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Rene 41 Heat Treatment Electron Microscopy

The problem:

Rene 41 is a high-temperature, precipitation-hardened, weldable alloy. Post-weld strain-age cracking of components made from Rene 41 alloy has been a serious problem. Variations in raw material or in processing may lead to excessive stress, which can contribute to post-weld strain-age cracking. The welding of 0.250-inch thick Rene 41 plates to a 1-inch thick forging in a rocket engine manifold gives a typical example in which complex heating and cooling cycles during manufacture leave no opportunity for conventional strength-developing heat treatments. Therefore, it is necessary for each manufacturer to find a unique solution to post-weld strain-age cracking problems with Rene 41.

The solution:

Because the mechanism of strain-age cracking appeared to be related to both γ' and metal carbide precipitates, a program was begun to determine microstructural changes resulting from heat treatment variations. The electron microscope was used as an inspection tool to identify in advance microstructures that are detrimental to welding.

How it's done:

Electron microscopy was used in the study of Rene 41 precipitation reactions because in this alloy, the γ' precipitate is so fine that magnification of 10,000X is required before it becomes possible to observe phase morphology. The electron micrographs produced in this study constitute an extensive catalog of the microstructure of Rene 41 as influenced by various heat treatments. At this stage of the investigation, a number of general results may be stated: 1) metal carbide may be dissolved given sufficient heat-treatment time at

1975°F; 2) a continuous grain-boundary (carbide) film is usually formed during aging following rapid cooling from solution heat treatment (exceptions were 5 and 10 hour solution heat treatment at 2200 and 2050°F respectively); 3) aging at 1650°F tended to agglomerate matrix (γ') precipitates, and, after low-temperature solution heat treatment, tended to produce spheroidal grain boundaries; 4) γ' precipitate was depleted by aging at 1800°F, and dissolved by aging at 1400°F, regardless of solution heat-treatment temperature; 5) the rate of precipitation in grain boundaries and in matrix increased with aging temperature and, to a lesser extent, with solution heat-treatment temperature; 6) the rate of hardening and maximum hardness rise was greater for higher temperature solution heat-treatments; and 7) recovery from cold-working under solution heat-treatment is not complete at 1975°F, but is complete at 2150°F.

The photographic data collected forms the basis for a better understanding of acceptable fabrication practices. However, a required further step is to correlate the observed microstructural characteristics with processing behavior, particularly with respect to the problem of strain-age cracking.

In order to identify more clearly the relationship of processing history and heat treatments to the occurrence of strain-age cracking, the following steps are recommended for further investigation: 1) positively identify grain boundary (carbide) and matrix (γ') precipitates; 2) quantitatively determine the γ' to metal carbide ratio and relate this ratio to strain-age cracking susceptibility; 3) study hardness and microstructural changes during early stages of precipitation (less than one-hour aging) and after slow cooling from the solution heat treatment temperature, 4) determine the ex-

(continued overleaf)

tent of matrix shrinkage and the resulting residual stress during γ' precipitation; 5) compare (by means of spot check of solution and aging heat treatments) other heats of Rene 41 with the present electron microscope and hardness data to establish the general validity of these results; 6) correlate microstructural and hardness data with the records and processing history of incoming material, to deduce the relationship between microstructural properties and behavior; 7) establish the effect of those solution heat treatments which cause discontinuous grain-boundary precipitate aging on post-weld strain-age cracking susceptibility and other mechanical properties; 8) investigate the nature and extent of γ' depletion near grain boundaries in weld-heat affected zones of known thermal history; and 9) determine the efficacy of welding Rene 41 that has been slow cooled from the solution heat treatment temperature.

Notes:

1. For information on a related investigation, using a weld-circle patch test to determine the characteristics of Rene 41 alloy material, refer to Tech Brief B69-10605.

2. The following documentation may be obtained from:

Clearinghouse for Federal Scientific
and Technical Information
Springfield, Virginia 22151
Single document price \$3.00
(or microfiche \$0.65)

Reference: Rene 41 Heat Treatment Elec-
tron Microscopy (N69-71272)

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No patent action is contemplated by NASA.

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