April 1971

Brief 71-10073

NASA TECH BRIEF

Goddard Space Flight Center

Process for Producing Molybdenum Foil and Collapsible Tubing

A manufacturing process has been developed for producing 0.002 cm (0.001-inch) thick molybdenum foil, and for forming the foil into high-strength, thin-walled tubing which can be flattened for storage on a spool. Lengths up to 305 meters (1000 feet) of unbroken foil or tubing are believed possible with this technique. Desirable properties of molybdenum metal for this application include high thermal conductivity stiffness, yield strength and ultimate tensile strength, and low coefficient of thermal expansion.

The foil produced during the development stage was rolled from pressed and sintered molybdenum ingot of 99.95% purity. The sintered ingot currently used has initial dimensions of 2.54 x 25.4 x 60.96 cm (1 x 10 x 24 in.). It is rolled in four steps, as follows: 1) warm rolling from a hydrogen-atmosphere furnace to a thickness of 0.831 cm (0.327 in.), followed by recrystallization; 2) warm rolling, again from a hydrogen-atmosphere furnace, to a thickness of 0.127 cm (0.050 in.), followed by cleaning in hot caustic and acid, annealing, and trimming to a width of 17.78 cm (7 inches); 3) cold rolling to 0.018 cm (0.007-in.) thickness, followed by annealing and retrimming to 17.15 cm (6.75-in.) width; and 4) final cold rolling to 0.002 cm (0.001-in.) thickness, followed by final cleaning and trimming to the desired width. Properties of the foil produced by this technique include yield strength of 1391 MN/m^2 (201,900 psi), ultimate strength of 1487 MN/m^2 (215,800 psi) and elongation of 2.5% in two inches.

In forming the foil into overlapped 1.27 cm (0.50 in.) diameter tubing, a stress-relief heat treatment was performed to sufficiently reduce the residual stress in the tubing to permit reflattening without exceeding the yield strength of the molybdenum. The heat treatment was performed within a constraining tube of stainless steel for two main reasons. First, under heat treatment without constraint, springback of the formed molybdenum would enlarge the tube diameter. To compensate for this, a smaller forming bend radius would be required. Second, the constraining tube provided a rigid member to conduct the foil tubing through the heat treatment and to provide a means of maintaining a non-oxidizing atmosphere around the molybdenum. This resulted in better control of the tube straightness and greater uniformity of the final tube diameter.

A three-section, continuous-forming pilot plant was constructed for the production of molybdenum-foil tubing. In the first section, flat molybdenum foil was unwound from a feed spool and formed through a sequence of ten dies into an overlapped tube about 1.02 cm (0.4 inches) in diameter. In the second section, the tubing was fed at a line rate of 3.66 m/hr (12 ft/hr) into the stainless steel constraint and passed through a 0.610 m (2 feet) long electric furnace, where it was stress-relief annealed at 839°K (1050°F). In the third section, the tubing was cooled, the constraint removed, and the formed tubing flattened and wound on a take-up spool.

Tensile tests made on samples cut from the formed tubing showed 0.2% yield strength values in excess of 1171 MN/m^2 (170,000 psi).

Notes:

1. This process was originally developed to produce extendable gravity-gradient stabilization rods for spacecraft. However, the rods might also be employed wherever extremely lightweight, high

(continued overleaf)

strength structural materials are required. The process may therefore prove useful to personnel in the piping, aircraft, and container industries.

2. The following documentation may be obtained from:

   National Technical Information Service
   Springfield, Virginia 22151
   Single document price $3.00
   (or microfiche $0.95)

   Reference:
   NASA-CR-78308 (X66-22958), Evaluation of Molybdenum Gravity Gradient Rods, Final Report

Patent status:

No patent action is contemplated by NASA.

Source: G. R. Bretts, Dr. R. B. Gavert, and
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under contract to
Goddard Space Flight Center
(GSC-10008, 10009 & 10010)