbon and glass fibres, with the aim of experimentally determining and quantifying their dynamic and damping properties. Laminated composites CFRP (carbon fibre reinforced polymer) and GFRP (glass fibre reinforced polymer) were investigated experimentally. Based on experimentally measured time responses of free vibration, key dynamic parameters were identified, namely the damped vibration period, natural damped and undamped frequency, damping ratio, logarithmic decrement of damping, equivalent viscous damping coefficient, dynamic stiffness, and the level of energy dissipation during vibration. The results of the experimental analysis enabled a quantitative comparison of the ability of the investigated composite systems to dissipate mechanical vibrational energy. From a materials behaviour perspective, the results are interpreted in accordance with Ashby material property charts, which highlight the inherent trade-off between stiffness, density, and damping capacity of composite materials. CFRP exhibits a lower density (approximately 1150 $kg \cdot m^{-3}$) compared to GFRP (approximately 1545 $kg \cdot m^{-3}$), resulting in reduced structural mass while maintaining high specific stiffness. From an economic perspective, GFRP composites are less expensive than CFRP, which represents an important factor for their broader practical application. From a mechanical standpoint, CFRP exhibits higher tensile strength and a higher Young's modulus compared to GFRP, while simultaneously showing lower internal energy dissipation and a shorter vibration decay time. In engineering practice as well as in lay perception, CFRP is often associated with a high-performance "high-tech" material implicitly assumed to possess favourable dynamic properties, including damping. However, this assumption is not consistent with its viscoelastic behaviour, as increased stiffness in CFRP does not imply a higher level of internal damping. In structural applications characterized by high stiffness and low inherent damping, such as bicycle frames or sports equipment, part of the vibrational energy may be transmitted to the contact interfaces and subsequently to the human musculoskeletal system, where it manifests as increased vibrational loading. Similar phenomena have been documented in tennis rackets, where differences in CFRP and GFRP composite construction significantly influence vibration transmission to the upper limb and the subjective perception of comfort. In the extended scope of the work, in addition to CFRP and GFRP, the time responses of other material systems will also be compared, namely particle-reinforced polymer concrete, sandwich structures, and SiC matrix-based composites reinforced with short carbon fibres, with the aim of providing a more comprehensive evaluation of their dynamic and damping behaviour.