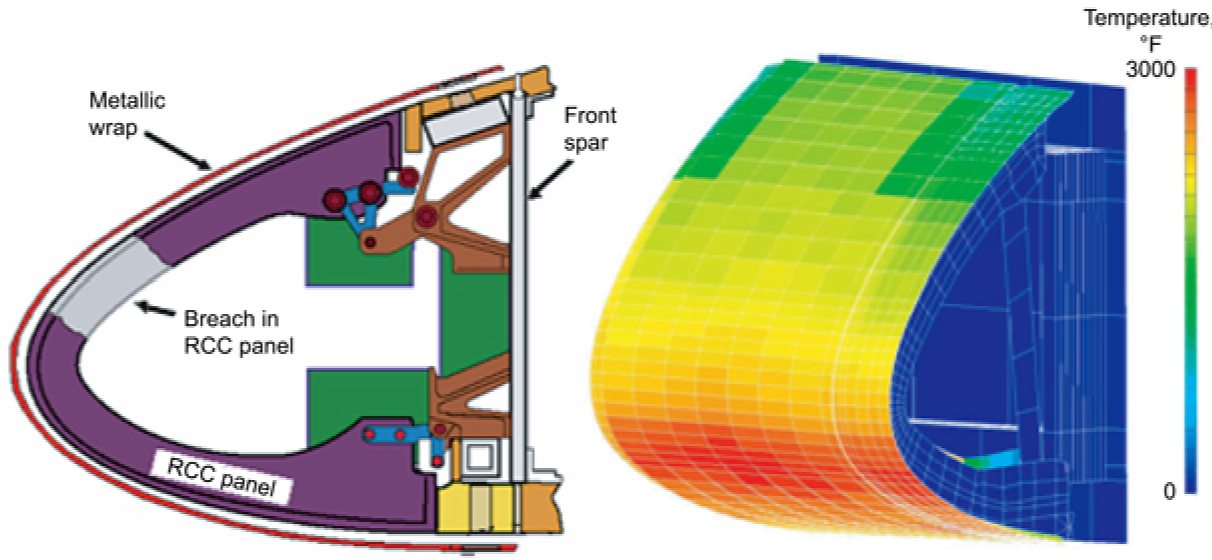
Flexible Metallic Overwrap Concept Developed for On-Orbit Repair of Space Shuttle Orbiter Leading Edges

The Columbia accident has focused attention on the critical need for on-orbit repair concepts for leading edges in the event that damage is incurred during space shuttle orbiter flight. Damage that is considered as potentially catastrophic for orbiter leading edges ranges from simple cracks to holes as large as 16 in. in diameter. NASA is particularly interested in examining potential solutions for areas of larger damage since such a problem was identified as the cause for the Columbia disaster.

Representation of concept for a refractory metal overwrap. Mockup of the space shuttle orbiter RCC panel 9.

One possible idea for the on-orbit repair of the reinforced carbon/carbon (RCC) leading edges is an overwrap concept that would use a metallic sheet flexible enough to conform to the contours of the orbiter and robust enough to protect any problem area from catastrophic failure during reentry. The preceding photograph shows a simplified view of the application of a refractory metal sheet over a mockup of shuttle orbiter panel 9, which experiences the highest temperatures on the shuttle during reentry. The metallic overwrap concept is attractive because of its versatility as well as the ease with which it can be included in an onboard "repair kit."

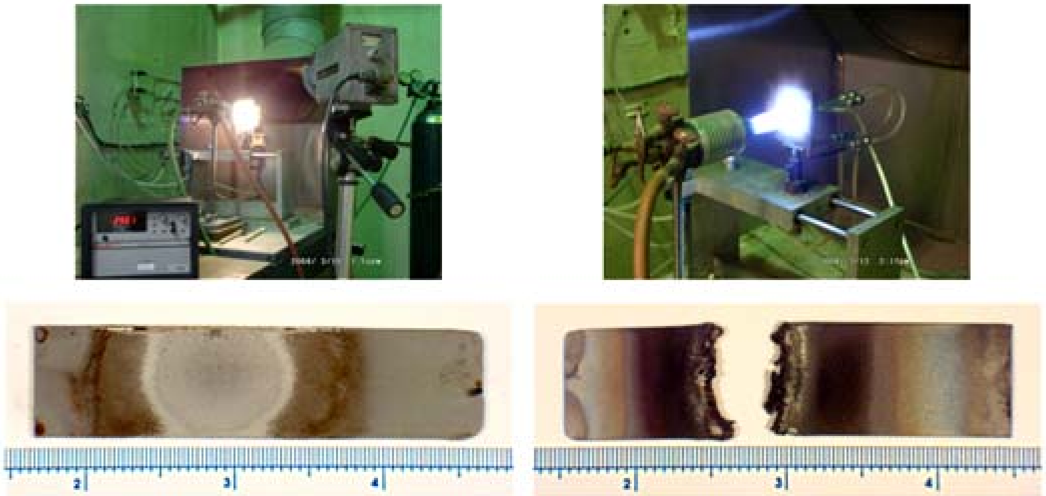
Reentry of the orbiter into Earth's atmosphere imposes extreme requirements on repair materials. Temperatures can exceed 1650 °C for up to 15 min in the presence of an extremely oxidizing plasma environment. Several other factors are critical, including catalysity, emissivity, and vibrational and aerodynamic loads. Materials chosen for this application will need to be evaluated with respect to high-temperature capability, resistance to oxidation, strength, coefficient of thermal expansion, and thermal conductivity. The following figure shows the temperature profile across panel 9 during reentry as well as a schematic of the overwrap concept itself.



Overwrap concept for leading-edge wing repair and a corresponding temperature profile for panel 9.

Refractory metals, which by definition have a melting temperature greater than 2000 °C, are candidates for a flexible overwrap repair concept. This class of metals exhibits high strengths and can withstand extreme temperatures. The significant problem with these materials, however, is their high propensity for oxidation. Coatings are critical for the success of a refractory metal leading-edge repair. Silicide coating can be applied to the metallic materials to improve the chances of survival through the oxidizing reentry environment. These coatings, however, are inherently brittle and crack as the overwrap is conformed to the leading edges. Processes are being investigated to mitigate oxidation through cracks in the coating either through introducing an oxidation-resistant underlayer or by introducing a crack-healing overlayer such as a type-A coating (e.g., sodium silicate).

Several refractory metal candidates were screened at the NASA Glenn Research Center as potential overwrap candidates. Alloys of niobium, tantalum, molybdenum, and rhenium were coated with an R512E silicide and were evaluated by a torch that simulates the temperature profile during a 15-min reentry. Although a few of the candidates showed potential for successful application, the rhenium sample was clearly the most promising. The final figure shows the torch setup used. Work is continuing with the development of an iridium underlayer that will mitigate oxidation attack of the rhenium in the event that cracks form in the silicide coating.



Screening of a candidate overwrap material using an oxygen-propane torch at Glenn. Photographs show examples of successful and failed torch screening.

Several design issues remain before a metallic overwrap can be considered as a reliable repair concept. Expansion differences with the RCC and attachment of the overwrap to the shuttle panels are two of the hurdles yet to be evaluated. The promising results gathered for rhenium and other refractory metal candidates have made this a primary concept for the repair of large damaged areas.

Find out more about this research:
NASA Glenn Research Center: http://www.nasa.gov/centers/glenn/home/index.html
Advanced Metallics Branch: http://www.grc.nasa.gov/WWW/AdvMet/webpage/

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