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Alloy Development of Nickel-Based Superalloy Weld Filler Metals[1]

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Lower strength, solid solution filler metals such as IN625 are commonly used in the industrial gas turbine industry to repair rotating turbine blades. While these alloys offer excellent weldability and ductility, they suffer considerably in overall high temperature strength and performance. As a result, these fillers are used only to repair lower stress regions of blade airfoils and other parts. The availability of high-strength precipitation strengthened filler metals for weld repair of nickel-based superalloy parts is highly desirable to allow repairs to be performed over the entire component.

Conventional alloy development is costly and time-consuming because it involves several trial and error iterations of processing and evaluation. This entire process can be shortened with the use of computational thermodynamics, which provides a convenient means for assessing phase stability as a function of alloy composition and temperature. This approach was used extensively to examine the influence of alloying additions on phase stability in alloys comparable to Rene80 and GTD111. The calculations indicated the limits for various additions, beyond which undesirable phases such as sigma phase, mu phase, and P-phase were stable. The calculations also provided valuable information with regard to the temperature ranges for processing. Limited TEM analysis was carried out and the results verified the accuracy of the calculations.

Specifically, over 80 different compositions were examined and the phase stability as a function of temperature was determined. In addition to identifying the amounts of key phases such as sigma phase, eta phase, P-phase, MC carbide, $M_{23}C_6$ carbide, gamma, and gamma prime, the solution temperature range was also evaluated. This range was defined as the interval between the solidus temperature and the gamma prime solvus temperature. This quantity was deemed to be important because a large solid solution temperature range is necessary for proper heat treating after welding. Elements that were identified as having a major influence on the phase stability included Cr, Mo, and C. Numerous calculations were made to identify the phase stability relationships when these elements were varied. In addition, the extent of the solution heat treating range was identified as a function of alloy content for these elements. A numerical analysis was then carried out to graphically display the phase stability and solution temperature range as a function of composition.

Sample plots are shown in Figures 1 and 2. In Figure 1, the phase stability as a function of temperature for a nominal R80 composition (Ni-9.5Co-14Cr-4Mo-4W-3Al-5Ti-0.17C-0.015B-

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0.03Zr, all in wt %) is plotted. Below approximately 920°C, P-phase is found to be stable. It is assumed that P-phase formation is undesirable and so composition adjustments to avoid this phase were examined. P-phase stability was found to be very sensitive to the Mo concentration. A slight decrease in Mo content, to 2.9 wt %, was found to destabilize P-phase to the point that it was not predicted to form over the temperature range shown.

The results of these calculations are being used to develop a new generation of weld filler metals that exhibit both high strength and high ductility. The development of such filler metals will allow for repair procedures on sections that cannot be properly refurbished with currently available filler wires.

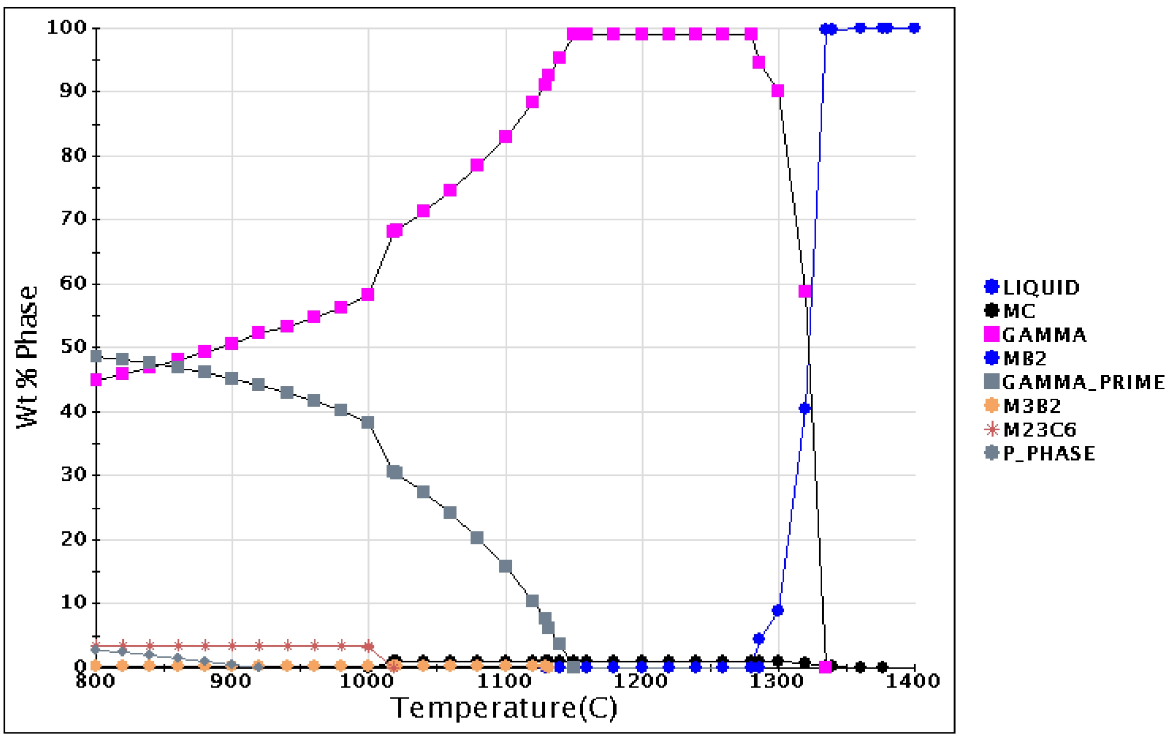

Figure 1: Calculated phase stability versus temperature for a nominal R80 composition showing the stability of P-phase at low temperatures.

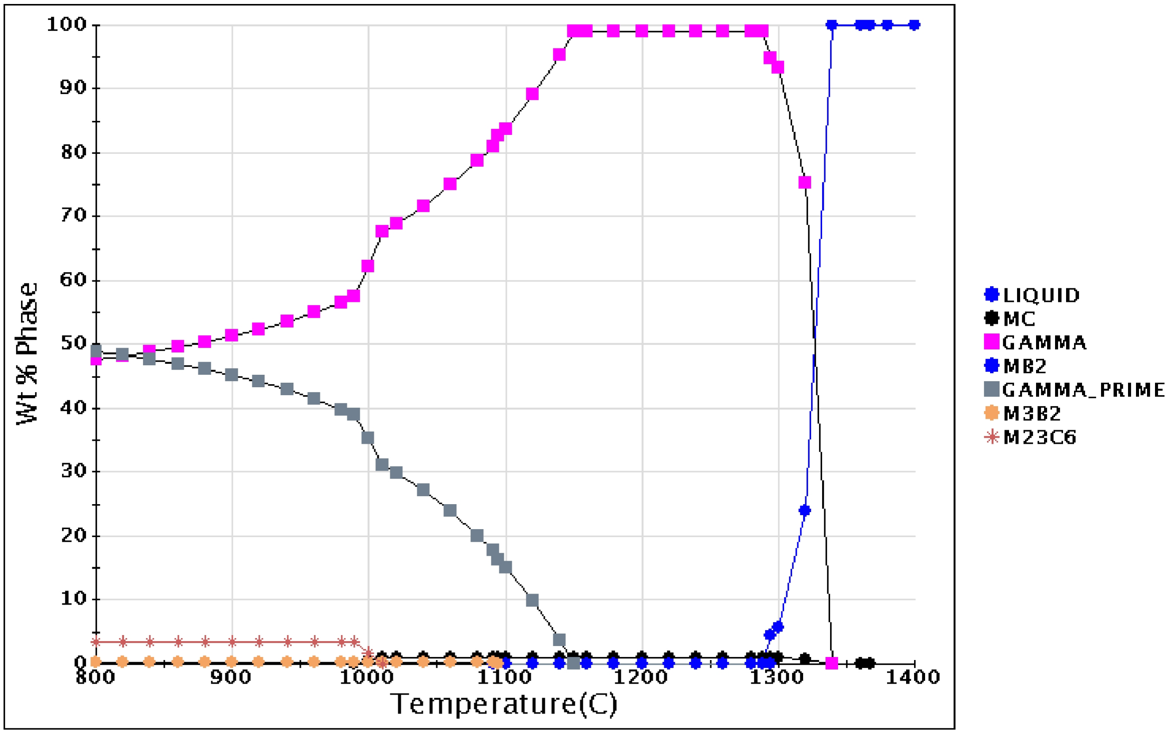

Figure 2: Calculated phase stability versus temperature for the same nominal R80 composition as in Figure 1 except Mo reduced to 2.9 wt %. The decrease in Mo content reduced the stability of P-phase so that it is not predicted to form above 800°C.