An investigation of non-destructive thermographic inspection exploiting phase transition of water for moisture detection in aircraft structures

Eetta Saarimäki*, Peter Ylinen**

* *VTT Technical Research Centre of Finland, Tampere, Finland*
** *FiAF Finnish Air Force, Pirkkala, Finland*

In this work, thermographic investigation is done to find a suitable procedure to find penetrated water from the composite aircraft structures. Penetrated water in the composite sandwich structures can cause problems, because moisture corrodes the honeycomb and further reduces the strength of the adhesive. Water can also cause additional defects during the composite repairs, which have resulted due to the expansion of the moisture (in closed cavity) and hence cause skin blow core phenomena during the curing cycle (heating) of the repair. This work is concentrating on the inspection method where the whole structure is cooled below the freezing point of the water and then warmed in the room temperature (Figure 1).

Figure 1. *Areas under investigation for the moisture detection (port and starboard side of the aircraft). Red indicates the interest area of flight control surfaces (rudder, trailing edge flap and horizontal stabilizer). Courtesy of the FiAF.*

Thermographic research has been done in close cooperation between VTT and the FiAF due to its potential to be used without removing aircraft composite parts from the aircraft and due to the possibility to investigate large areas simultaneously. Large area inspection without removing parts from the aircraft reduces the maintenance and inspection time significantly.

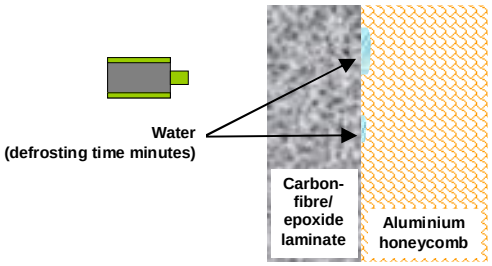

Figure 2. *Principle of the thermographic inspection based on the phase transition of water.*

Thermographic inspection based on the phase transition of water exploits the phase transition energy that is needed for the water defrosting (melting) (Figure 2). Advantage of this method is that no additional excitation source is needed for the tests. Method based on phase transition can be specially exploited during the long period of arctic weather conditions in Finland and other cold areas. Whole aircraft or separated parts of the aircraft can be placed in frozen conditions for few hours. Moisture or penetrated water can be detected due to the much larger need of specific heat of water during defrosting compared to the warming up of the surrounding structure (Figure 3). Aircraft can be either inspected right after flight or it can be left outside in freezing conditions during the night and inspected when it has been brought to the maintenance hall to warm conditions.

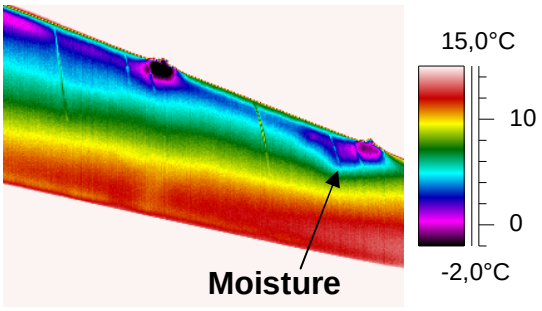

Figure 3. *Moisture detected under the upper hinge of the rudder test sample.*

Thermographic inspection based on the phase transition of water has proved to be very sensitive to the moisture. Multiple tests with different specimen and different amounts of water showed that penetrated water can be detected for several minutes as a colder area in the structure. The time and the developed temperature difference when the defect can be seen are strongly dependent of the amount of water and the environmental conditions during the inspection. Artificial defected areas showed that very small amounts (less than 1 g) of water in the laminate honeycomb (carbon fibre/epoxide composite with aluminium honeycomb core) interface can be detected with this method (Figure 4).

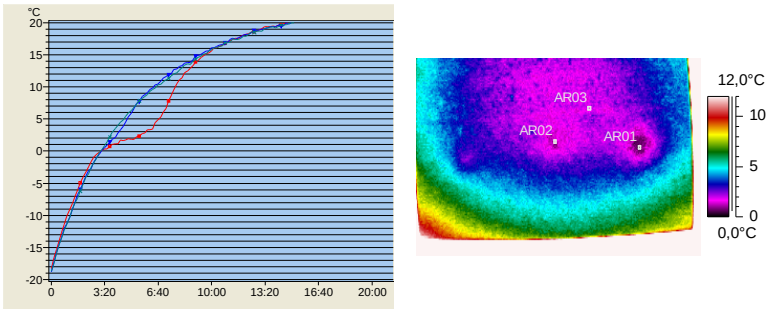

Figure 4. *Penetrated water (in laminate/honeycomb interface) detected with thermographic inspection based on phase transition of water. AR01 refers to red line (0,7 g water), AR02 refers to blue line (0,1 g water) and AR03 is a reference of dry area (green).*

The effects of environmental conditions were investigated to insure reliable inspection conditions for the inspected structure. Different cooling temperatures and times were investigated to make sure that the whole structure is frozen before the warming phase. Different defrosting conditions showed however that weather and cooling conditions affected strongly to the results. To prevent the condensation of the moisture and hence formation of rime layer on the surfaces is critical factor and can be significantly reduced by cooling the whole aircraft or composite structure in a hangar with proper ventilation.

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