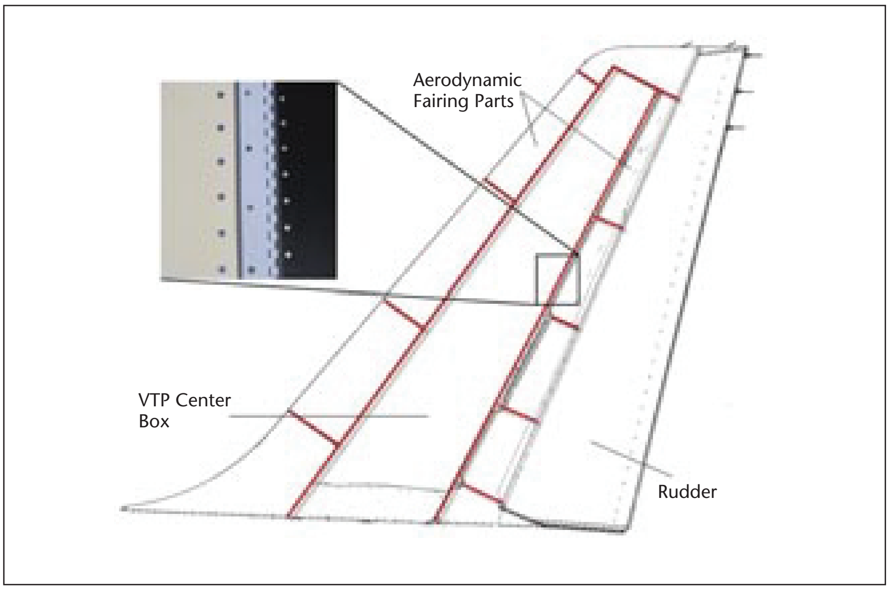
Heated Air Technology Helps Optimize CFRP Assembly

In today's assembly of large and complex carbon-fiber-reinforced plastic (CFRP) components such as passenger-aircraft vertical tail planes (VTPs), liquid resin-based materials are used for several applications. Commonly, these materials are used to close gaps between the CFRP single parts during assembly (shimming) or to smooth outer surfaces to fulfill aerodynamic requirements (aerodynamic sealing).

Depending on temperature and air humidity, these materials generally require curing times up to 12 hours. From an efficiency and cost optimization perspective in running aircraft production, such long curing times are definitively wasteful in terms of lead time (critical path).

By heating and/or air-conditioning these resin-based materials, the common curing time can be drastically reduced — to 2 hours. Due to the use of heated air — instead of, for example, heating lamps — the curing process can reliably be controlled, without any risk of overheating and destroying the sealant or shim material.

Researchers from Airbus Operations GmbH and Marcotodo GmbH describe two applications of heated air technology for the accelerated curing of resin-based shim and sealant materials. The first example is the aerodynamic sealing of a VTP; curing time of the aerodynamic sealant can be reduced by 8 to 10 hours using the newly developed heated air technology. The second example is the shimming of gaps between a VTP center box and metallic parts attached to the box.



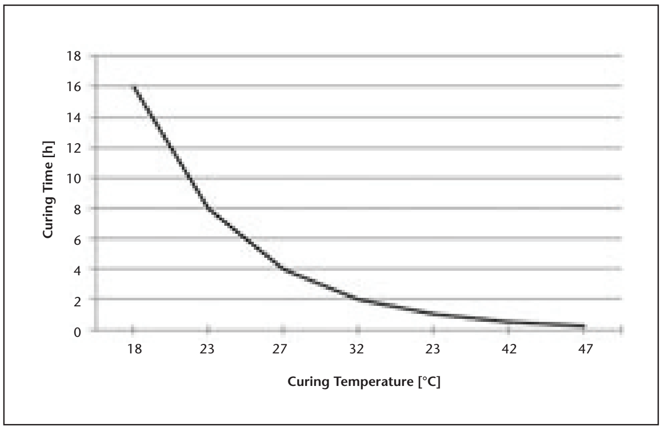
Vertical tail plane (VTP) of a single-aisle passenger aircraft showing gaps on the outer surface (in red) that have to be filled by aerodynamic sealing.

Tolerance Compensation Using Resin-Based Materials

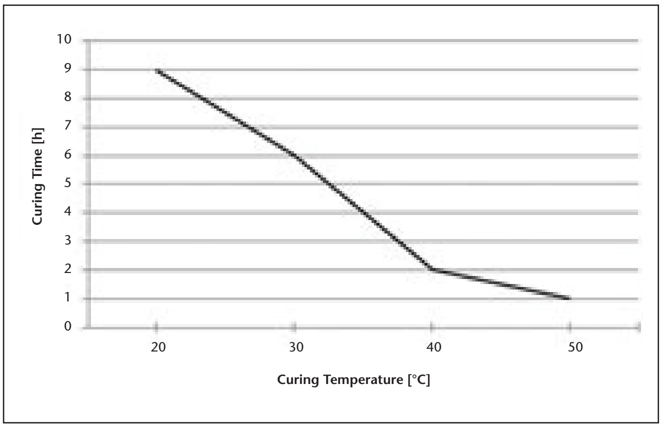
Large and complex parts made of CFRP commonly show larger tolerances regarding form and thickness accuracy compared to metal parts since higher accuracy would directly lead to exponentially higher costs of the single parts. Therefore, as a compromise, tolerance compensation has to be performed as part of the assembly process.

Shimming has to be performed between the single parts to close gaps that are caused by stack-up of thickness tolerances and to guarantee correct transfer of loads through the parts and the fastener elements. Closing gaps on the outer surface of assembled components, or aerodynamic sealing, has to be performed to smooth the surface.

The sealing material is a two-component polysulfide-based compound from



Curing time of the used sealant material dependent on the curing temperature.

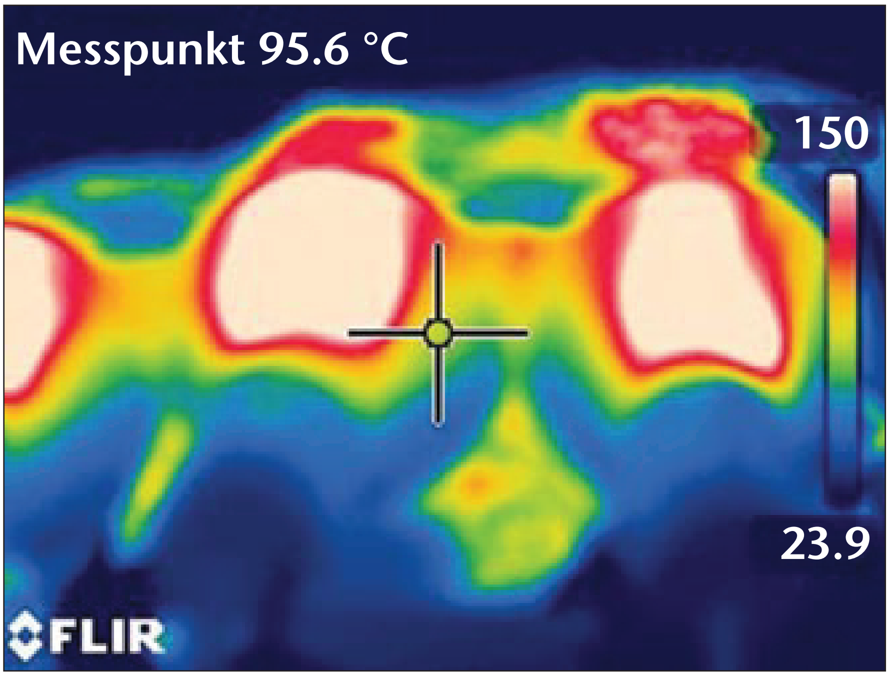


Curing time of the used shim material dependent on the curing temperature.

Chemetall. With the current product variant, the curing time is about 8 hours at 23 °C to achieve a hardness of Shore A ≥ 30 of the cured material. By increasing the temperature, the curing time can be reduced; a decreased temperature leads to longer curing times. Especially during winter (with shop-floor temperatures less than 20 °C), this could lead to curing times of up to 16 hours.

In addition, a minimum relative humidity is necessary for the initiation of the chemical curing reaction (vulcanization). Especially during winter, relative air humidity could be less than 10%, which leads to further extension of the curing time.

The shim material used is a two-component epoxy-based compound from Henkel. The curing time at 20±3 °C is 9 hours. By increasing the temperature, the curing time can be reduced to less than 2 hours.



Heat distribution on the surface when using heating lamps (example).

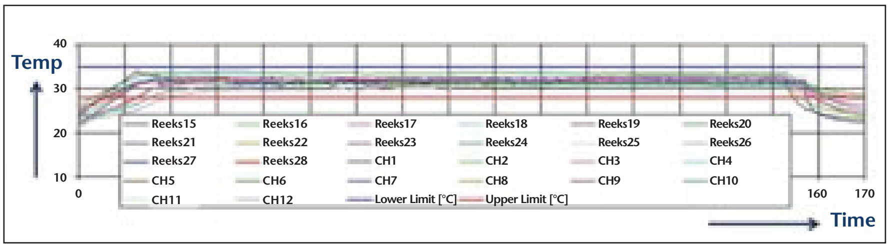
Improved Aerodynamic Sealing with Heated Air

Heating (IR) lamps have traditionally been used to heat the sealants; however, the heat distribution on the surface is very uneven, leading to uneven curing of the sealant. There also is a risk of overheating and damaging the sealant, or in the worst case, the CFRP material itself.

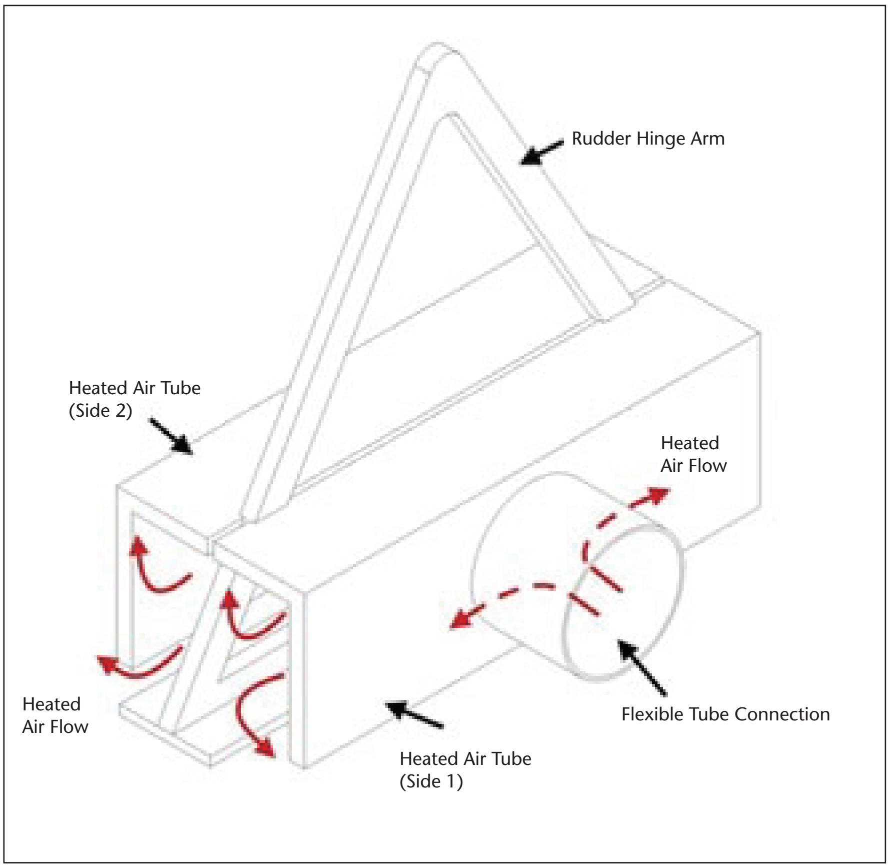
To overcome this risk, a new technology was introduced using heated air instead of lamps. By using heated air flowing slowly and continuously over the sealant material, a homogeneous heat distribution and curing process can be realized. The maximum temperature on the surface cannot be higher than the maximum air temperature independent of the position of the system. Therefore, the curing process can be reliably controlled, without any risk of overheating.

Together with other specialized companies, including Oellerich and CFK-Valley Stade, dedicated tooling was developed and introduced. It consists of a U-shaped air tube made of CFRP. Vacuum cups are used for mounting the tooling onto the surface without damaging it. Rubber lips at the edges guarantee a closed canal for the heated and moisturized airflow. The air tube is connected to a dedicated fan heater via flexible hoses. Several air tubes can easily be connected to each other, depending on the length of the gap to be sealed. By means of a control unit, the air temperature and humidity can be adjusted, automatically controlled, and recorded. An additional electrical heating system and temperature sensors are installed inside the air tube.


The prototype heated air tube system, bottom view (top left), inside view (bottom right), ventilating fan (top right), and control unit (bottom left).



Heat distribution inside heated air tube. The air temperature inside the system can be controlled very accurately, within a range of ±3 °C.



Schematic representation of the heated air system for accelerated curing of shim.

The air temperature inside the system can be controlled very accurately (by means of internal heating elements) within a range of ±3 °C, which meets the curing requirements for the sealant material.

To maintain a relative humidity between 10% and 90%, a humidity control unit can be added to the system.

In first trials using the prototype, the operational readiness of the heated air tube system could be demonstrated. A curing time of 2 hours was achieved including temperature ramp-up and installation time. The next step will be the introduction of serial heated air tubes.

Improved Tolerance Compensation with Heated Air

Heat can also be used to decrease the curing time of shim material. As risk mitigation, heating lamps are no longer used in the assembly of the VTPs. Another possibility to introduce heat is using flexible heating mats or metallic heating elements (e.g., beams) that are placed on the surface with the shim material underneath. In principle, this is only possible for less complex part geometries — e.g., flat or slightly curved surfaces. For complex surfaces, heated air again becomes an interesting option.

For joining the rudder with the VTP center box, aluminum hinge arms have to be assembled to the center box. Shim has to be used to fill the gaps between the rudder hinge arms and the rear spar of the center box to guarantee accurate positioning of the hinge arms and rudder hinge line. The heat introduction into the interface between hinge arms and the rear spar cannot be realized with a heating mat or other conventional heating elements due to the complex assembly situation. In particular, thermal expansion of the surrounding fittings has to be avoided. Therefore, a specifically adapted heated air tooling was developed that fits to the hinge arms.

In this case, the heated air system consists of two L-profiles that fit to the geometry of the dedicated hinge arm. Since the geometry of each hinge arm is different, individual systems have to be used per hinge arm. Rubber lips at the edges of the L-profiles ensure a closed inner room for the heated airflow. The profiles can easily be fixed at the part using conventional clamping devices. The heated air system is connected to a dedicated fan heater with flexible hoses and controlled by a control unit.

First trials at a test VTP were done using a prototype system. Again, a curing time of 2 hours was realized. Next steps will be the implementation of the heated air system in serial production.

Heated air technology enables the stabilization of the production process with regard to a clearly structured process and delivery planning since the curing time remains the same independent of the environmental conditions (temperature and air humidity) in the shop floor.

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