NATIONAL BUREAU OF STANDARDS REPORT

9947

FAILED MCCAULEY PROPELLER HUB

To

Bureau of Aviation Safety
National Transportation Safety Board
Department of Transportation
Washington, D. C.

NBS

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

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The National Bureau of Standards[1] was established by an act of Congress March 3, 1901. Today, in addition to serving as the Nation's central measurement laboratory, the Bureau is a principal focal point in the Federal Government for assuring maximum application of the physical and engineering sciences to the advancement of technology in industry and commerce. To this end the Bureau conducts research and provides central national services in three broad program areas and provides central national services in a fourth. These are: (1) basic measurements and standards, (2) materials measurements and standards, (3) technological measurements and standards, and (4) transfer of technology.

The Bureau comprises the Institute for Basic Standards, the Institute for Materials Research, the Institute for Applied Technology, and the Center for Radiation Research.

THE INSTITUTE FOR BASIC STANDARDS provides the central basis within the United States of a complete and consistent system of physical measurement, coordinates that system with the measurement systems of other nations, and furnishes essential services leading to accurate and uniform physical measurements throughout the Nation's scientific community, industry, and commerce. The Institute consists of an Office of Standard Reference Data and a group of divisions organized by the following areas of science and engineering:

Applied Mathematics—Electricity—Metrology—Mechanics—Heat—Atomic Physics—Cryogenics[2]—Radio Physics[2]—Radio Engineering[2]—Astrophysics[2]—Time and Frequency.[2]

THE INSTITUTE FOR MATERIALS RESEARCH conducts materials research leading to methods, standards of measurement, and data needed by industry, commerce, educational institutions, and government. The Institute also provides advisory and research services to other government agencies. The Institute consists of an Office of Standard Reference Materials and a group of divisions organized by the following areas of materials research:

Analytical Chemistry—Polymers—Metallurgy — Inorganic Materials — Physical Chemistry.

THE INSTITUTE FOR APPLIED TECHNOLOGY provides for the creation of appropriate opportunities for the use and application of technology within the Federal Government and within the civilian sector of American industry. The primary functions of the Institute may be broadly classified as programs relating to technological measurements and standards and techniques for the transfer of technology. The Institute consists of a Clearinghouse for Scientific and Technical Information,[3] a Center for Computer Sciences and Technology, and a group of technical divisions and offices organized by the following fields of technology:

Building Research—Electronic Instrumentation — Technical Analysis — Product Evaluation—Invention and Innovation— Weights and Measures — Engineering Standards—Vehicle Systems Research.

THE CENTER FOR RADIATION RESEARCH engages in research, measurement, and application of radiation to the solution of Bureau mission problems and the problems of other agencies and institutions. The Center for Radiation Research consists of the following divisions:

Reactor Radiation—Linac Radiation—Applied Radiation—Nuclear Radiation.

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[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D. C. 20234.
[2] Located at Boulder, Colorado 80302.
[3] Located at 5285 Port Royal Road, Springfield, Virginia 22151.

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By

T. R. Shives
Engineering Metallurgy Section
Metallurgy Division

To

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Hardness: A diamond pyramid hardness traverse was made on a transverse section through the failed hub socket near the crack origin. These values and the approximate Brinell equivalents are given below:

Distance from edge of section adjacent to threads	$DPH_{10\ kg}$	Approx. $BHN_{500\ kg}$
1 mm	162	140
2	160	138
3	161	139
5	162	140
7	163	141
9	168	144
11	168	144
12	168	144
13	167	143

The hardness is relatively uniform and in all cases is well above the minimum Brinell hardness of $125_{500\ kg}$ for aluminum alloy 2014-T6 as specified in ASTM Specification B247-67.

The blade retention nut was specified to be aluminum alloy 7075 in the T-6 condition. Brinell hardness measurements as follows were taken on the back of the nut:

Measurement	$BHN_{500\ kg}$
1	137
2	143
3	140
4	143
5	144
6	143

All measurements were above the minimum Brinell hardness of $135_{500\ kg}$ as specified in ASTM Specification B247-67.

Metallographic Examination: The fracture originated at a fatigue crack near the root of the innermost thread in blade socket No. 2 and extended across the socket (fig. 1). The fracture surface is shown in figures 3 and 4. The fracture was sectioned adjacent to the fatigue crack origin and examined metallographically. Figure 5 shows a representative area of the material in the unetched condition near the crack origin. The material is clean and shows little or no porosity. Figures 6 and 7 show

the microstructure of the hub socket adjacent to the crack origin and away from the origin, respectively. There appears to be nothing abnormal or detrimental in the 2014-T6 heat treated structure shown. The smaller grain size observed immediately adjacent to the fracture origin may have resulted from relatively faster cooling after forging in this area. No unusual material condition that may have contributed to crack initiation was found at the origin.

Thread Examination: There was a good deal of fretting in the threads of all three blade sockets as well as in the threads of the retention nut from socket No. 2 (figs. 8 and 9). (The other two retention nuts were not available for examination.) Fretting occurred adjacent to, but not directly at the fatigue crack origin.

The Engineering Metrology Section of the National Bureau of Standards made measurements of the minor diameter and the thread depth of the threads on the retention nut and the threads of one of the intact blade sockets (socket No. 3).

The minor diameter of the socket was measured at three places in each of two planes: the 0° plane which is parallel to the drive shaft, and the 90° plane which is in the plane of the blades. These measurements are as follows:

Location	Minor diameter, 0° plane	Minor diameter, 90° plane
Entering end	5.251 in	5.238 in
Center	5.252	5.240
Back	5.254	5.232

The permissible range for the minor diameter as calculated from specifications on drawing No. E-3497 (Propeller hub) of McCauley Industrial Corporation is as follows:

Minimum diameter	5.2294 in
Maximum diameter	5.2350 in

All but one of the six measurements were greater than that allowed indicating that the over-all minor diameter of socket No. 3 was too great. No meaningful data could be obtained on the minor diameter of the failed socket, No. 2.

The thread depth in socket No. 3 was determined to be 0.0947 in. The tolerances specified by McCauley drawing E-3497 are 0.0966 to 0.0930 in. The thread depth, therefore, meets specifications.

The retention nut pitch diameter projected to the reference plane (0.087 in below nut face) is 5.320 in with the tolerances being 5.324 to 5.322 in (McCauley drawing C-3493; nut, blade retention). The thread depth measured 0.0966 in with tolerances being 0.0966 to 0.0930 in. The thread depth on the nut meets specifications, and while the minor diameter measured slightly less than specifications, the measured value does not differ sufficiently from specifications to be considered significant.

The threads over a large portion of the blade retention nut were rather badly damaged. Figure 10 shows the thread profile in a damaged area as well as in an area where the threads are intact. The thread profile appears satisfactory in the undamaged area.

The threads of the failed hub socket were also damaged badly as is shown by the profile of two threads adjacent to the fracture (fig. 11a). Figure 11b shows the thread profile of socket No. 1 which was not damaged and the threads appear to be satisfactory. In figure 12, the thread nearest to the fracture is shown at a higher magnification. The material has been deeply etched to show flow. The top of the thread has been severely deformed. Other damaged threads exhibited deformation of this nature.

<u>Conclusions</u>: The material in the hub meets specifications for chemical composition of aluminum alloy 2014 and it also meets hardness specifications for the T-6 condition. The blade retention nut meets hardness specifications for aluminum alloy 7075-T6. The microstructure of the hub material appears to be satisfactory. Examination of the thread profile of undamaged threads of both the hub and retention nut indicate that the threads are satisfactory. It is the opinion of this investigator that the hub and nut damage (deformation) observed occurred subsequent to failure, and therefore did not contribute to the fracture.

The oversize minor diameter found in measuring socket No. 3 indicates a possible mismatch between this socket and its related retention nut. It is conceivable that the mismatch is responsible for the fretting observed in the threads of socket No. 3. Inasmuch as fretting was also observed in the threads of sockets No. 1 and No. 2, it would seem that a mismatch condition was also present in these sockets.

Fretting is indicative of cyclic stressing and it is possible that this stressing could have initiated the fatigue crack that propagated to cause the failure of the hub in socket No. 2. Fatigue cracks may be associated with fretting, and their origins, as in this case, are sometimes found not directly in a fretted area, but adjacent to it.

Blade Socket No. 2

Blade Socket No. 1

Blade Socket No. 3

Figure 1. McCauley Propeller Hub as received. Arrow on photograph points to approximate location of fracture origin on inside of hub. X 3/8

Figure 2. Blade retention nut from blade socket No. 2 as received. X 2/3

Figure 3. Fracture surface of failed hub socket, No. 2. X 1

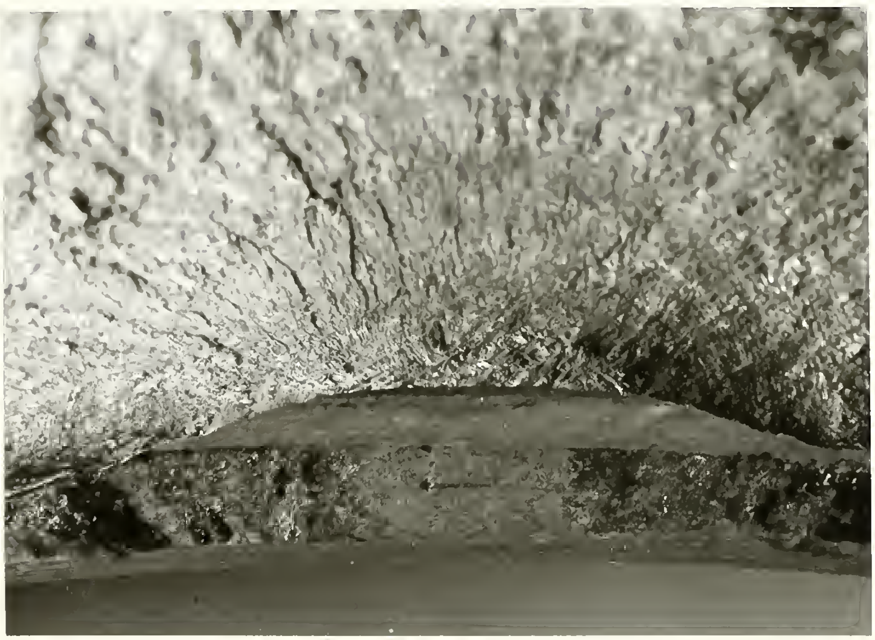

Figure 4. Origin of fatigue crack in failed hub socket, No. 2. X 10

Figure 5. Representative longitudinal area adjacent to origin of fracture. Unetched. X 100

Figure 6. Longitudinal microstructure immediately adjacent to origin of fracture. Keller's etch. X 100

Figure 7. Microstructure of longitudinal section away from fracture. Keller's etch. X 100

Figure 8. Threads of failed hub socket showing fretting. X 2

Figure 9. Threads of blade retention nut showing fretting. X 2

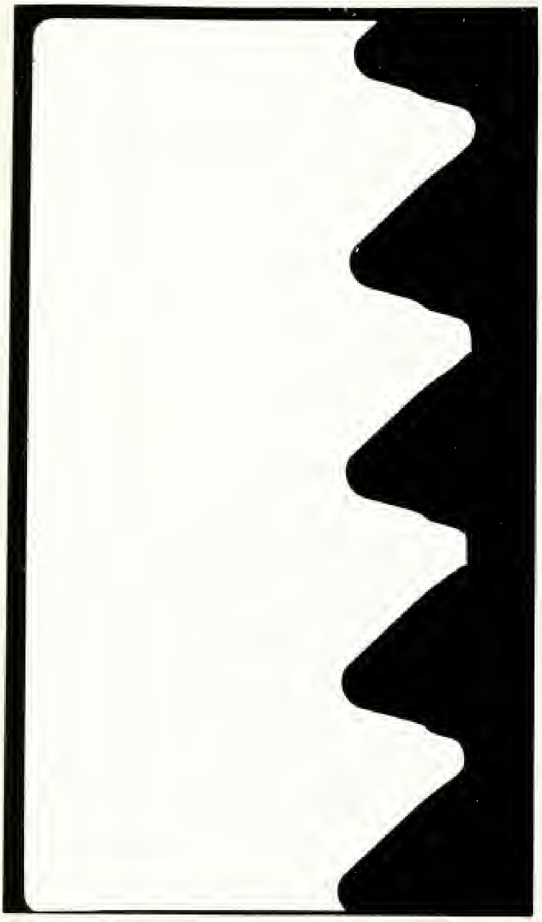

Figure 10a. Thread profile of damaged threads of blade retention nut. X 7

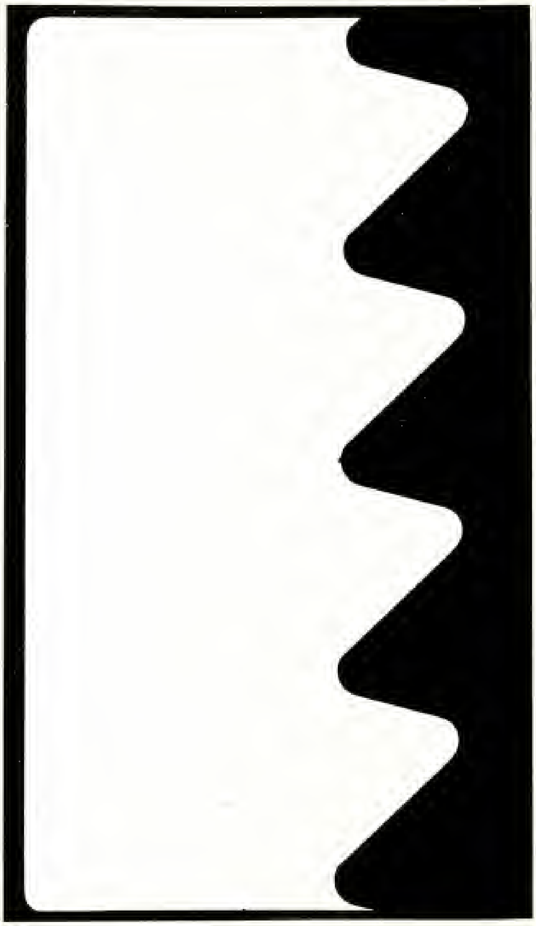

Figure 10b. Thread profile of undamaged threads of blade retention nut. X 7

Figure 11a. Thread profile of hub socket No. 2 showing two damaged threads adjacent to fracture. X 18

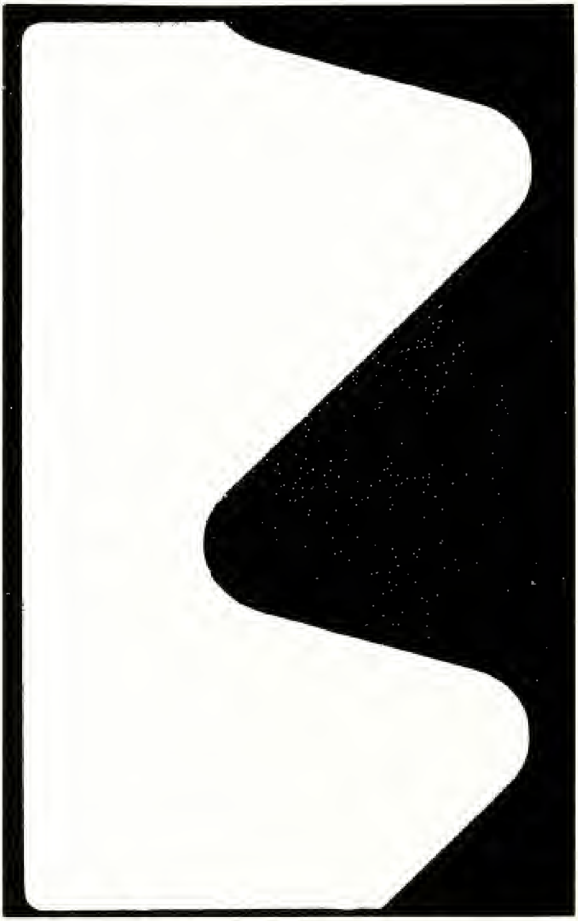

Figure 11b. Thread profile of hub socket No. 1 showing undamaged threads. X 18

Figure 12. Thread adjacent to fracture in hub socket No. 2 showing deformation. Keller's etch. X 200

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