INNOVATIONS AND CHALLENGES IN COMPOSITE REPAIR

Michael J. Hoke

Abaris Training Resources Inc.

www.abaris.com

REPAIRS TO THICK MONOLITHIC STRUCTURES, SUCH AS IN THE BOEING 787 AND THE AIRBUS A-350

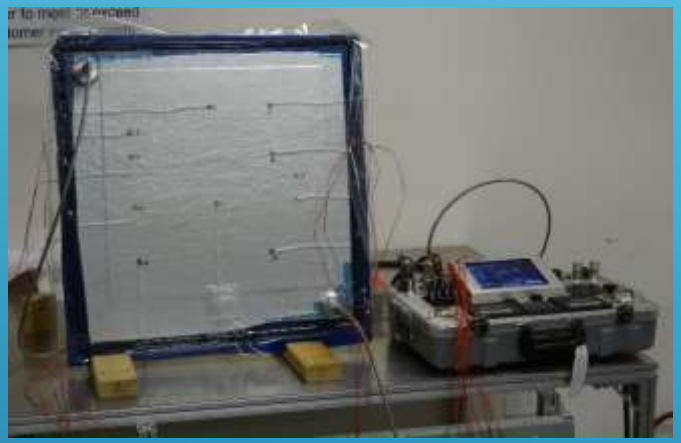
A-350 LOWER WING SKINS, WITH INTEGRAL STIFFENERS

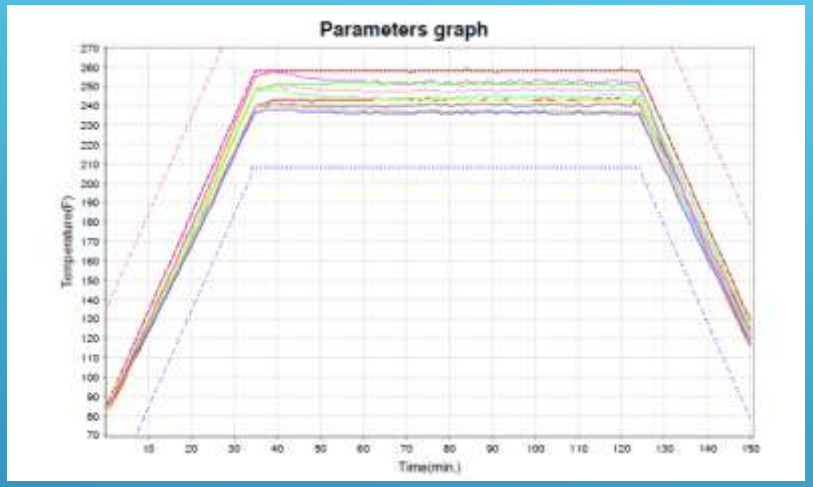
Thermal Uniformity Challenges: Exotherms

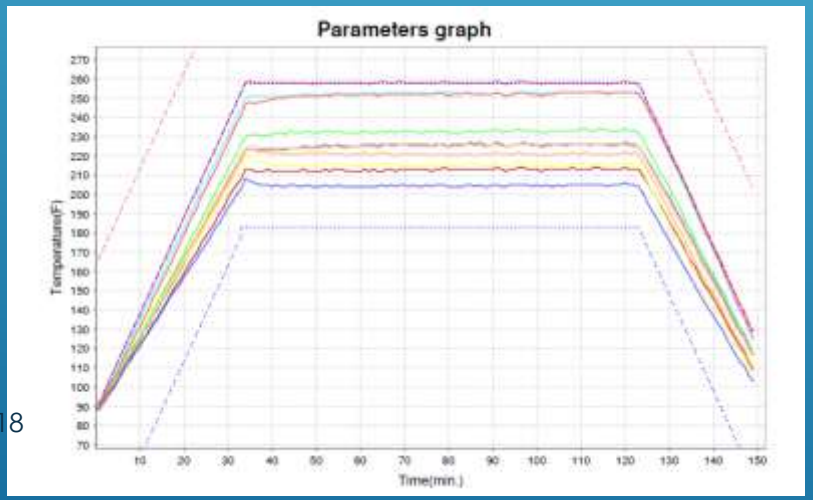
- **Effect of exothermic reaction on cure temperatures:**
  - **Temperature variation becomes more noticeable with thicker laminates, and more reactive (quicker-curing) resins.**
  - **With thin repairs, perhaps 4-6 plies, exotherm is minimal.**
  - **However, with a thick repair (25 to 100+ plies?) exotherm near the middle of the repair area is very high, but much lower near the edges of the repair where it is only a few plies thick.**
  - **This leads to large temperature variations across the repair; too hot in the middle and simultaneously too cold near the edges.**

Thermal Uniformity Challenges: Part orientation

Example: Effect of part orientation on temperature profile







Horizontal orientation = Δ20F
Vertical orientation = Δ57F

Convective flow of heat has a significant effect on temperature uniformity

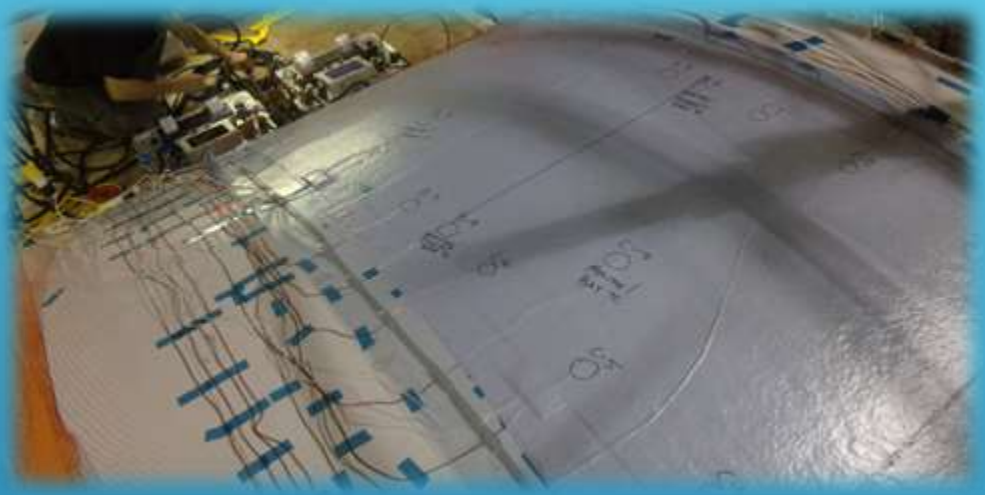
Courtesy of Heatcon

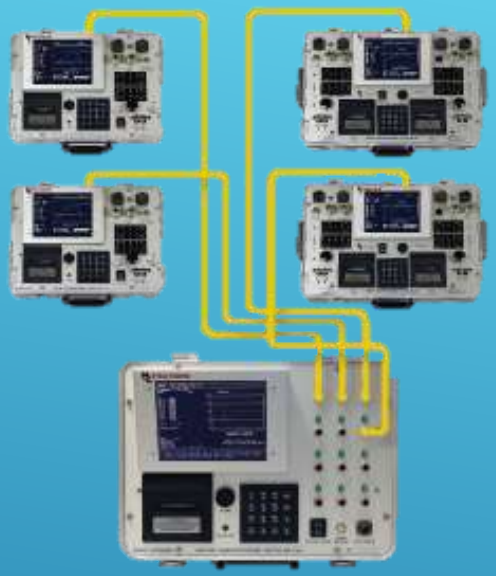
787 BURN DAMAGE DUE TO ELT BATTERY FIRE

787 UPPER AFT FUSELAGE BURN AREA

REPAIR ENCLOSURE AT HEATHROW

Large Area Repairs
Using multiple zones to managing large area repairs





- Multiple heated zones were used to improve thermal uniformity of repair area due to part orientation and size of structure.
- Each zone running on its own control loop to manage temperature.
- Common cure profile managed by Heatcon master controller “network controller”. Up to 24 heater blankets can be controlled with this system.
- Heat blankets configured to allow for minimal cold regions at edges of heat blankets.

AUTOMATED REPAIR TECHNIQUES UNDER DEVELOPMENT…

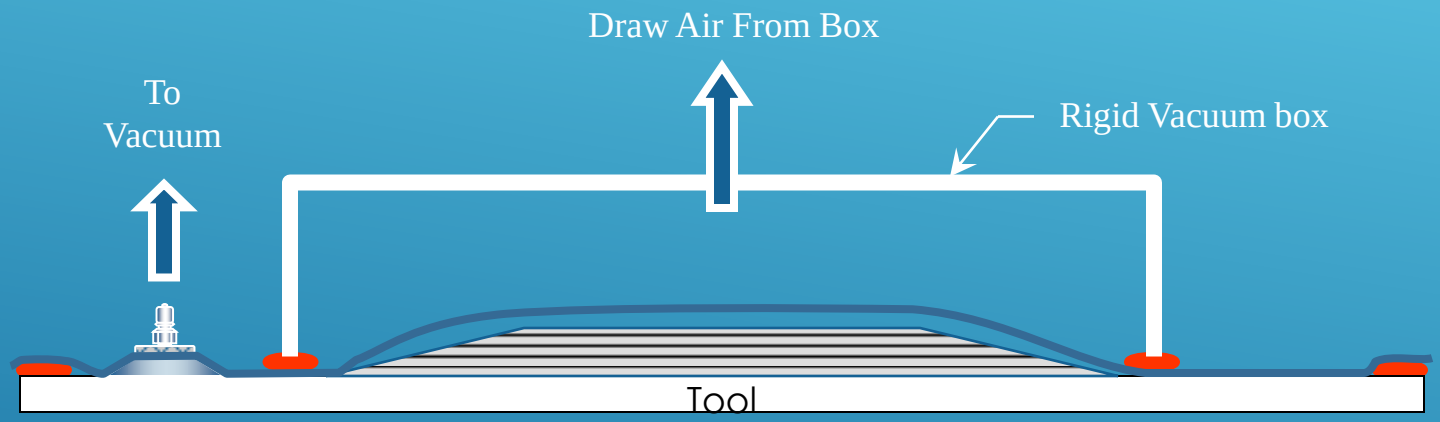
LUFTHANSA HAS A PROTOTYPE MOBILE ROBOT WHICH HAS BEEN BUILT AND TESTED ON ACTUAL AIRCRAFT, DEMONSTRATING THE ABILITY TO COMPLETE BONDED COMPOSITE REPAIRS “ON WING” FOR AREAS UP TO $1M^2$ ON THICK CARBON FIBER LAMINATES.

ULTRASONIC MOBILEBLOCK, 5-AXIS MILLING UNIT.

THE UNIT PERFORMS LASER SURFACE SCANNING AND ULTRASONIC MILLING, AS WELL AS SURFACE CLEANING, AND SURFACE ACTIVATION, USING ATMOSPHERIC PRESSURE PLASMA.

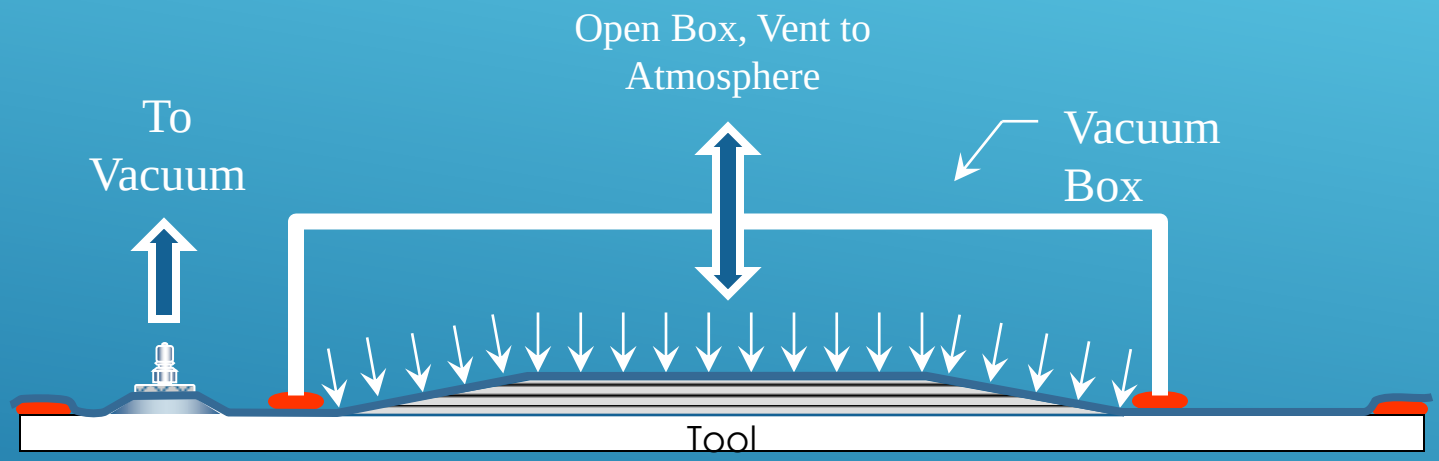
PLASMA TREATMENT FOR SURFACE PREPARATION

DOUBLE VACUUM DEBULK (DVD) PROCESS (ORIGINALLY FROM US NAVY V-22 WORK IN THE 1980S)



By pulling vacuum inside the box, the pressure is equalized; the layers under the bag are no longer under pressure, yet are still under vacuum. This allows for the repair laminate to "de-gas" as if it were in a vacuum chamber. Low heat is applied during the process to lower the resin viscosity and promote de-gassing. After sufficient time the box is vented and the layers are then compacted within the inner vacuum bag.

DVD PROCESS



Venting the box allows the inner vacuum bag to now pull down tight against the repair laminate, effectively consolidating the freshly de-gassed layers against the tool surface. The resulting "B-staged" repair layup is now ready for transfer to repair area, for full curing and bonding to the prepared structure.

DVD CURING TABLE – GOOD DEVICE, BUT FOR ONE-OFF REPAIRS YOU CAN BUILD ONE FROM 2 X 4'S AND THICK PLYWOOD.

COURTESY OF HEATCON

WHAT IS “HEWABI” ? HIGH-ENERGY WIDE-AREA BLUNT IMPACT

HEWABI DAMAGE TO A COMPOSITE PRESSURE VESSEL:

- May not be clearly visible;
- May be spread over a large area of the composite structure;
- May cause considerable structural damage with minimal external indications; for example disbonding of internal stiffeners.

SPECIAL INSPECTION PROCEDURES FOR A HIGH-LOAD EVENT IN A COMPOSITE STRUCTURE:

- Identify that a very high-load event has occurred;
- Assure that indications of structural damage are found in an initial inspection;
- Involve the OEM, if necessary;
- Provide a process for additional inspections that are designed to identify all of the structural damage; and
- Provide a process for approval for return to service.

TO SUMMARIZE…

- Thick Monolithic Structural Repairs, perhaps in a wing skin or a pressure vessel...
- Thermal uniformity problems…
- Automated repair techniques on the horizon…
- DVD repairs, to try to match autoclave quality porosity levels…
- And – HEWABI damage concerns.

SO THAT'S IT – TIME FOR QUESTIONS…

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