Energy Efficient Thermoplastic Composite Manufacturing

DE-EE0005780

Project Team/Boeing, Solvay (Cytec), Temper, AjaxTOCCO

Budget Period #3

Boeing Research & Technology (Marc Matsen)

U.S. DOE Advanced Manufacturing Office Program Review Meeting
Washington, D.C.
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Overview Slide

Timeline

- *DE-EE0005780 award issued May 2015*
- *Projected end date June 30th, 2019*
- *Project is 98% complete*

Budget

	BP #1	BP #2	BP #3	Total
DOE (plan)	1.19M	2.54M	0.77M	$4.50M
DOE (actual)	1.01M	2.04M	1.38M	$4.43M
Cost Share (plan)	0.64M	1.07M	0.16M	$1.87M
Cost Share (actual)	1.10M	0.64M	0.50M	$2.24M

Barriers

- *Technology readiness particularly in regard to scalability*
- *Validation of the potential economic advantages and energy savings*

Partners

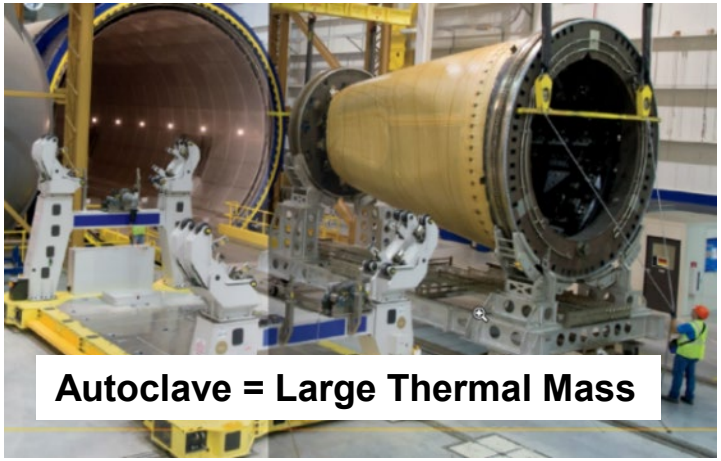
- *The Boeing Company - OEM - product pull - project leader*
- *Solvay (Cytec) - materials leader - material supplier*
- *Temper, Inc. - tool and equipment leader*
- *Ajax TOCCO - induction heating leader*

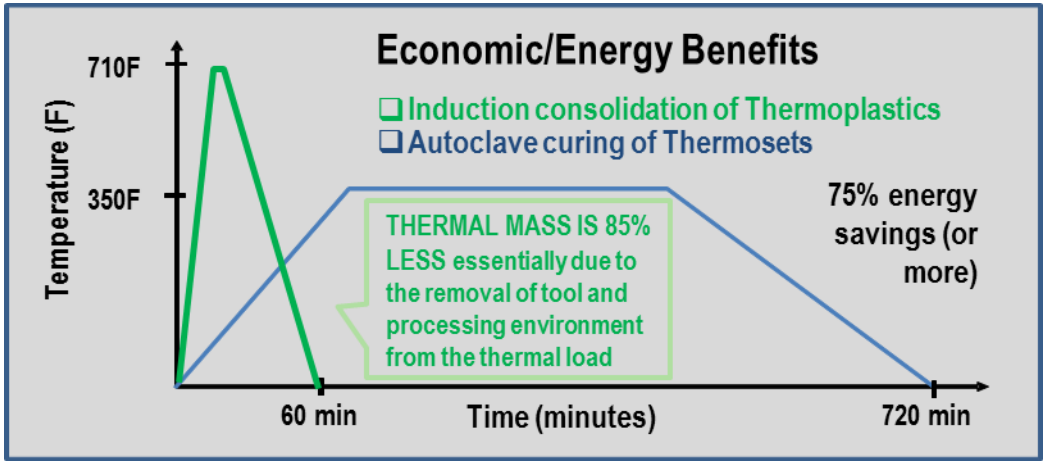
AMO Multi-Year Program Plan

- *Process Heating: Develop low-thermal-budget manufacturing technologies that reduce energy intensity by approximately 75%*
- *Sustainable Manufacturing: Advance technologies and tools to improve resource efficiency in the manufacturing industries, including recycling and reuse.*

Project Objective

- *Problem Statement:*
  - *Current composite airplane designs have proven efficient and effective*
  - *Future potential product production rates are challenging what the current systems can efficiently produce due to material lay-down constraints and extended thermal cycle times.*
- *Project Relevance/Benefits:*
  - *Establish an effective and affordable method to lay-up, consolidate/join large thermoplastic composite aerospace structure and*
  - *Benefits - cycle times measured in minutes vs hours with 75% improvement in energy efficiency*
  - *Validate these benefits on a section of a notional high rate airplane wing skin design*
- *Difficult Challenge:*
  - *Efficiently lay-up then rapidly/precisely heat, consolidate, and cool large complex composite structures plus very accurately tool them (i.e. matching CTE of composite materials)*

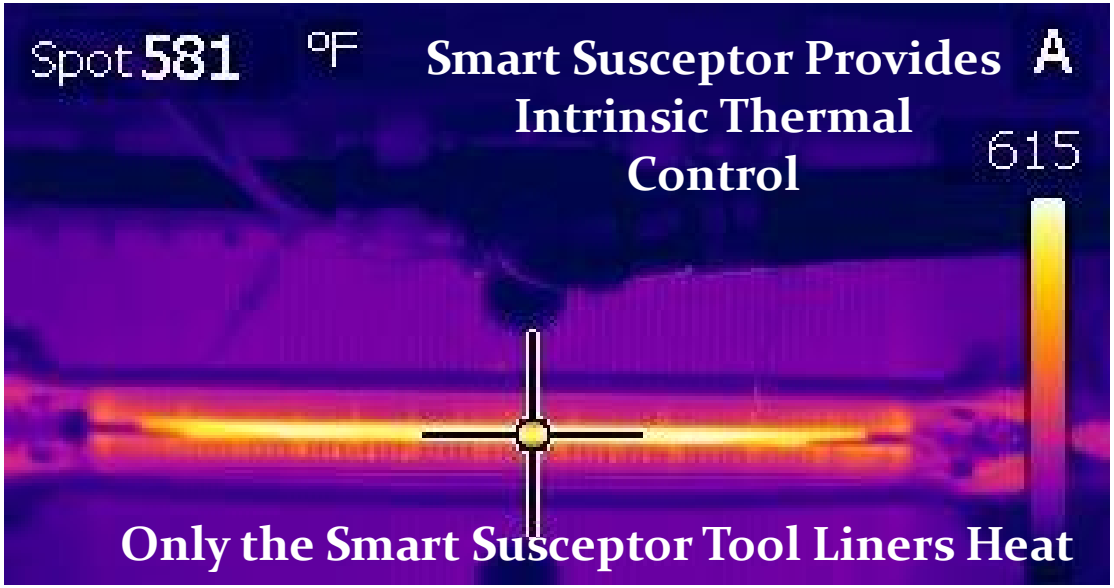




Technical Innovation

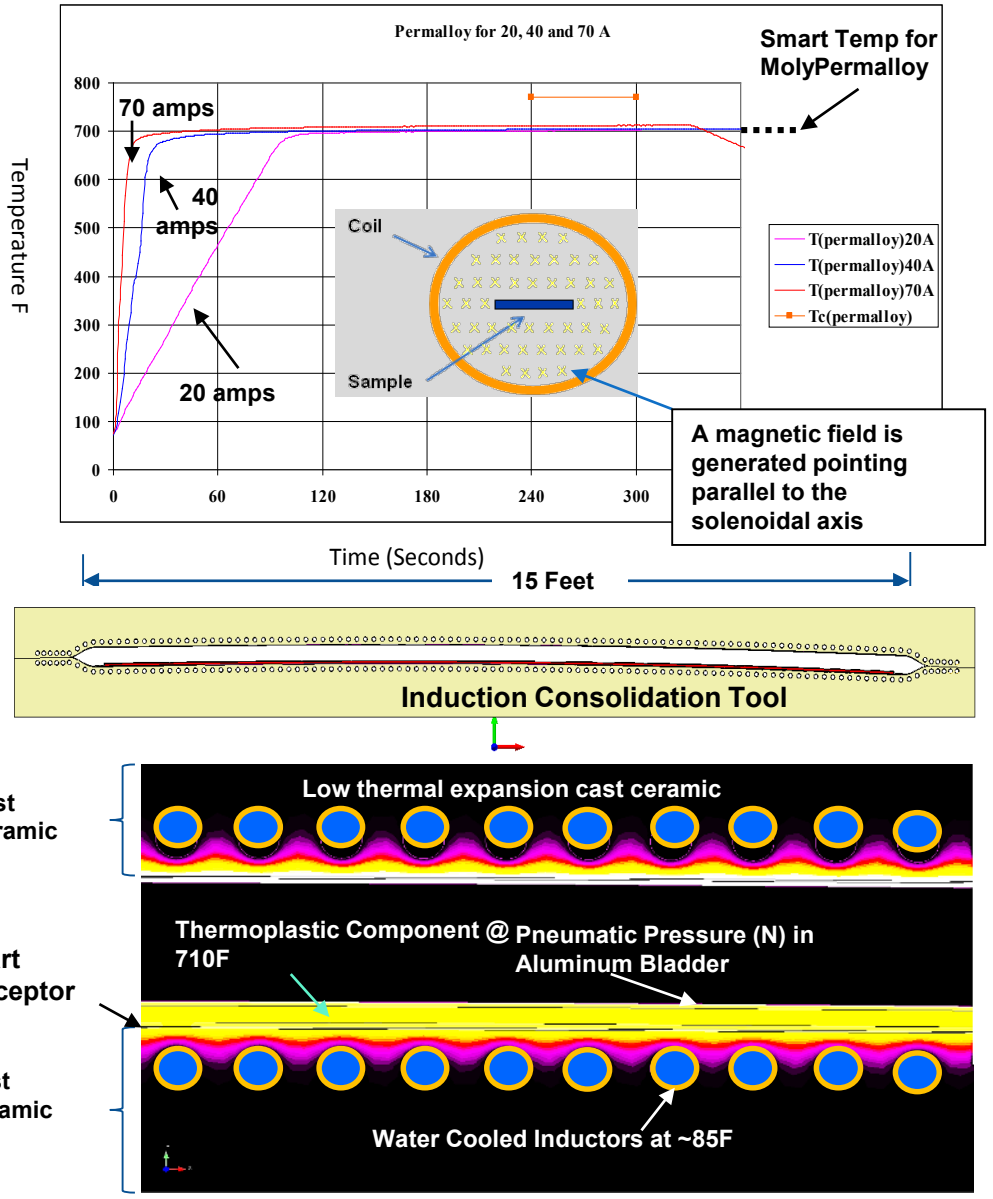
- *Current Approach Autoclave Curing of Thermoset Composites:*
  - *Autoclave processing of thermoset materials require long cycle times due to method of heating and the large associated thermal masses.*
  - *These extended cycle times inhibit the ability to meet higher rate production scenarios due to the need for multiple sets of equipment and tools.*
- *New Approach Induction Consolidation of Thermoplastic Composites:*
  - *Thermoplastic composite materials are being used to facilitate more rapid cycle times via the elimination of a need for a cure dwell at temperature and their tolerance of quick heat-up and cool down thermal ramps.*
  - *Utilization of induction heating with smart susceptors to enable the quick cycle times needed while providing precise intrinsic thermal control.*

Induction Consolidation & Molding Press and Tool



Technical Innovation (cont.)

- *The smart susceptors act as the thermal control mechanism:*
  - *As the smart susceptor sheet metal becomes substantially non-magnetic it's heat generation drops by ~1 order of magnitude or more.*
  - *This essentially creates a thermal ceiling when properly engineered.*
  - *The appropriate ferromagnetic alloy is chosen to match the desired processing temperature.*
- *Reinforced cast ceramic tooling allows the inductive magnetic field to pass through it thereby eliminating the need to heat (and cool) the bulk of the tool mass*
- *Rapid thermal cycles result in significant non-recurring cost savings when considering a 70 airplanes per month (or greater) "greenfield" facility.*

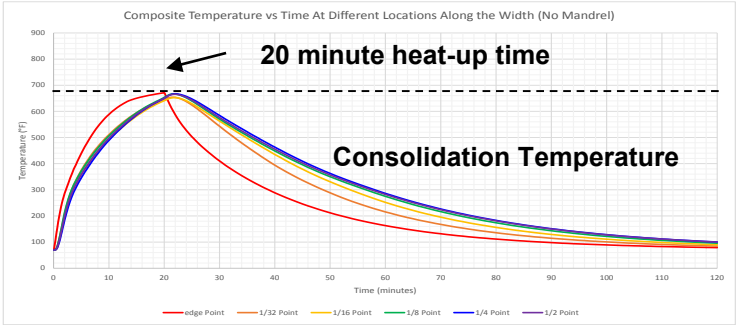


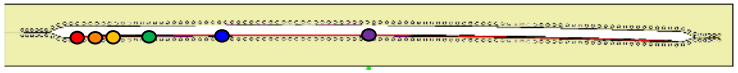
Technical Approach

- *Induction heating using smart susceptors in conjunction with the reinforced cast ceramic tooling for rapid heating and cooling along with the precise control of the temperature during consolidation of the component will be used to fabricate process verification components.*
- *It is this unique processing capability coupled with the thermoplastic material characteristics along with rapid lay-up methods that are novel and advantageous.*
- *The project team consists of Boeing as the prime and Temper, Solvay (Cytec), and Ajax TOCCO as sub-recipients. This team provides the key industrial elements for making the technical progress needed to be successful.*
  - The Boeing Company - *OEM - product pull - project leader - preform process development - part design - ceramic tool analysis - part fabrication requirements - characterization of smart susceptors*
  - Solvay (Cytec) - *materials leader - material supplier - thermoplastic processing - recyclability (deliverables / reports)*
  - Temper, Inc. - *tool and equipment leader - tooling design - forming equipment design (FEA) / build - process design and tryout*
  - Ajax TOCCO - *induction heating leader - FEA of induction heating integrated with thermal response - inductive heating equipment - die assembly and coil manufacturing*

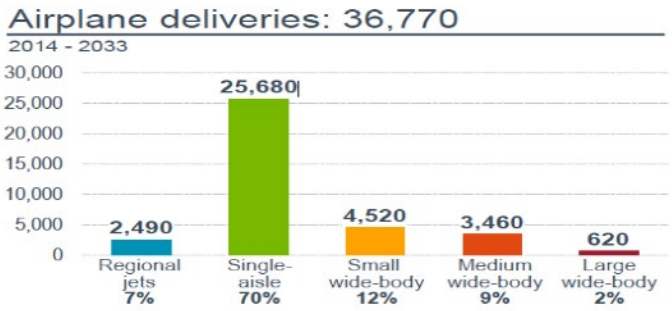
Technical Approach (cont.)

- *Project Risks:*
  - *Large scale induction heating and the resulting smart susceptor and power supply response*
  - *Robustness of large scale induction consolidation reinforced ceramic tooling*
  - *Financial significance of thermal cycle and resulting cost savings*
  - *Computational modeling and cost models are being used to understand these risks and assist in mitigation efforts as needed.*
- *Boeing has a Key Leadership Position within the Aerospace Industrial Community:*
  - *The forecast of accelerated production rates and the recent performance successes of composites in airplane manufacture provide an opportunity for this processing technology to have significant influence.*
  - *This project will establish process verification data that will assist in erasing a number of unknowns surrounding this technology and enable its consideration for future production applications*



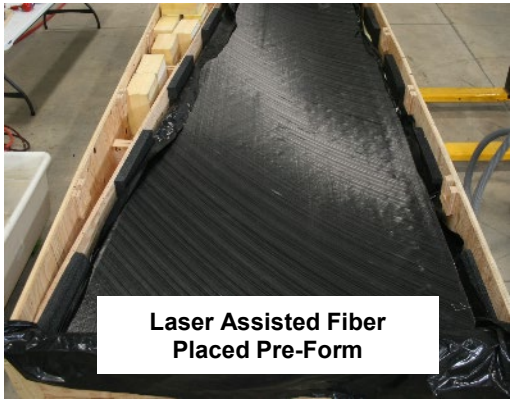


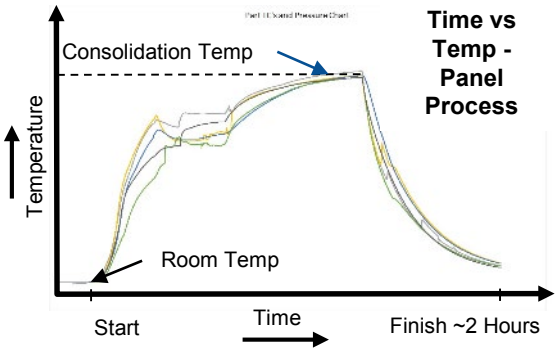
15 Feet

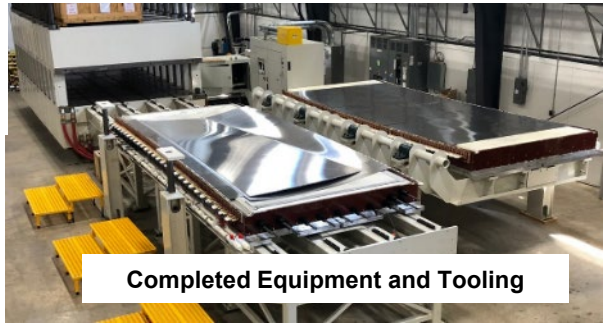


Results and Accomplishments

- *This project was initiated : 5/14/2015*
- *Recent accomplishments include:*
  - *Two large part lay-ups have been completed*
  - *1st panel has been successfully consolidated*
  - *Rapid heat-up and cool down capabilities with intrinsic thermal control have been validated.*



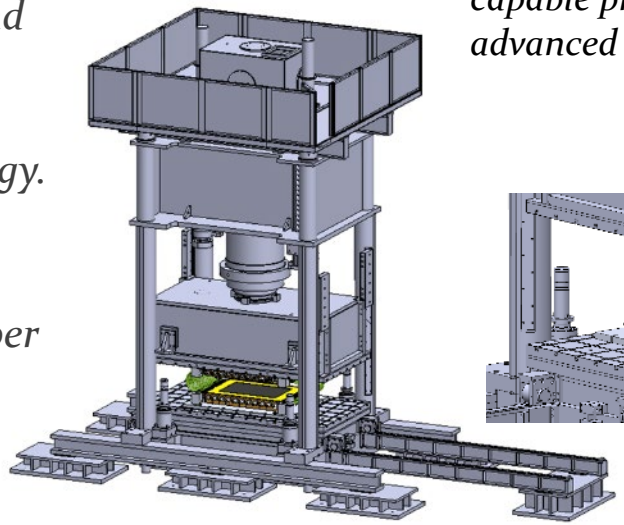




- *The main objective of this project is to verify and document the energy efficiency plus the technical and economic viability of induction consolidation using smart susceptors for full-scale thermoplastic composite aerospace structures:*
  - *Successful fabrication of a large scale component has verified the process to be capable of meeting high production rates for aerospace thermoplastic composite structures.*
  - *Successful verification of the rapid heating and cooling rates along with needed thermal uniformity have been accomplished on the large scale component with approximately 80% of the required energy saved over autoclave processing of thermoset materials.*

Transition (beyond DOE assistance)

- *Stakeholders Interests:*
  - *As Boeing defines its future products, new more efficient production methods that enable improved performance like this process will help in reaching long term goals.*
  - *The Department of Energy and Boeing will be interested in the significant energy savings that is enabled by this technology over the use of standard processes like autoclaves.*
- *Aerospace Industry will be the End User:*
  - *The intent is that this process will be used to fabricate composite aerospace structure affordably and efficiently at accelerated rates of production.*
  - *Composite aerospace structures have shown to provide significant performance advantages.*
  - *Other industries (such as wind energy) may have an interest in this technology.*
- *Sustainment Model:*
  - *Boeing is installing a large press and induction power supply to take advantage of the improved rate of fabrication offered by this technology.*
  - *The current plan for the processing system constructed under this program is for it to remain at Temper Inc and be available for use by interested parties in support of further development work.*



"This process gives us a more rate capable process for fabrication of advanced composite structures."

Craig Abler – Advanced Composites Center Leader