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The use of thin-ply prepregs for the fiber reinforced polymer composites with small radius curvatures manufactured in the autoclave technology

Doctoral thesis in the field of Materials Engineering.

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Abstract

This thesis was written as a result of the growing demand of using thin ply prepregs to manufacture advanced CFRP structures with different curvatures in the autoclave technology. All research were done in cooperation with Śląskie Centrum Naukowo-Technologiczne Przemysłu Lotniczego Sp. z o.o. Thin ply prepregs provide a lot of benefits, such as the possibility of mass reduction, higher design flexibility or increased in-plane strength and this is why these materials are gaining more and more interest. However, in accordance with the current state-of the-art, the influence of the ply thickness on the composite forming processes and out-of-plane strength is not known yet. The objective of this work was to understand the influence of the ply thickness on the curved composites quality and strength. To reach this goal, all research was done using the same unidirectional carbon-epoxy prepreg with two different areal weights: 75 g/m^2 for thin ply prepreg and 150 g/m^2 for standard prepreg. The scope of this work was to check uncured prepreg properties which influence curved composites forming processes: bulk factor, out-of-plane bending stiffness and in-plane shear. Then, the basic mechanical properties of both laminates were tested: tensile properties, flexural properties, Interlaminar Shear Strength and In-Plane Shear response. Next, the compared prepregs were used to produce CFRP curved beams with different inner radius and different angles between the legs. Composites manufacturing process with the use of examined prepregs was also assessed. The quality of the manufactured samples was checked by the visual inspection, geometrical measurements, determining of the density and constituent content of composites, Active Infrared Thermography NDT and X-ray Computed Tomography of representative areas. Finally, the samples were used to determine the Curved Beam Strength (CBS) in a four-point bending test. For the samples which were destroyed by delamination, the Interlaminar Tensile Strength (ILTS) was also calculated. Performed tests showed that 75 g/m^2 prepreg is more prone to create manufacturing defects because of the higher thickness change during the debulk before curing, lower out-of-plane bending stiffness and very weak response to in-plane shear. Mechanical tests of flat laminates showed higher 90° tensile strength and higher ILSS for the composites made of 75 g/m^2 prepreg. During the Curved Beam Strength tests of the curved samples it was noticed that CBS value depends on the curvature geometry. For the lowest inner radius and angles between the legs, higher CBS was measured

for the laminates made of 150 g/m^2 prepreg. As these samples were destroyed by delamination, the ILTS was also calculated. Laminates made of 150 g/m^2 shown higher ILTS. For the samples with higher inner radius and angles between the legs, higher CBS was measured for the laminates made of 75 g/m^2 prepreg. The obtained dependency indicates that the ply thickness influence on curved laminates strength is related to the curvature geometry and the stress state. For the lowest inner radius and angles between the legs, higher CBS was measured for laminates made of 150 g/m^2 prepreg, but while increasing the inner radius and angles between the legs, the difference of strength between the same geometry samples changes to be higher for the laminates made of 75 g/m^2 prepreg.