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A Review of Nitrogen Solubility in Nickel-based Alloys

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Compared with liquid iron, pure liquid nickel has a relatively limited solubility for nitrogen. Studies that have measured solubility have found values ranging from literally zero in one case to 35 ppm at 1600 C at the high end. Studies that examined the effect of temperature found the reaction to be endothermic with solubility increasing with temperature. Solubility predictions based on studies that determined free energy equations of solution generally range from 5-20 ppm over a temperature range of 1480-1700 C. Studies of solubility in nickel alloys found that most alloying elements increase nitrogen solubility (Al and Cu are possible exceptions) and that Sievert's Law was followed up to very high pressures with exceptions for Ni-Cr and Ni-W alloys above a certain alloying level. Both chromium and niobium were found to change the solubility reaction to exothermic and reverse the temperature dependence. Interaction parameters reported from these specific studies were constants, however, rather than functions dependent on temperature as with stainless steels. As a result, using these constants to calculate solubility could give the incorrect trend with temperature. These parameters were reevaluated to include the temperature effect. For Ni-based superalloys with high Ti levels, nitrogen solubility may become limited by the formation of titanium nitride. One known published experimental work on nitrogen solubility in high titanium superalloys was reexamined to develop a regression equation for solubility based on a chromium equivalence term and temperature. By comparison, when predictions of solubility using interaction parameters with the free energy of the titanium nitride reaction were extended to high titanium levels, substantially higher solubility levels for nitrogen were predicted. Further fundamental research may be needed for these types of alloys to address the difference in solubility predictions from low to high titanium levels and the effect of other alloying elements.

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