New Materials

Nickel Aluminide

Nickel and aluminum, when combined in a ratio of about 3 parts to 1, with trace amounts of boron added, can be formed into a unique metallurgical alloy with some extraordinary and useful properties. The development of this remarkable material, whose full potential has yet to be realized, was aided substantially by a research break-through in 1982 funded by the Seed Money program.

Nickel aluminide is much stronger than steel. In contrast to most other materials, it actually increases in strength in high temperature environments up to about 1300°F, and maintains its strength well above 1600°F. It is lightweight and highly resistant to corrosion by oxidation. It is malleable, making it easy to form into different shapes. Yet, with the addition of certain other elements, it can be made to resist strongly permament deformation and rupture at elevated temperatures, two common modes of metal failure.

While more expensive than ordinary steel, nickel aluminide promises to be highly cost competitive with other specialty materials, such as heat resistant alloys made of nickel, titanium, and vanadium.

The mechanical properties of nickel aluminide provide significant advantages over many currently available heat resistant materials in a number of economically important applications. These range from machine tools and boilers to parts for the automotive and aerospace industries. For example, at 1500°F, a temperature well within the operating temperature ranges experienced by most metal parts in today's gas turbines, jet engines, and diesels, nickel aluminide is four times stronger than high temperature steel.

Because of its high strength at these temperatures, the alloy is now being examined under exclusive license by Cummins, Inc., a major United States manufacturer of heavy diesel engines. An initial application under investigation is its use in strengthening exhaust valves. This part of the engine, which is subjected to high temperatures, corrosive environments, and repeated pounding, is often the first part to fail. Extending valve life with an improved material would increase the engine's reliability, stretch out maintenance schedules, reduce costs of repairs under warranty, and make the entire engine more competitive in international trade.

Because the alloy is made partly of aluminum, it is 10 percent lighter than steel. Also, because of its strength, a part made from the alloy can be designed smaller, further reducing its weight. Hence, the alloy has also generated considerable interest in the aerospace industry as a substitute for heavier materials now required for strength, such as fasteners, rivets, and certain structural components.

Another valuable property of the alloy is that once it has formed an initial, protective layer of aluminum oxide, it is nearly impenetrable to further corrosion and oxidation. Its corrosion resistance has been measured at 1000 times better than competing steels. As a result, it is now being investigated for use in heat processing equipment subjected to fouled environments, such as steam boiler tubes and hot exhaust gas heat recovery equipment in industry.

As a material, nickel aluminide is part of a larger family of materials known as "ordered" intermetallic alloys, so-named because of the precise ordering and interweaving of the atomic structures or lattices of the two metals. This particular situation, called a low "free energy" condition, makes it difficult to remove an atom from its position in the lattice, which gives the material its strength, or to have it react chemically with outside agents, which gives it its property of corrosion resistance. While these materials were well known in the 1950's and 1960's, the problem with them in the past had always been that they were