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BERYLLIUM STRUCTURE SUPPORTS ELEMENTS OF ROTOR MAST SIGHT

Lightweight, pure beryllium structure provides ultra-high resistance to G-force inertial loads, minimizes effect of helicopter's rotor vibrations, thermal loads

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BERYLLIUM STRUCTURE SUPPORTS ELEMENTS OF ROTOR MAST SIGHT

Lightweight, pure beryllium structure provides ultra-high resistance to G-force inertial loads, minimizes effect of helicopter's rotor vibrations, thermal loads

E. J. Stefanides, Central States Editor

Elmore, OH —The new U.S. Army's OH-58D Scout observation helicopter, scheduled to go into service in mid-1986, will have a rotor mast-mounted opto-electronic imaging and targeting system. The new overhead system will allow tree lines, foliage, ridges, and other terrain features to be used for cover and concealment during missions in support of front-line troops. This capability will make the helicopter less susceptible to enemy fire. It is combined with the most advanced opto-electronic systems yet developed for observation, surveillance, and the direction of artillery fire and air strikes.

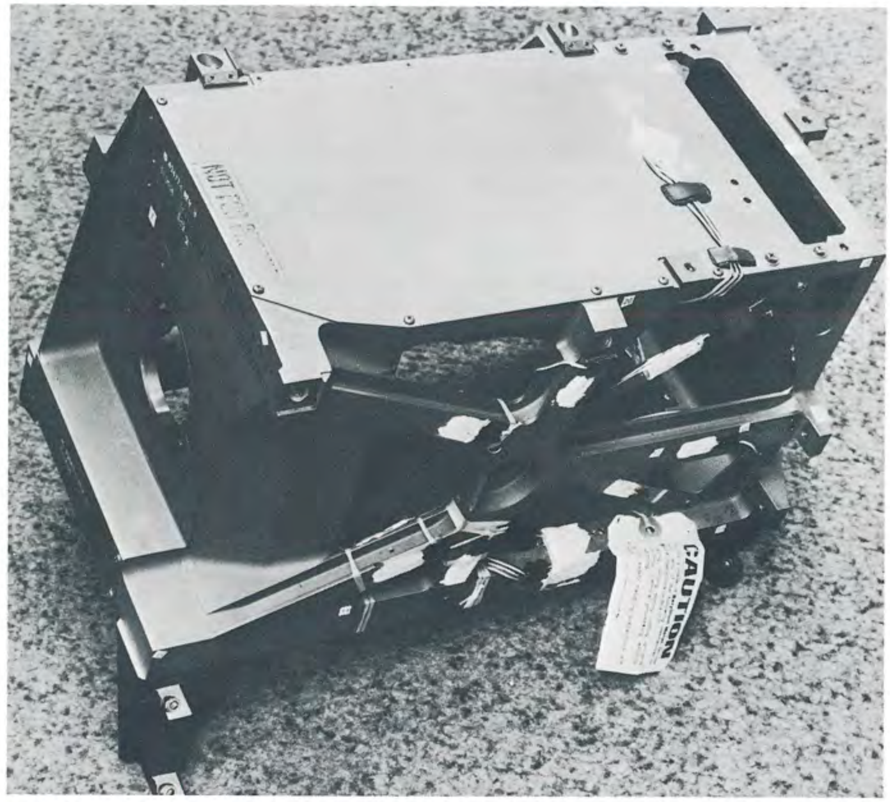
The new targeting and sighting system was designed and engineered by the McDonnell Douglas Astronautics Co., Huntington Beach, CA. It is based on some 10 years or so of stabilized platform research and is a 26-inch dia spherical package containing a cluster of precision, optoelectronic sensors. It has a telescopic TV camera for long range daylight viewing of enemy targets. It also has an infrared thermal imaging system for use at night and under the low-visibility conditions caused by inclement weather, haze and battlefield smoke.

These basic imaging systems are supplemented by a laser rangefinder and target designator, an optical boresight assembly, and a gyro electronics unit. The laser system can place a laser spot on the target for "homing in" of laser-guided missiles and "smart" artillery shells. The optical boresight assembly and gyro electronic provides for alignment and directional orientation of the other systems.

These sensor systems have a total weight of about 95 lb and are mounted on a 6-lb, cage-like structure made of pure beryllium. This structural design was one of three candidate structures considered for the system. The others were structural systems that would be fabricated from 6061-T6 aluminum alloy and a pseudo-isotropic, graphite epoxy composite.

The choice was based on best satisfaction of combined needs for low weight, high tensile strength, high rigidity, high fatigue strength (i.e., extended endurance limit), reasonable raw material and overall costs and availability within the time frame of the program. Of these needs, the cost requirement was the only one to pose any real problem.

The original (i.e., prototype) mounts were machined from a solid block of pure beryllium. The high material and machining costs of this approach have been reduced by a



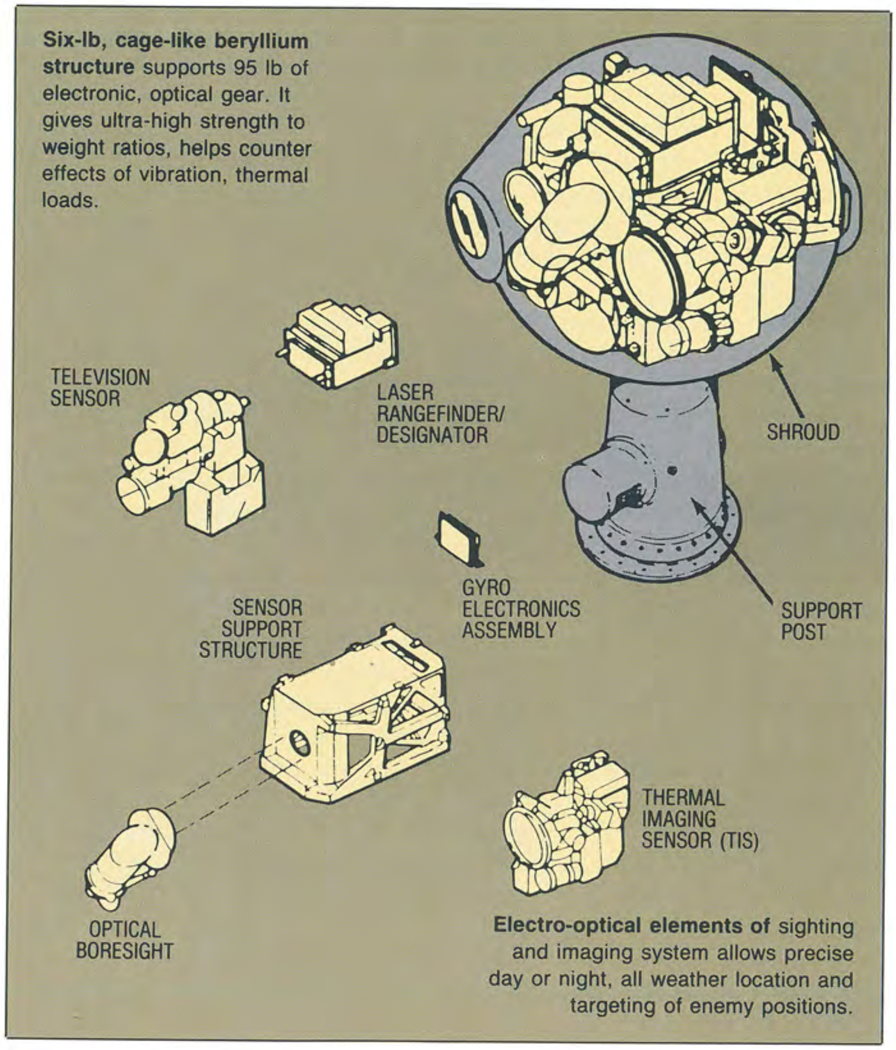
U.S. Army's OH-58D Scout's rotor (opposite page), mast-mounted sighting system allows use of terrain features for cover and concealment during front-line observation missions. Original mount (right) was machined from single block of pure beryllium. It may be replaced by less costly brazed assembly made from near net shape beryllium billets.

subsequent alternative design. The alternative design is produced as a brazed assembly of independently machined subparts made from near net shape billets pressed from powdered beryllium.

The redesign was implemented without change in selection of the basic pure beryllium material, as its combination of high mechanical properties and ultra-light weight are the key to the success of the design. Brush Wellman, Inc., the suppliers of the beryllium used in the mounts, point out beryllium with a density of 0.067 lb/cu inch (two thirds that of aluminum), is one of the lighter structural metals available. Further, the ultra-low weight is combined with mechanical properties that give the beryllium structure load-carrying capabilities far beyond that of other lightweight (and some heavyweight) metals.

The ultimate tensile strength of beryllium ranges from 40 ksi for hot pressed block to 120 ksi for extruded rod. These levels of tensile strength and the low density give specific strengths (tensile strength/density) that ranges from 11.5×10^5 inches for cross rolled sheet to 6×10^5 inches for hot pressed block. Beryllium also has a high modulus of elasticity (e.g., 44×10^6 psi) that is four times that of aluminum and two and one half times that of steel. This high elastic modulus and low density gives a high stiffness to density ratio that makes the metal ideally suited to use in lightweight structures requiring maximum rigidity.

Dynamic properties of beryllium are also excellent. It has high resistance to fatigue cracking and high endurance strength levels that combine with the low density to give fatigue strength to density ratios much higher than those of aluminum and titanium. It also has inherent vibration damping properties that



Six-lb, cage-like beryllium structure supports 95 lb of electronic, optical gear. It gives ultra-high strength to weight ratios, helps counter effects of vibration, thermal loads.

Electro-optical elements of sighting and imaging system allows precise day or night, all weather location and targeting of enemy positions.

help control resonance effects and minimize generation and transmission of noise.

There are two other considerations that make beryllium the best choice for this application. One is its suitability for use at both ultra-high and ultra-low temperatures. Beryllium provides useful levels of strength and rigidity at temperatures as high as 1500F. (This temperature is far beyond the melting point of such competitive lightweight metals as aluminum and magnesium.) It also has low-temperature toughness properties (i.e., impact strength and ductility) that even allow use in cryogenic applications.

The other major consideration is its excellent thermal properties. Beryllium has a heat capacity at room temperature of 0.45 BTU/lb/F that is higher than that of any other metal. (This superiority is maintained up to its melting point of 2345F.) Beryllium's thermal conductivity at room temperature is 104 BTU/hr/ft^2/ft/F. On the basis of equal weight, this value makes beryllium the best thermal conductor of the lightweight metals.

Beryllium also has a thermal diffusivity of 1.97 ft^2/hr that gives rapid temperature equalization characteristics that tend to eliminate distortion caused by thermal gradients. This useful quality is combined with a coefficient of thermal expansion that is comparable to those of the stainless steel and nickel and cobalt alloys. The beryllium is also transparent to X-rays. This latter property is useful for obtaining non-destructive verification of a part's structural integrity.

The mount or support structure is a complex combination of flat surfaces, strengthening and support members, mounting pads, protrusions, access openings, and tapped holes. This shape was generated by the machining of each mount from a single block of S-200F vacuum, hot-press pure beryllium produced by Brush Wellman, Inc., Cleveland OH. Each block measured 16½ x 9½ x 9½ inches and met requirements of MIL-B-21531. To minimize raw material and machining costs, the center portion of each block was removed by Brush Wellman before shipment from its Metal and Oxide Products plant, Elmore, OH.

The machining was done by Speedring Div., Schiller Industries, Cullman, AL. It involved the removal of large amounts of beryllium material, and was done with solid carbide cutters, mills and drills. These machining processes were very closely controlled, as section thicknesses were generally around 0.100-inch and one (the thinnest section) was only 0.050-inch thick. The only details machined to final dimensions were the threaded holes provided for fasteners. The others were machined to provide a part whose contours were within 0.003 inch of final dimensions.

To bring the part to final geometry, the threaded holes were plugged and the excess stock was uniformly removed from all surfaces by immersion in a nitric-hydrofluoric acid bath accurately maintained at 80F. This final etch process was used to remove the damaged (twinned) surface and to restore ductility.

The various electronic and optical components were assembled to the finished support structure with self-locking screws. Most of these screws were installed directly in holes tapped into the beryllium. However, threaded inserts were used for the self-locking screws of some components that were scheduled for frequent removal during testing. These threaded inserts were made of a cadmium-plated alloy steel, selected to be galvanically compatible with the beryllium.

The resulting system was subjected to about 300 hr of U.S. Army laboratory and field testing. It has also completed more than 250 hr of flight testing at the U.S. Army's Yuma, AZ proving grounds and operational testing at Fort Hunter, Liggett, CA. The helicopter on which it is installed is expected to become operational by mid-1986.

A tentative redesign of the original monolithic support structure has subsequently been made to reduce cost. This redesign was a joint effort of McDonnell Douglas Astronautics, Brush Wellman and Speedring. The new design provides for fabricating the part as a brazed assembly of independently machined subparts. The subparts would be made from hot, isostatically pressed, near net shape billets made from impact-ground pure beryllium powder. (The processes and techniques for the near net shape billets were developed by Brush Wellman; the brazing process by Speedring.)

The near net shape billets would reduce material costs by an impressive 40%. This reduction in material costs reflects reductions in the amount of material to be machined away, so the amount and complexity of the required machining required is also reduced. Overall costs will be reduced by 50% while allowing increased production rates without increase in equipment or machine shop personnel. They will also provide for a reduction in the possibility for raw material loss in the high risk machining process and a shortening of manufacturing lead time. The major disadvantage will be a very small increase in weight of the part.

The development of the pure beryllium support structure has provided a solution to an extremely difficult aeronautical engineering problem associated with the new helicopter and its sighting system. In doing this, it has also added to the technical data concerning performance of beryllium, and increased the fabricating technology available for its use. It has thus helped pave the way for use of this ultra-high performance metal in the solution of other difficult design problems.

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