Advances in Ultrasound Longitudinal Speed Characterization of Unidirectional CFRP Laminates: Simulations and Measurements

*Universidade Estadual de Campinas – UNICAMP,
Rua Mendeleyev, 200 - Cidade Universitária, 13083 860 Campinas, Sao Paulo, Brazil
(ppj@fem.unicamp.br)

Abstract

Carbon Fiber Reinforced Plastic (CFRP) products are present in many commercial and scientific applications, such as the fuselage of aircrafts Boeing 787, Airbus A350 or NASA rocket nozzles. Both high thermal and weight saving applications take benefit of its advantages. This work introduces a comparison between velocity measurements of longitudinal body ultrasonic waves and calculations from Finite Element Analysis (FEA) for a specific CFRP made of AS4/8552 prepreg. This particular FEA model is composed of an epoxy resin matrix and carbon fibers as reinforcement, simulating the microstructure of the material. In this first study, we address the generation, propagation, and detection of longitudinal waves in a unidirectional laminate, i.e., each lamina having the same orientation. An innovative equation used to insert the ultrasonic pulse is proposed by the authors, considering the effects of a non-perfect coupling between transducers and material. Experimentally, we developed a 197 mm long, 197 mm wide, and 18.6 mm thick test specimen. For that, 97 layers were necessary. Afterwards, we machined this test specimen and a 24 side polygon was achieved, in order to measure the ultrasonic speed in seven different fiber orientations. Adjusting modeling parameters is very important because each composite has a unique set of characteristics, which depend on design, manufacturing process, and properties of each individual component. Our initial simulations consider an ideal model, where each layer is perfectly glued to its neighbor. Therefore, we do not take into account problems like delamination and voids. Each layer, in reality, is composed of thousands of filaments of fibers, inserted into the matrix. Here, these tows are treated as only one larger fiber. This simplified approach requires a much less refined mesh for the model. An ultrasonic pulse of 1 MHz was used to minimize the attenuation of the signal while propagating through the material. The sampling rate of the data acquisition system and the FEA were set to reach the necessary time resolution. Velocity predictions at 0° and 90° are being reported. This paper also proposes a model to simulate the wave propagation in other angles. The estimations showed a good correspondence with measurements and a great potential to simulate more realistic models. They might consider the effects of unconformities and a more heterogeneous distribution of the fibers, allowing the development of better inspection tools.