Development and Testing of woven GRFP Flexure Hinges for Pneumatic Actuated Cellular Structures (PACS)

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Shape-variable structures open up new potentials for a variety of applications. Active and passive concepts can be found in the literature. During the Last Years, the DLR investigated several of these concepts. One of the most sophisticated approaches are the Pressure Actuated Cellular Structures (PACS) which is a bionic concept based on the motion of nastic Plants. The Institute of Composite Structures and Adaptive Systems has developed, build and tested several prototypes. These Structures are monolithic designs and there flexibility relies on integrated flexure hinges. In contrast to rigid body joints, the displacement of the center of rotation leads to a deviation of the centrode. The correct forecast of the movement of such hinges is essential for The PACS design.

Former tests have shown that the most suitable Material for PACS is fiber-reinforced plastic due to the very specific requirements of stability and varying stiffness. In cooperation with the Technical University of Dresden, the DLR develops a 3D-weaving process for GFRP which will lead to a significant increase in production accuracy as well as production speed. But the movement and working loads of the FRP flexure hinges under multiaxial Loads are unknown jet.

The first part of the Paper will briefly describe the functionality of the PACS Structure in general. After this introduction into the mechanism, the results of the material tests for woven GRFP will be addressed and a summary of the suitability for the targeted function as flexure hinges and cell sides in a monolithic PACS structure is given. Furthermore the developed FEM material model is presented and the calculation results for the flexure hinges will be discussed and compared to the experimental results in order to examine the potential of this material model to forecast the movement and structural working loads under influential factors such as crimped Fibers due to the weaving process.

In the second part a numerical design process for PACS structures is presented. The current design process is based on a numerical approach, which, with its limitations such as rigid body joints, provides sufficient forecasts only for one specific load case. Since PACS structures are meant to operate over a large range of load cases the new design process is able to forecast the movement over the whole operational range. The results of the analytical and the numerical approach will be presented and compared with the experimental data of pressurized GFRP cell structures.