Induction Consolidation Using Smart Susceptors

Demonstrating energy savings, improved cycle times for large composite structures

Composite aircraft structures have been shown to enable lightweight efficient designs. However, the extended thermal cycles when using existing methods and materials makes them less attractive for higher rate production applications.

Current manufacturing systems such as autoclave processing of thermoset materials require long cycle times due to the method of heating and large thermal masses. These elongated cycle times, while effective for lower rate applications, inhibit the ability to meet forecasted high rate production scenarios due to the need for multiple sets of equipment and tools.

Alternatively, thermoplastic composite materials facilitate more rapid cycle times by eliminating the need for a cure dwell at temperature. Furthermore, induction heating can heat materials very quickly and efficiently especially when coupled with low thermal mass tool designs.

Utilizing induction heating along with smart susceptors can enable quick cycle times while providing precise intrinsic thermal control. Since this processing method only heats a very small portion of the tool for the consolidation and molding of thermoplastic components, the opportunity for increased energy efficiency over resistive, conductive, and convective heating of an entire tool is significant.

This project will demonstrate and document the energy efficiency and technical and economic viability of induction consolidation using smart susceptors for full-scale integrated thermoplastic composite structures in an aerospace application. Smart susceptor technology enables large part fabrication using induction heating since advanced coil designs that previously had not been practical due to thermal control issues can now be used. The project will leverage this intrinsic thermal control to provide rapid, precise heating for both consolidation and joining.

Benefits for Our Industry and Our Nation

Induction consolidation of thermoplastic composites using smart susceptors is expected to significantly reduce the cycle time and energy used for manufacturing. This process improvement is projected to reduce energy consumption by approximately 80% compared to typical autoclave processing. The rapid cycle times should result in more affordable and efficient fabrication of composite aerospace structures at accelerated rates of production. The increased integration of lightweight composite components into aerospace applications will also reduce fuel consumption and carbon emissions throughout the useful life of aircraft.

Applications in Our Nation’s Industry

With many markets transitioning to lightweight composites for performance gains, the use of these components is increasing. The processing technology under development has broad application to a number of industries in addition to aerospace including wind, automotive, marine, and heavy trucks. Implementing efficient production methods that enable significant energy savings and improved manufacturing processes keeps the United States globally competitive.

Project Description

The objective of the project is to establish an effective and affordable method to lay-up and consolidate large thermoplastic composite aerospace structures with thermal cycles measured in minutes rather than hours. This project will demonstrate and document the viability of induction consolidation using smart susceptors for full-scale integrated thermoplastic composite structures in aerospace applications. Initially, the process will be demonstrated on a medium-scale scale-up of a thermoplastic consolidation system. Induction heating with smart susceptors is an efficient energy method for consolidation and molding of thermoplastic composites.
component for risk mitigation purposes. The development of equipment, tooling, and processes along with fabrication of a full-scale component will subsequently be performed. This component will demonstrate an improved capability to meet high production rates for large aerospace thermoplastic composite structures and will validate the ability to precisely control temperatures required to consolidate the part with improved energy efficiency.

**Barriers**
- While this technology can be adapted to retrofit existing equipment, the cost of switching from thermoset materials to thermoplastic materials needs to be financially attractive.
- The ability to achieve the scale needed to be relevant in the aerospace and other industries.

**Pathways**
Project partners will utilize predictive modeling and simulation of the processes in conjunction with validation through fabrication of mid-scale components to establish system scalability and reduce project risk. This validation will consist of comparing the predicted values of items such as current levels, power usage, and thermal distribution measured during the processing of the scale-up components.

Full-scale designs of the machines and tools required to meet both the rate and the general size for aerospace industry will be developed. In addition, full-scale candidate components will be fabricated using the rapid, energy efficient induction processing technology. A representative candidate component with potential near term economic benefit will be chosen and developed.

The project will further quantify the existing energy used in standard heated autoclaves and compare these values to the new process. In addition, the lifecycle energy costs of materials being replaced will be quantified.

**Milestones**
This three-year project began in July 2015.
- Demonstrate complex part consolidation with less than 120 minutes processing time, and 40% reduction in energy consumption compared to autoclave processing (2016).
- Establish and integrate scale-up fabrication system capable of processing a large (5 ft. by 15 ft.) component scale-up demonstration (2017).
- Consolidate large, complex component with improved thermal uniformity, less than 60 minutes processing time, and 80% reduction in energy consumption compared to autoclave processing (2018).

**Commercialization**
While many factors influence the materials and processes utilized for airplane manufacturing, an accelerated production rate forecast and recent performance successes of composites in airplane construction provide an opportunity for this processing technology to have a significant influence. The Boeing Company has a key leadership position within the aerospace industrial community. All project partners have extensive commercialization knowledge and experience in their own market segments and will ensure that once the process is developed, a supply base for equipment and tools will be in place so that the infrastructure will be readily available to all potential industrial areas.

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