CASE STUDY:

Co-Cured I-Beam Using **Bladder Smart Tools**

PROBLEM

How to fabricate a flight quality I-Beam composite structure in an environment that enables high volume manufacturing

OPPORTUNITY

Generate a viable solution that will produce a high quality composite with an accelerated curing cycle using Smart Tools that act as bladders during cure.

SOLUTION

A PLC controlled, self-heating, and self-pressurizing cure mold was combined with three (3) Smart Tools that act as bladders during cure to create a NDT verified, high quality composite I-Beam with a 50% reduction in cure cycle versus the autoclave cured baseline.

SOLUTION REQUIREMENTS:

One (1) three Cavity Smart Tool Master/Reforming Mold, three (3) Smart Tools that act as bladders during cure, One (1) PLC controlled self-heated and self-pressuring Cure Mold.

Smart Tools are made from a combination of Shape Memory Polymers (SMP) and trade secret continuous fibers that allow them to transition from being rigid at room temperature to highly elastic, like a balloon, when they are heated above their activation temperature. For this case study the Smart Tools act like bladders during cure. They are rigid for lay-up, they are elastic and apply compaction force onto the composite laminate during cure, and they are elastic for a low force extraction from the cured composite part. Smart Tools are durable and reusable, with typical cycle life of 50 – 70 cycles, and deliver improved quality, reduced labor and consumable cost, and higher manufacturing through-put.

METHOD OF MANUFACTURE:

This case study was focused on proving the feasibility to use Smart Tools that act as bladders during cure, combined with an out of autoclave and out of oven curing solution, to produce a high quality, co-cured I-Beam composite structure.

Smart Tools were made to the Net Inner Mold Line (IML) of the composite I-Beam and had a shrink wrapped release film applied to them. The Smart Tools acted as rigid mandrels for hand applied pre-preg lay-up that was de-bulked every three (3) layers. A total of seventeen (17) layers were applied.

Skin pre-preg plies were placed into the lower half of the self-heated, two (2) cavity, female cure mold followed by

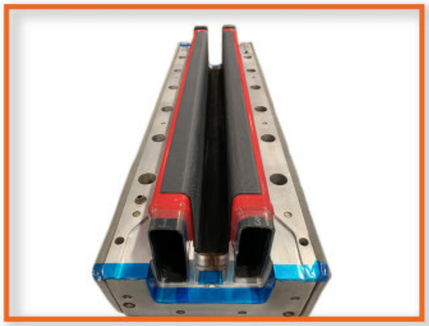

Figure 1 - Two Smart Tools loaded into the lower half of the cure mold

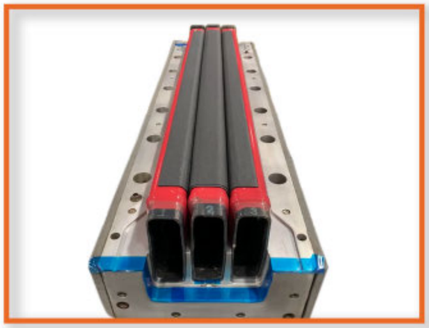

Figure 2 - All three Smart Tools loaded into cure mold with pre-preg carbon fiber

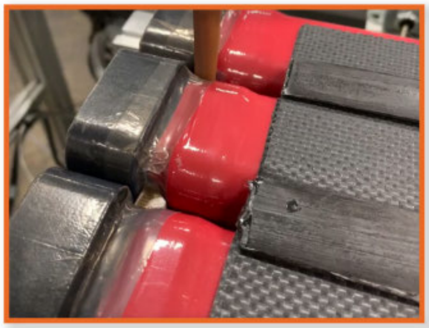

Figure 3 - Custom molded noodles fitted in-between Smart Tools to create flush surface

custom molded noodles that fit in between the Smart Tools. The Smart Tools are laid up with many plies of pre-preg and loaded into the lower half of the cure mold, side-by-side. Custom molded noodles are placed between the top of the Smart Tools to create a flush top surface and pre-preg skin plies are applied to the top surface.

Vacuum bags were then pulled through the center of the Smart Tools and after the upper cure mold cavity was put in place, the vacuum bags were sealed to the outside ends of the mold with bag tape. End fittings were applied on each end of the cure mold to create a pressurizable environment. The cure mold Is heated by a combination of cartridge heaters and a forced air heater. Pressure is supplied by heated shop air serviced by a shop wide compressor.

The automated cure mold was turned on and ran a specified cure and pressure profile. Initially vacuum was applied to the cavity and once the temperature exceeded 160°F (71°C) vacuum was stopped and the vacuum bags were inflated with 85 psi (≈6 Bar) that in turn, pressurized the now elastic Smart Tools to apply nominal pressure on the underside of the composite laminate and against the inside of the cure mold to force out air and excess resin.

Post the cure cycle and while the mold temperature was still above 160°F (71°C), the Smart Tools were removed from the cured composite and placed into a pre-heated reforming mold (the same mold the Smart Tools were made in), vacuum bags were run through the Smart Tools and taped to the outside of the mold, vacuum was applied to reset the Smart Tool to its original geometric shape, and once the mold cooled the Smart Tool was ready for making the next composite I-Beam.

RESULTS:

The I-Beam has the same structure as many unitized, co-cured, multi-chamber composite parts, like a horizontal stabilizer, a blade spar, or a winglet. The actual composite I-Beam produced had shear webs that were within 0.007" of nominal, flight quality void content and a 50% reduction in cure cycle versus the autoclave cure baseline.

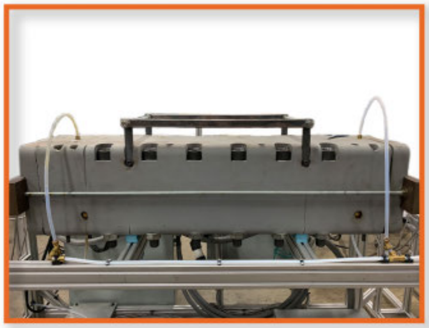

Figure 4 - PLC controlled, self-heated and self-pressurized cure mold

Figure 5 - Smart Tools being extracted while still elastic from the cured composite

Figure 6 - Smart Tool with FEP release film

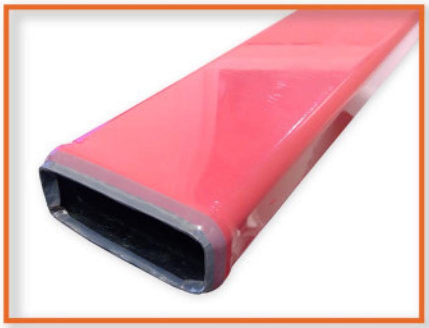

Figure 7 - Close-up of Smart Tool with FEP release film

Figure 8 - Completed composite I-Beam

Figure 9 - Completed composite I-Beam end view