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Techniques for Controlling Warpage and Residual Stresses in Welded Structures

Distortion and high residual stresses caused by welding large tanks are serious problems. Either condition could result in stress concentrations and cause premature failure of the structure, especially when flaws are present and the structure is stressed in low-temperature environments. When normal welding techniques are used, both distortion and high residual stresses are probable.

An investigation was undertaken to determine the feasibility of applying a new technique for controlling both distortion and residual stresses in aluminum weldments typical of those in the Saturn V booster tanks. The technique involves the use of cryogenic liquids and auxiliary heat sources to produce contraction and expansion of metal in the vicinity of the weld in such a manner as to counterbalance expansion and contraction caused by welding. By properly altering the thermal pattern of the weldment, it will be possible to control warpage and residual stresses.

Earlier work indicated that the tensile strength of welds in 2219-T87 and 2014-T6 aluminum alloy plate can be increased approximately 10 percent by using liquid carbon dioxide to extract heat to shorten the time-temperature cycle for the weldment. It was also observed that warpage appeared to be reduced when compared to unchilled welds.

In the initial phase of the recent investigation, analyses were performed to establish a theoretical thermal pattern which would counterbalance expansion and contraction due to welding. This selected target thermal pattern consisted of confining the heated portion of the plate to a 2-inch-diameter circle around the welding torch with a surrounding 8-inch-diameter ring at a temperature of approximately $-100°$F.

The experimental portion of the investigation was performed in two phases. The first phase consisted of tests on small samples to determine basic data on the feasibility of counterbalancing weld expansion and contraction by using liquid cryogenics. This work produced definite evidence that such counterbalancing is possible, thus verifying the fundamental concept. The second phase consisted of development of beneficial thermal patterns in $12 \times 48 \times 5/16$-inch 2014-T6 welded panels by application of the concept. Results of this work demonstrated conclusively that the concept can be successfully applied for controlling warpage and residual stresses in larger weldments. Some patterns actually reversed the normal warpage, while other patterns reduced residual tensile stresses to less than 5 percent of those present in conventionally welded panels. Four major systems for changing the thermal pattern of the weld, with a total of 30 variations of these systems, were developed and experimentally investigated during the course of the program. One hundred 12×48-inch weld panels were produced. Approximately 20 percent of these were unchilled; 45 percent were chilled from the front side; 20 percent were chilled from the back side, and 15 percent were chilled from the front side with the application of auxiliary heat. More than 50 panels were instrumented for measurement of temperature and warpage. Residual stresses were determined for 30 panels, requiring placement of over 200 strain gages and 100 slicing operations. X-rays, macrosections, and tensile tests were performed for 15 panels.

(continued overleaf)

Note:

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No patent action is contemplated by NASA.

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