NBSIR 74-441

Fractographic Examination of Failed Helicopter Tail Rotor Hub Yoke

T. Robert Shives

Mechanical Properties Section
Metallurgy Division
Institute for Materials Research
National Bureau of Standards
Washington, D. C. 20234

January 1974

Failure Analysis Report

Prepared for
Bureau of Aviation Safety
National Transportation Safety Board
Department of Transportation
Washington, D. C. 20591

NBSIR 74-441

FRACTOGRAPHIC EXAMINATION OF FAILED HELICOPTER TAIL ROTOR HUB YOKE

T. Robert Shives

Mechanical Properties Section
Metallurgy Division
Institute for Materials Research
National Bureau of Standards
Washington, D. C. 20234

January 1974

Failure Analysis Report

Prepared for
Bureau of Aviation Safety
National Transportation Safety Board
Department of Transportation
Washington, D. C. 20591

U. S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary

NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

Fractographic Examination of Failed Helicopter Tail Rotor Hub Yoke

Reference: Bureau of Aviation Safety, National Transportation Safety Board, Department of Transportation, Washington, D. C. Request by Mr. Michael L. Marx, dated August 29, 1973.

Accident Information: Brantly Helicopter Model 305, registration number N2203V. The accident occurred on May 22, 1973, in Denver, Colorado.

Part Submitted: One fractured tail rotor hub yoke as shown in figure 1.

Purpose: The Bureau of Aviation Safety requested a fractographic examination of the failed yoke in order to determine the mode of fracture.

Results of Examinations: Visual and macroscopic examinations of the fracture surface indicated that two crack fronts had formed, and had originated almost diametrically opposite each other at the outside surface of the yoke. "Ratchet marks" on the fracture surface indicated that each crack front had formed by the joining of several separate cracks. The general regions of crack initiation are indicated by A and B in figure 2, which shows one of the fracture faces. The crack front originating in region A propagated slowly to a depth of about one millimeter, while the one originating in region B propagated slowly to a much greater depth before final rapid failure occurred in region C (figure 2).

Examination of the fracture surface with the scanning electron microscope revealed strong evidence of fatigue striations in one area of the fracture crack originating in region B. An example is shown in figure 3. Other evidence of fatigue striations, although not as strong as that shown in figure 3, was found in other areas of the fracture crack originating in region B. Examples are shown in figures 4 and 5.

Weak evidence of fatigue striations was found in areas of the fracture crack originating in region A, an example of which is shown in figure 6. Several large inclusions were found on the fracture surface near region A, but none of those observed appeared to be associated with a crack origin. One such inclusion is shown in figure 7.

Figures 8 and 9 show areas in the final fracture region (region C, figure 2). The principal fracture feature is dimpled rupture, but there appears to be a significant amount of porosity. There also appears to be a number of "holes" where inclusions may have been.

Discussion and Conclusions: This tail rotor hub yoke appears to have failed due to the propagation of two almost diametrically opposed crack fronts to sufficient depths so that the reduced cross section of the part could no longer sustain the applied load, resulting in final fracture due to overload. There is evidence that the deeper crack front propagated in fatigue, and, while the evidence is less strong, the shallower crack probably also propagated in fatigue. A number of large inclusions were found on the fracture surface, but none of these appeared to be associated with a crack initiation site. A significant amount of porosity was evident, particularly in the overload region of the fracture.

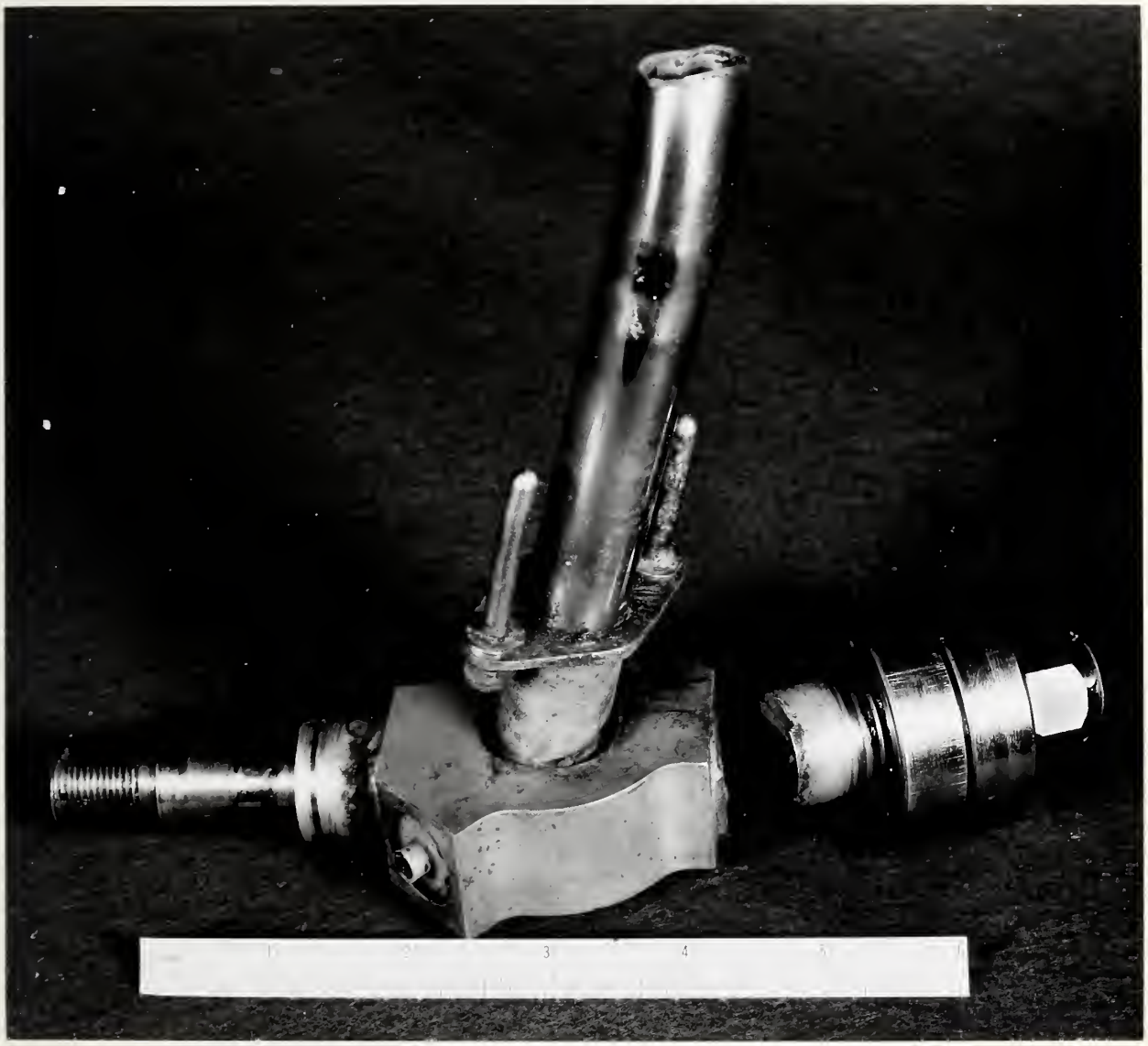

Figure 1. Tail rotor hub yoke as received.

Figure 2. One of the fracture faces. A and B are regions of crack initiation. C is region of overload. X 4

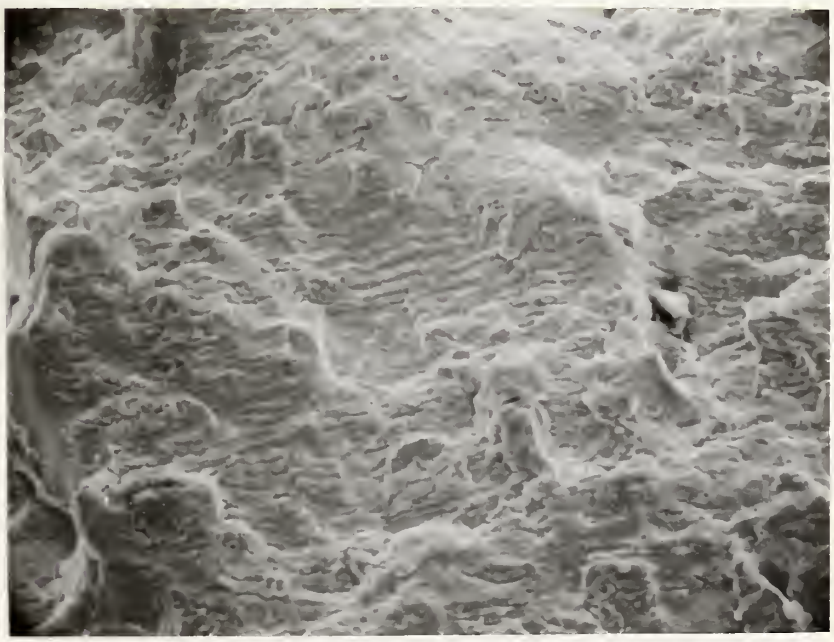

Figure 3. Scanning electron photomicrograph showing strong evidence of fatigue striations on the fracture crack initiating in region B. X 1000

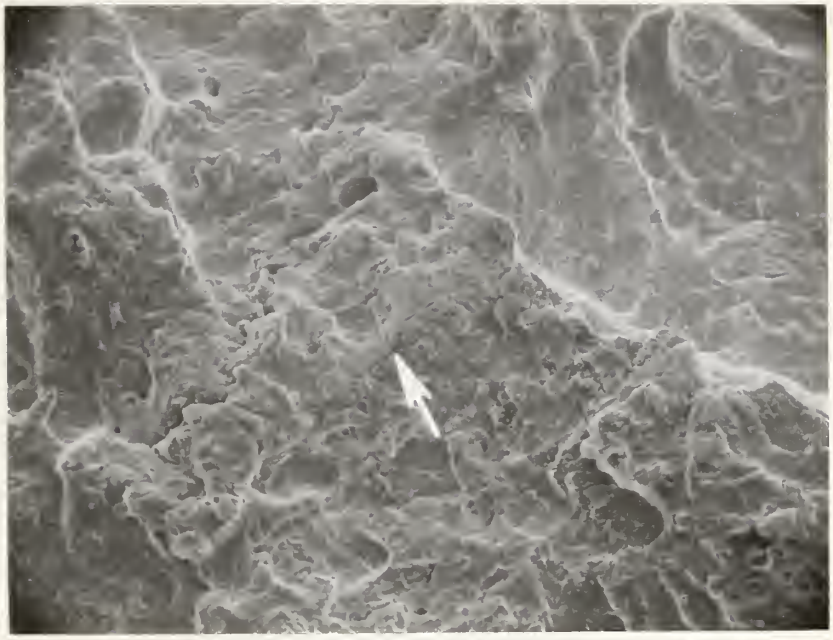

Figure 4. Scanning electron photomicrograph showing evidence of fatigue striations (arrow) on the fracture crack initiating in region B. X 475

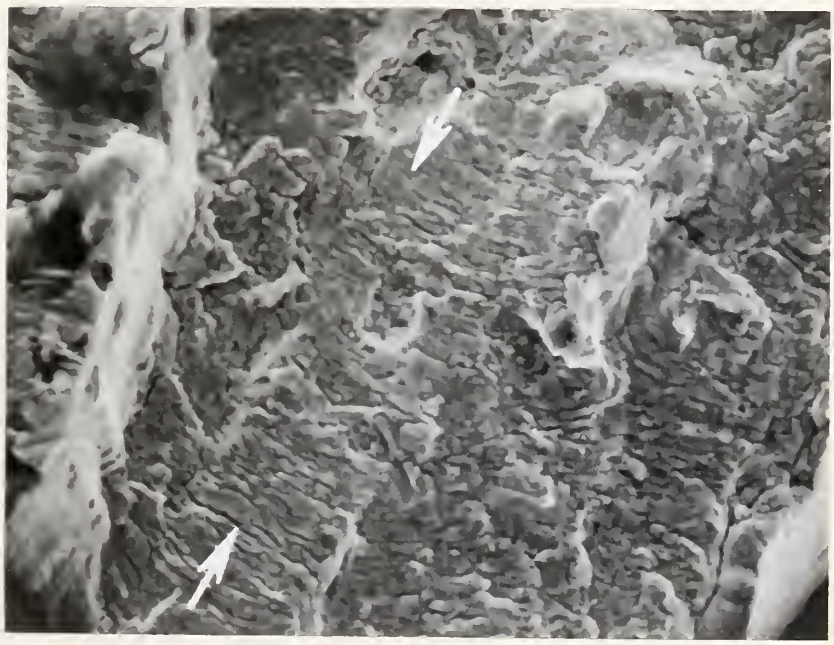

Figure 5. Scanning electron photomicrograph showing evidence of fatigue striations (arrows) on the fracture crack initiating in region B. X 1800

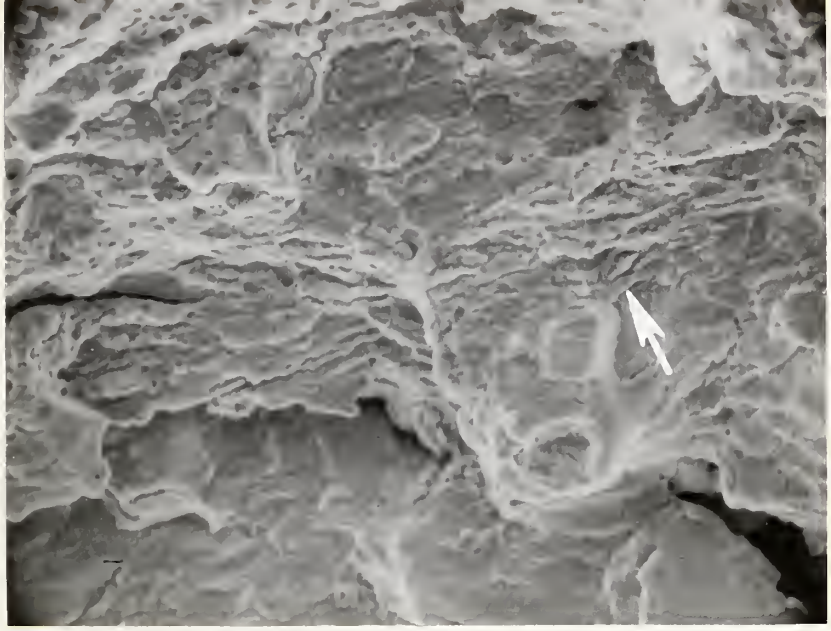

Figure 6. Scanning electron photomicrograph showing weak evidence of fatigue striations (arrow) on the fracture crack initiating in region A. X 1100

Figure 7. Scanning electron photomicrograph showing large inclusion on the fracture surface near region A. X 1100

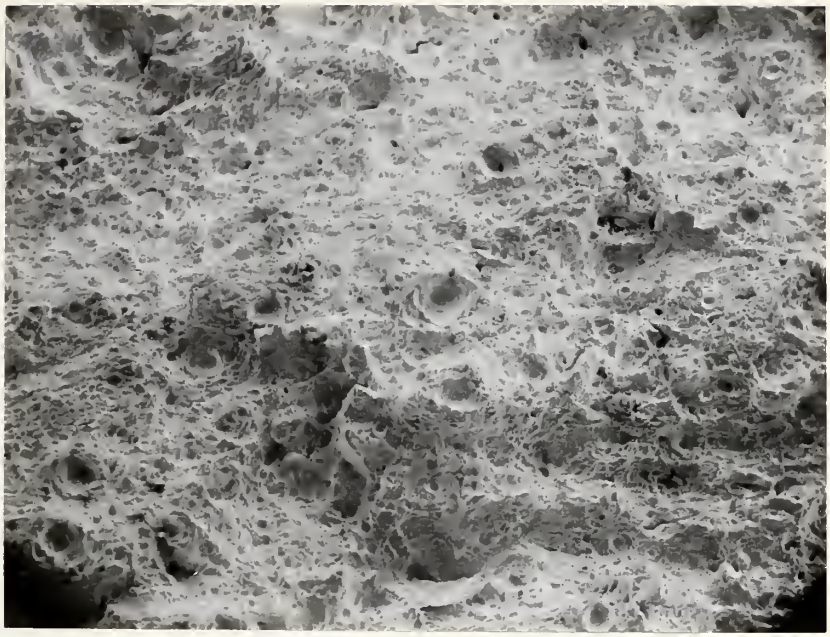

Figure 8. Scanning electron photomicrograph of overload area of the fracture showing porosity and "holes" where inclusions may have been. Dimpled rupture is the primary fracture feature. X 100

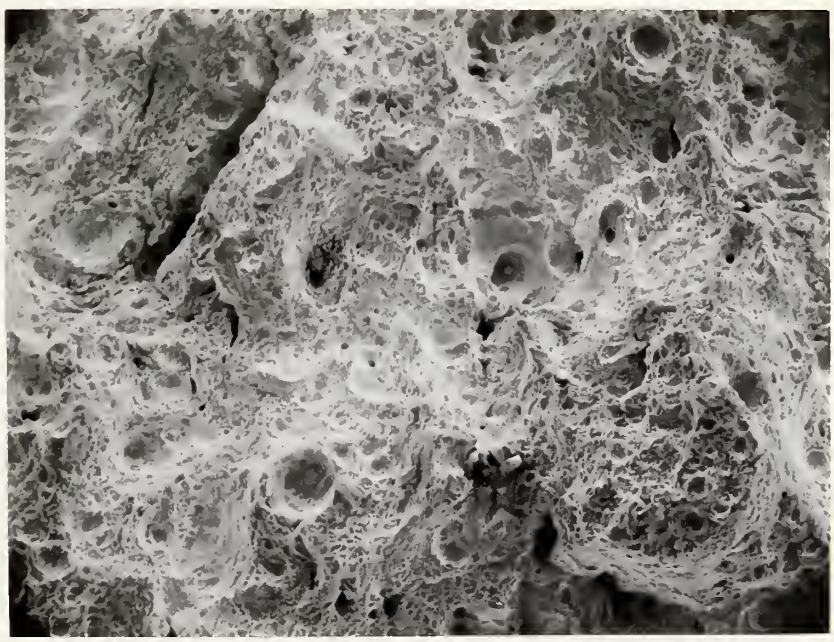

Figure 9. Scanning electron photomicrograph of overload area of the fracture showing porosity and "holes" where inclusions may have been. Dimpled rupture is the primary fracture feature. X 200

NBS-114A (REV. 7-73)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBSIR 74-441	2. Gov't Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE

FRACTOGRAPHIC EXAMINATION OF FAILED HELICOPTER TAIL ROTOR HUB YOKE

5. Publication Date: January, 1974

6. Performing Organization Code

7. AUTHOR(S)
T. Robert Shives

8. Performing Organ. Report No. NBSIR 74-441

9. PERFORMING ORGANIZATION NAME AND ADDRESS

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

10. Project Task Work Unit No. 3120412

11. Contract Grant No.

12. Sponsoring Organization Name and Complete Address (Street, City, State, ZIP)

Bureau of Aviation Safety
National Transportation Safety Board
Department of Transportation
Washington, D. C. 20591

13. Type of Report & Period Covered: Failure Analysis Report

14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

A fractographic examination of a failed helicopter tail rotor hub yoke revealed that apparent fatigue crack fronts had initiated at the surface of the yoke at two nearly diametrically opposed regions. These crack fronts propagated until the cross section of the part was reduced sufficiently so that it could no longer sustain the load to which it was subjected and final failure occurred due to ductile overload. Some large inclusions, none of which appeared to be associated with a crack origin, were found on the fracture surface. Porosity was also found on the fracture surface.

17. KEY WORDS (six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)

Dimpled rupture, fatigue crack, fractographic examination, metal fatigue, striaticns.

18. AVAILABILITY

___ Unlimited

X For Official Distribution. Do Not Release to NTIS

Order From Sup. of Doc., U.S. Government Printing Office Washington, D.C. 20402, SD Cat. No. C13

Order From National Technical Information Service (NTIS) Springfield, Virginia 22151

19. SECURITY CLASS (THIS REPORT)	21. NO. OF PAGES
UNCLASSIFIED	9
20. SECURITY CLASS (THIS PAGE)	22. Price
UNCLASSIFIED	

USCOMM-DC 29042-P74