

Carbon composite plates for running shoes: a novel testing method for the measure of flexural stiffness, rebound and damping

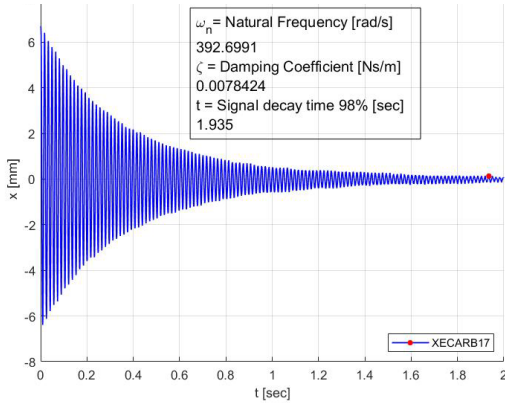
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Plates made of carbon-based composites are widely used in running disciplines such as marathon, speed running etc [1]. The mechanism of action and the real efficiency and advantages of these carbon plates as insoles or inside the midsole are still under discussion in the scientific literature and among athletes [1-4]. The mechanism of action has been ascribed to a spring effect [2] that provides an energy return after bending and/or to the modification of metatarsal-phalangeal and ankle joint bio-mechanics [1]. Some studies have pointed out that the design of the insole may have an effect on performances [1,4]. On the other hand, other studies [3] point out that the main improvement in the running efficiency is mainly connected with the foam used for the midsole and not to the carbon plate itself. Even if several designs and materials have been developed in the last few years, no scientific research has ever compared the effect of those designs and materials on the flexural stiffness, rebound and damping characteristics of the insole. For this reason, we have developed a new testing method for the measure of the characteristics (stiffness, rebound and damping) of the materials used at different temperatures. Due to the lack of studies on the mechanical properties on carbon insoles we have started our work testing the insoles by applying a perpendicular force to the sole. Indeed, this is a simplification of the forces applied during running since the propulsive and braking forces during running occur in all directions at different loading rates. We therefore consider our present work as a starting point for a deeper investigation using more complex force application patterns. We have designed and built a test bench for measuring the flexural stiffness and the rebound and damping characteristics of the composite materials used, of the carbon insoles and of the entire sole. The system locks one part of the sole, of the insole or of the specimen to the base, while the upper part is flexed with a cable attached to a tensile testing machine (MTS 200) that can measure the displacement and the force applied. Once a certain deflection is obtained, the insoles, sole or specimen is released and the damping curve (position vs time) is measured using a Laser detector OptoNCDT 1402 from MICRO-EPSILON recording

at 1 kHz. The damping curves have been interpolated using a model that permits to obtain the natural frequency and the damping coefficient (Figure 1). The tests have also been conducted using the entire sole in order to measure the damping behavior of the foam. The system has been designed to apply forces with different application directions for future tests.



$$T_d = \frac{2\pi}{\omega_n \sqrt{1-\zeta^2}}$$

Figure 1: damping curve measured on specimen and equation used to fit the data.

The information about damping and stiffness at different temperatures have been obtained by Dynamic Mechanical Thermal Analysis (DMTA) on a Rheometrics DMTA instrument in a range from -40°C to 80°C. This type of test gives as output the storage modulus (connected with flexural stiffness) and the tanDelta (the ratio between storage and loss moduli that is connected with the damping behavior). The DMTA data have been correlated with the results obtained with the test bench, providing a powerful tool to predict the rebound and damping behavior in different environmental conditions.

The data obtained on the flexural stiffness, rebound and damping characteristics of the plates will constitute a baseline for a comparative analysis of the performances of the shoes in order to understand how the stiffness, rebound, damping and geometry of the carbon plate affect the running efficiency.

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