High Temperature Materials

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As the required temperatures for rocket and missile applications increase, it is obvious that refractory metals such as molybdenum, columbium, and tungsten will become important. Together with this we are finding more exacting requirements placed on the older more familiar nickel and cobalt-base superalloys. These materials are being produced to meet the design needs today as they were 10 to 15 years ago. Eight years ago, the standard turbine bucket alloy was used at 1475° to 1525°F. Today alloys are available for service above 1700°F. This increase is the result of a better understanding of the materials themselves and a better knowledge of the properties required for adequate service.

Our understanding of the materials has been increased by an analysis of the relation of microstructure and properties in commercial alloys and a synthesis of the knowledge gained from the study in simple systems. An example of this kind of analysis is shown in a series of papers by J. Glen.^(1,2,3) In many commercial alloys he shows that the strengthening (as shown by a reduction in creep rate) can be traced to precipitation reactions (or transformations of the precipitated phases). He demonstrates that the regularities in these reactions permit more accurate extrapolation of short-time data than the usual methods. In addition to this, it follows that by changing the rate of transformation or precipitation or by causing another reaction to take place, one can make an alloy with superior long-time properties. While this principle has been anticipated by other workers, Glen's work demonstrates the results on commercial alloys.

Extrapolation methods, which have found favor previously, have again been examined by Goldhoff.⁽⁴⁾ His conclusions are of interest since he has dealt most specifically with the use of parameters in extrapolation for very long times. Somewhat disconcertingly, he finds that often the more precise the parameter used the lower the extrapolated strengths at long times. While most of his data are for ferritic steels, the same effect may exist for austenitic materials as well.

While we can not claim that Al-Cu alloys are superalloys, a recent report⁽⁵⁾ on their high temperature behavior might shed some light on a problem now being encountered in some short-time applications. What happens when an age-hardened alloy is heated above the solvus temperature? Because diffusion is relatively slow the precipitate may persist for a short time. The rate of solution (and the loss in strength accompanying solution) are influenced by stress and particle size as well as the amount of *overtemperature*. Simultaneous straining can inhibit the dissolution process at least in the early stages. Further study of this process may permit the design of alloys for particular applications involving short life but requiring reasonable strength.

SAP-type materials

When it was first discovered a decade ago that cold-worked aluminum powder bars retained their strength considerably above the usual recrystallization temperature, much hope was expressed in the use of this principle for giving remarkable strengths to other materials. It has since been demonstrated that a fine dispersion of Al_2O_3 coming from the surface skin on the powder is responsible for the unusual properties. Although much work has been expended on SAP-type alloys, only moderate success has been achieved in other systems. It appears that the important characteristics of this kind of material are a) a very fine and stable metal particle size;^(6,7) b) a stable dispersed phase;⁽⁸⁾ and c) the proper interparticle distance.⁽⁹⁾ In any system both composition and processing must be controlled to optimize all three factors. One method of obtaining items a) and c) is by internal oxidation of very fine alloy powders.

Russian notes

In a recent article in the JOURNAL OF METALS⁽¹⁰⁾ some of the Soviet research in high temperature strengthening was reviewed. A few additional remarks on people, places, and things seem appropriate. The A. A. Baikov Institute now publishes a yearly volume entitled *Investigations of Heat Resistant Alloys*.⁽¹¹⁾

This publication is a broad coverage of both fundamental and applied research. Volume III has 46 papers totaling 428 pp. covering such diverse subjects as *Self Diffusion in Iron*, *The Structure of Chromium Carbonitrides*, *The Cr-Nb-Va Constitution Diagram* and *X-ray Spectroscopic Studies in Fe-Mo and Fe-Al Alloys*. The contents do not suggest any significant change in the directions of their work. There is still a great deal of work on the relation of X-ray spectra and bond strength and diffusion and heat resistance. There are few direct references to commercial materials. We can infer from their work, however, that they face much the same problems we do in this country.

Two other research groups working on related research are the Leningrad Polytechnic Institute where Zhurkov and Stepanov are working on the effect of temperature on deformation and the Ukrainian Academy Institute for Metal Physics under Dekhtyar where work on the relation of diffusion and deformation is being carried out. In the next column of Phases and Processes devoted to high temperature materials, the latest Soviet work will be reviewed in more detail.

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