Process Development and Technological Advances in Double Diaphragm Forming of Advanced and Uniform Short Fiber Composites using Fixed and Reconfigurable Tooling

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ABSTRACT

This thesis discusses research related to advances in automated composites forming by (1) developing process and simulation capabilities for forming composite parts incrementally with a pin-based reconfigurable tool using Double Diaphragm Forming (DDF) and (2) investigating the formability and analytical modeling of a new Stretch Broken Carbon Fiber (SBCF) material from Hexcel Corporation.

The DDF process begins with a flat, uncured stack of prepreg carbon/epoxy plies each oriented based on some pre-defined ply schedule. The stack is then placed between two rubber diaphragms, evacuated, heated using low power conduction and formed over a fixed or reconfigurable tool using vacuum pressure. The reconfigurable tool consists of a close-packed bed of 96 pins with hemispherical tops in a vacuum chamber that can be raised or lowered incrementally via computer, effectively controlling strain rate and strain path.

The SBCF material being researched is an advanced composite material consisting of intentionally broken carbon fibers immersed in an epoxy matrix (prepreg). The SBCF material is extensible but still maintains 80% and 60 % of the cured tensile and compressive strength of comparable inextensible materials respectively. It was thought that both the reconfigurable tool and the SBCF material could increase the range of parts that could be made using DDF.

This research successfully implemented DDF over the reconfigurable tool and incorporated new single and multi-zoned conformal heating blankets into the process. The new process suppressed wrinkles in formed parts and zonal heating was shown to improve part quality as well. Forming trials showed that using the reconfigurable tool's ability to vary the strain path during forming increases the range of parts that can be formed. A comparison between parts formed using conventional and SBCF materials were inconclusive. The tensile forces required to stretch the SBCF material cannot be generated using the current DDF system.

Finite element simulation capabilities have been partially realized. The limiting factors are processing time and lack of a complete material model. Off-the-shelf material models proved to be inadequate for modeling the SBCF material so a representative

volume model is being developed in preparation for being turned into a user defined model.