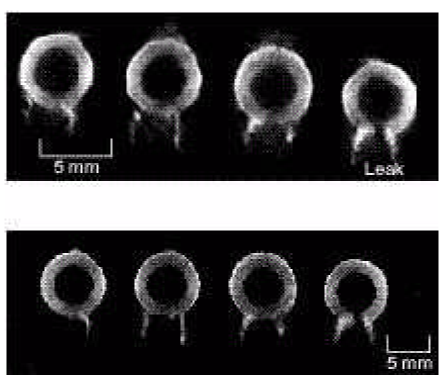
Rapid Prototyping Integrated With Nondestructive Evaluation and Finite Element Analysis

Most reverse engineering approaches involve imaging or digitizing an object then creating a computerized reconstruction that can be integrated, in three dimensions, into a particular design environment. Rapid prototyping (RP) refers to the practical ability to build high-quality physical prototypes directly from computer aided design (CAD) files. Using rapid prototyping, full-scale models or patterns can be built using a variety of materials in a fraction of the time required by more traditional prototyping techniques (refs. 1 and 2).

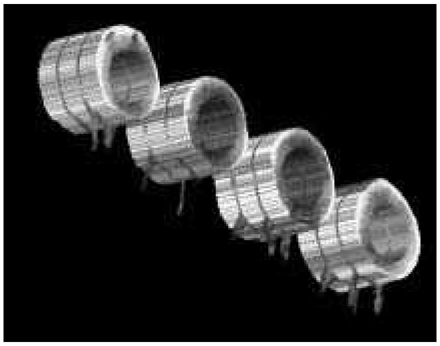
Many software packages have been developed and are being designed to tackle the reverse engineering and rapid prototyping issues just mentioned. For example, image processing and three-dimensional reconstruction visualization software such as Velocity[2] (ref. 3) are being used to carry out the construction process of three-dimensional volume models and the subsequent generation of a stereolithography file that is suitable for CAD applications. Producing three-dimensional models of objects from computed tomography (CT) scans is becoming a valuable nondestructive evaluation methodology (ref. 4). Real components can be rendered and subjected to temperature and stress tests using structural engineering software codes. For this to be achieved, accurate high-resolution images have to be obtained via CT scans and then processed, converted into a traditional file format, and translated into finite element models.

Prototyping a three-dimensional volume of a composite structure by reading in a series of two-dimensional images generated via CT and by using and integrating commercial software (e.g. Velocity[2], MSC/PATRAN (ref. 5), and Hypermesh (ref. 6)) is being applied successfully at the NASA Glenn Research Center. The building process from structural modeling to the analysis level is outlined in reference 7. Subsequently, a stress analysis of a composite cooling panel under combined thermomechanical loading conditions was performed to validate this process.



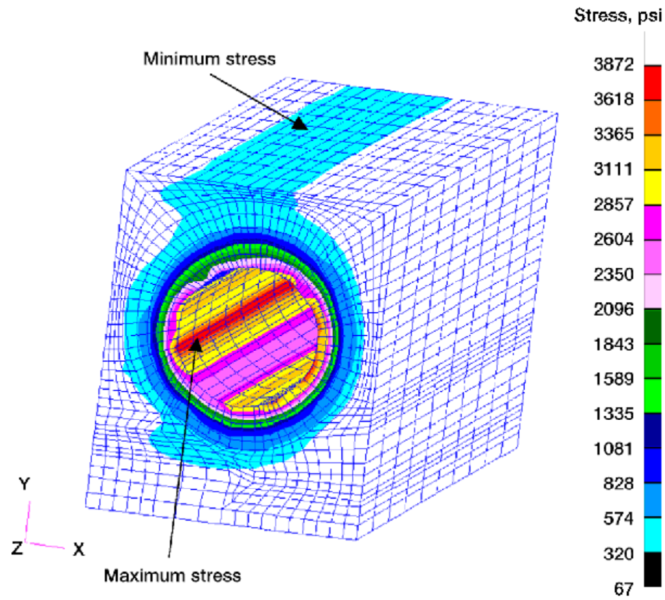
Top: Selected CT slice of the cooling panel. Bottom: Preprocessed and filtered image of the CT slice shown in the top part of this figure.

The preceding figure shows a representative CT scan slice of a composite material cooling panel that has four metal tubes that were brazed to it by a brazing alloy. The bottom part of this figure shows an aligned, preprocessed, filtered image of the CT scan shown in the top part. The following figure represents the three-dimensional volume rendering of a set of 50 of the two-dimensional filtered CT slices shown in the top part of the first figure. The panel underwent a broad test matrix investigating its thermal performance, thermal shock performance, and thermomechanical life cycle.

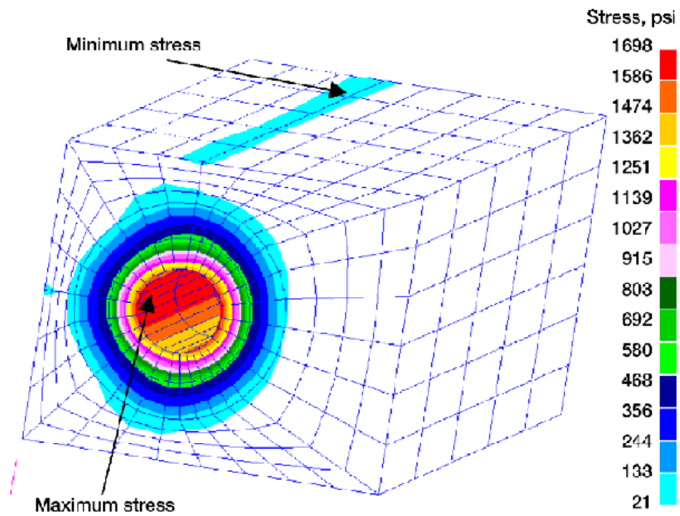


Three-dimensional volume rendering of a set of 50 two-dimensional filtered CT slices.

The finite element analyses were performed on the cooling panel under elastic conditions and combined thermomechanical loading using the MARC code (ref. 8). High-pressure coolant injected through the cooling holes and a temperature were the applied loads considered. The next figure shows the stress distribution reported in one tube section of the cooling panel using a CT-scan-developed model. The maximum stress location is at the metal tube inside wall, which was expected. Furthermore, the brazing material deformation is clearly noted because of the high pressure of the cooling gas. Such data were noticed in the CT scan, and interpretation of the information collected confirmed failure and leaking at the metal-wall-brazing material interface. Similar results are reported in the final figure, a model generated manually with MSC/PATRAN. This confirms that the NDE and the finite element findings are in good agreement. However, the advantage of analyzing an NDE-produced model is that it offers more details than a CAD model concerning deformities and structural abnormalities, which can assist greatly in the structural evaluation of tested components. In contrast, in CAD modeling, all the flaws have to be artificially modeled.



Von Mises stress distribution for tube A and surrounding based on CT data.



Von Mises stress distribution for tube A and surrounding based on MSC/PATRAN data.

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