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NASA TECH BRIEF

Bearing Alloys with Hexagonal Crystal Structures Provide Improved Friction and Wear Characteristics

The problem:

Catastrophic bearing failure results when lubricant surface films fail because of surface speed, load, or environment. Space vacuum is a particularly difficult environment, for conventional lubricants evaporate and surface oxide films do not re-form when worn away. The loss of lubricant film, from whatever cause, results in metal-to-metal contact, high friction, repeated surface welding-shear reactions, metal transfer, and subsequent bearing failure.

The solution:

Make the bearings from metals and metal alloys with a stabilized hexagonal crystal lattice structure and with a maximum C/A ratio (where C = distance between hexagonal planes; A = distance between adjacent atoms.)

Extensive research into the basic structure of metals and metal alloys and the influence of crystalline structure parameters on friction and wear has produced data showing large and consistent differences in the shear forces required for cubic and hexagonal crystals. When welding occurs between two metal surfaces and the welds shear, they do so along distinct planes in the crystals. Shear forces in cubic crystals are commonly up to 100 times greater than the corresponding shear forces in hexagonal crystals. Further, hexagonal crystal alloys shear smoothly at the original surface without changing the surface geometry and allow the bearing to operate much longer. Additional research showed that the shear force in hexagonal crystals varies with the relative spacing of the atoms in the crystal lattice. The studies show that the careful selection of hexagonal crystal alloys can significantly improve the friction and wear characteristics of bearing metals in vacuum and in air and at higher temperatures than previously experienced.

How it's done:

Of the various metals studied during the research program, cobalt and titanium are more commonly used, and hence, are of the greatest immediate practical interest. Titanium is well known as a metal subject to surface welding or galling and otherwise possessing poor friction properties. Cobalt alloys have been used in bearings but usually in alloys with predominantly cubic structure. Studies have shown that improved friction and wear properties can be obtained if cobalt and titanium are alloyed in such a way as to stabilize their hexagonal crystal structures over greater ranges of temperature and to increase the crystal lattice ratio. It is known, for example, that cobalt transforms from hexagonal to cubic structure when heated above 750°F. A marked increase in friction accompanies this crystal transformation, and wear rate is about 100 greater for cubic cobalt than for hexagonal cobalt.

These studies have shown that the cobalt hexagonal form can be stabilized over greater temperature ranges by certain alloy additions of tungsten and molybdenum. Simple binary alloys of titanium with either tin or aluminum were found to provide the desired structural characteristics. Increasing the percentage of aluminum or tin produced higher crystal lattice ratios, greatly reduced friction, and minimized surface failure tendencies.

Notes:

1. These temperature stabilized hexagonal crystal structure alloys are potentially useful in many applications. They are presently being investigated for

(continued overleaf)

use in bearings and seals in aircraft, in hydraulic equipment, and in vacuum installations.

2. For the medical field, the hexagonal crystal cobalt-molybdenum alloys have been shown to have lower friction and wear properties than the cubic crystal cobalt-molybdenum alloy presently used in artificial human hip and elbow joints.
3. Further information concerning these alloys is given in the following NASA reports: TN D-2523, "Marked Influence of Crystal Structure on the Friction and Wear Characteristics of Cobalt and Cobalt Base Alloys in Vacuum to 10^{-9} Millimeter of Mercury. I—Polycrystalline and Single Crystal Cobalt," by Donald H. Buckley and Robert L. Johnson, December 1964; TN D-2524, "Marked Influence of Crystal Structure on the Friction and Wear Characteristics of Cobalt and Cobalt Base Alloys in Vacuum to 10^{-9} Millimeter of Mercury. II—Cobalt Alloys," by Donald H. Buckley and Robert L. Johnson, December 1964; TN D-2671, "Influence of Crystal Structure on the Friction and Wear of Titanium and Titanium Alloys in Vacuum," by Donald H. Buckley, Thomas J. Kuczkowski, and Robert L. Johnson, March 1965; TN D-3235, "Friction, Wear, and Adhesion of Titanium–Aluminum Alloys in Vacuum," by Donald H. Buckley and Robert L. Johnson, January 1966. A summary of these reports is given in American Society of Lubrication Engineers Transactions, volume 9, no. 2, pages 121 to 135, April 1966, "Friction and Wear of Hexagonal Metals and Alloys as Related to Structure and Lattice Parameters in Vacuum to 10^{-10} Millimeter of Mercury," by Donald H. Buckley and Robert L. Johnson.
4. Inquiries concerning this invention may be directed to:

   Technology Utilization Officer
   Lewis Research Center
   21000 Brookpark Road
   Cleveland, Ohio 44135
   Reference: B66-10373

Patent status:

This invention is owned by NASA, and a patent application has been filed. Royalty-free, nonexclusive licenses for its commercial use will be granted by NASA. Inquiries concerning license rights should be made to NASA, Code GP, Washington, D.C. 20546.

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