Project Plan for Developing a Software Tool for Field Use for Precise Control of Cure Processes During Repair

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Goals

The goal of this project is to develop a software tool that can be used in the field to optimize the repair of composites.

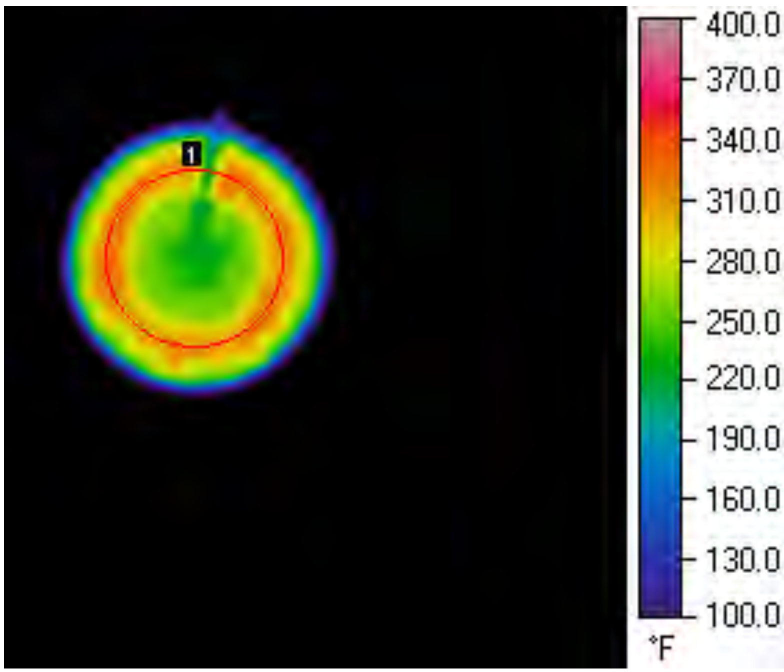
Producing the desired field requires the specification of the heating intensity as a function of position and time consistent with the boundary conditions that exist at the time of repair.

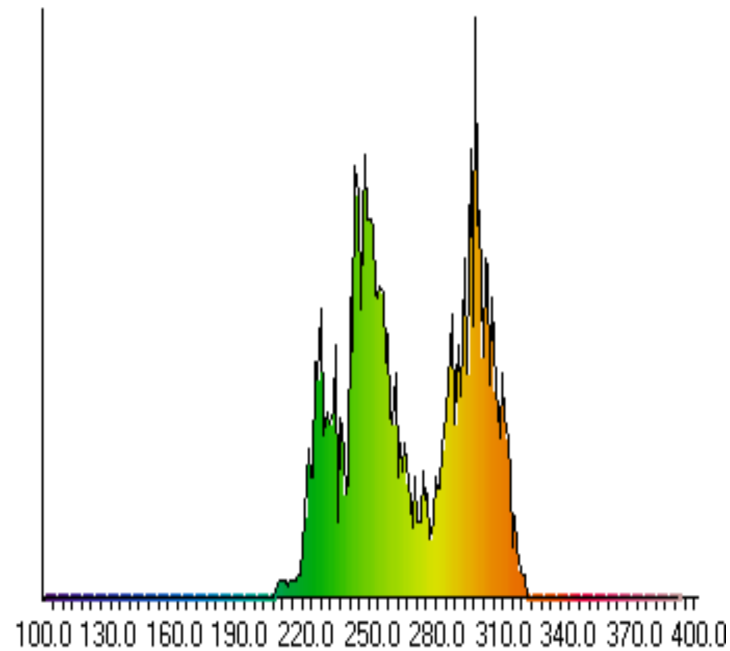
We aim to produce a tool that will tell the technician where to place the heating blankets, what the intensity of heating should be as a function of position, and how long the heating is to be applied. All of these results will come from a dynamic simulation of the heating process.

Capabilities

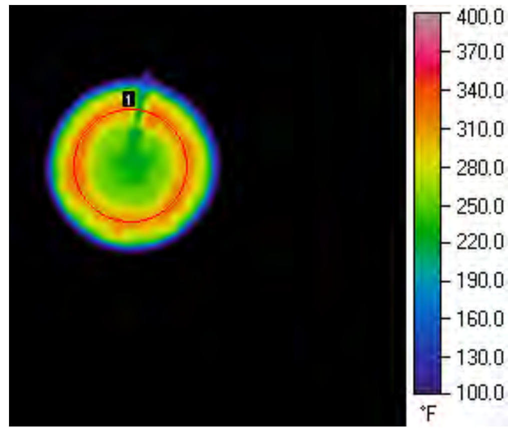
Thus the software will have to be capable of using local measurements to define the thermal conditions at the boundaries and in the composite structure, e.g., any contact resistances that exist between layers of material, variations in layer thickness, glue thickness, voids, zones of failure, or conductivity. This will be done by exposing the system to be repaired to a diagnostic thermal test in which transient temperatures are measured by infrared cameras as a function of spatially varying heating intensities.

Experimental Result





Typical Infrared Photo of a heated composite:
The temperatures range from 209 (1 pixel) to 303 (106 pixels)



The picture is typical of an infrared photo. From this isotherms can be developed that show the temperature patterns. (Note that in this photo the range of temperatures is insufficient for a reliable repair. Usually a delta T of at least 10F is desired.)

Inverse/Optimization

Given such measurements, the software will estimate the properties, usually referred to as ‘parameters’, needed to simulate the repair process, i.e., the *Inverse Problem*.

Once the parameters are known, and given a specification of the temperatures needed to effect the repair, the software tool will determine the best spatial and temporal distributions of the heating intensity to achieve the fastest and the most reliable repair – the *Optimization Problem*.

Roadmap

1) Obtain descriptions of likely systems to be repaired.
2) Obtain samples of composite systems
3) Construct and calibrate test fixture
4) Test sample systems and measure back side thermal conditions and front side temperatures using infrared cameras
5) Using the measured data, solve the inverse problem to determine the parameters of the system
6) Establish statistical levels of confidence for each of the estimated parameters
7) Revise and improve the inverse approach until the software is capable of accurate predictions.

Roadmap

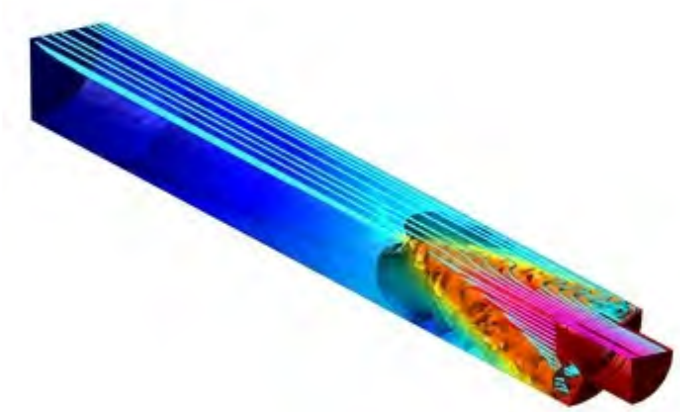
8) If field repairs are to be carried out, these studies may show the need to require deploying tents around the repair site to reduce local air currents or to block radiation from the sun or the tarmac
9) Once we are satisfied with the predictions of the parameters of the site to be repaired, using the optimizing software to define the necessary heating histories.
10) Applying these defined histories to samples and measuring temperatures, heat fluxes and infrared patterns to determine if the desired repair conditions have been met.
11) Although we will not know how complex such software is until we develop it, it may be that computing facilities capable of running the initial versions of the programs will not be available to technicians performing the repairs in the field. In this case, reduced programs will be needed.

Heatcon's Activities

1) Assist with obtaining composite parts needed for study and excising them to make any necessary measurements
2) Assist in constructing any auxiliary test facilities, for example guarded heat boxes for measuring conductivity and assist in obtaining such thermal data
3) Provide any additional composite materials and adhesives needed for study
4) Fabricate all heat blankets needed
5) Conduct the experiments in house, obtaining the thermal data capture using infrared cameras and thermocouples
6) Assist in interpretation of thermal data captured during testing
7) Interface with Boeing personnel as needed.

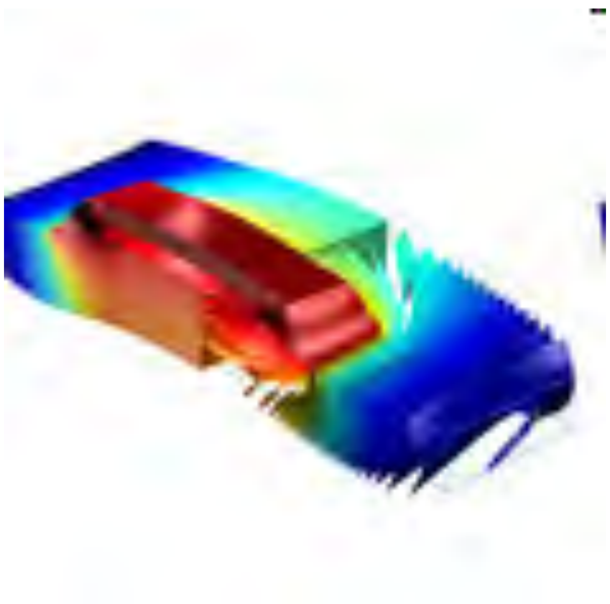
Status

1) Have installed COMSOL (multiphysics)
2) Conducting initial assessment
3) Debugging license borrowing
4) In partnership with Boeing, have submitted a WTC proposal



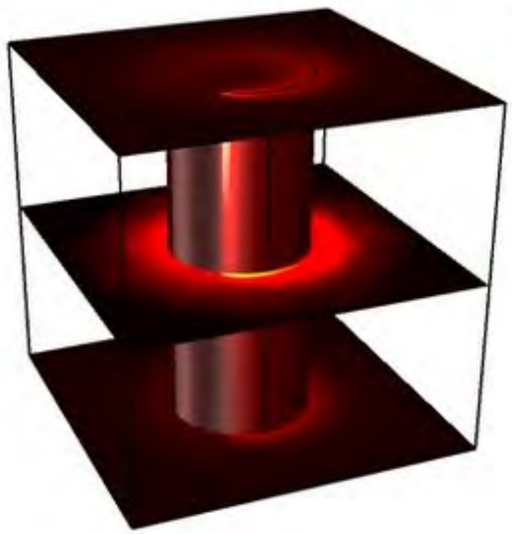
In this model, continuous casting processing of a metal rod from melted to solid state is modeled. The results of the model allows for optimization of the process in terms of casting rate and cooling. The model also allows the influence of the die shape on the flow field of the melted metal.

Status



This multiphysics example models the heat transport, structural mechanical stresses and deformations resulting from the temperature distribution using the General Heat Transfer application mode and the Solid Stress-Strain application mode.

Status



Lasers are commonly used to achieve precision heating or welding. The beam often moves over the surface of the substrate. One difficulty with modeling a laser heat source is the fact that the beam is very narrow (nm-mm).
Another is that the laser has a certain penetration depth which may be important.

The purpose of this model is to demonstrate how to model a moving depth-distributed line heat source in COMSOL Multiphysics using a 3D-1D coupling. The results show that the penetration depth plays an important role in the heating process.