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OTTAWA July 19th, 1943.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1451.

Examination of a Broken Spider Arm taken from a Hamilton Standard Propeller, Type 12D40-211, Serial No. 76762.

(Copy No. 10.)

Bureau of Mines
Division of Metallic
Minerals
-
Ore Dressing
and Metallurgical
Laboratories

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

O T T A W A July 19th, 1943.

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Source of Material and Object of Investigation:

On June 30th, 1943, Flt./Sgt. E. J. Cassidy, Resident Inspector, Trans-Canada Air Lines, Winnipeg, Manitoba, sent in a broken spider arm taken from a Hamilton Standard Propeller, type 12D40, Serial No. 76762.

On July 10th, in a letter (File No. 902-69-8, AMAE DAI) written for Chief of the Air Staff, Department of National Defence for Air, Ottawa, Ontario, W/C A. J. Smith stated that it was reported that when the propeller was dismantled the spider was found to be almost completely cracked through and as soon as the barrel was removed, it had completely separated. A full metallurgical examination of the broken part was requested, in order to determine, if possible, the cause of failure.

Macro-Examination:

Figure 1 is a photograph showing the broken spider as received at these Laboratories.

Figure 1.

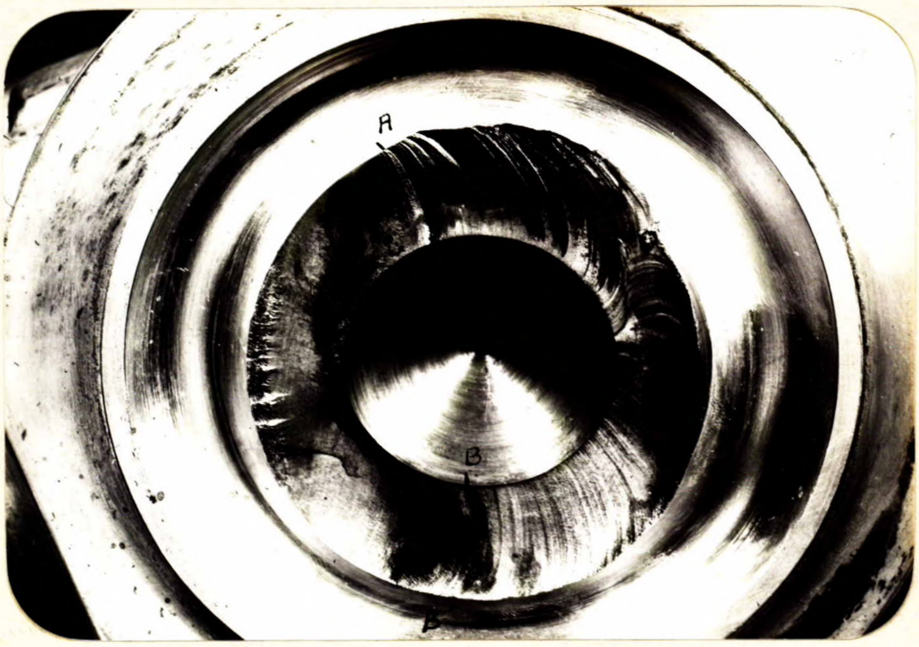
BROKEN SPIDER AS RECEIVED.
(Approximately 1/3 actual size).

The fracture was of the duplex type. In Figure 2, the break is seen to show concentric circles originating from lines marked AA and BB. In Figure 3, a fairly sharp tool mark may be observed at "A". Another sharp tool mark can also be seen (see "B" on Figure 4) on the opposite inner side of the shaft, about a quarter of an inch from the fracture.

(See Figures 2, 3, and 4 on next page.)

(Macro-Examination, cont'd) -

Figure 2.

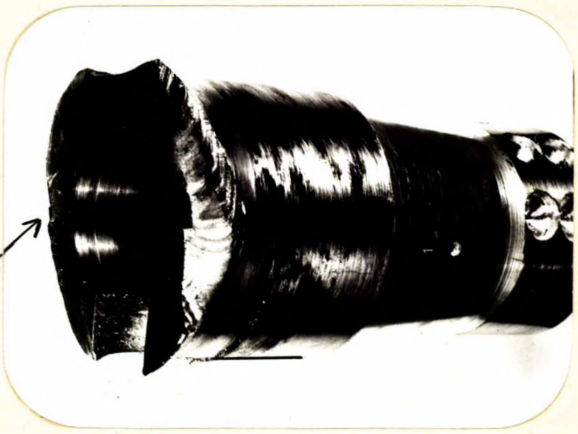


(Approximately twice actual size).

Figure 3.

(Approximately ½ size).

Figure 4.



(Approximately ½ size).

PHOTOGRAPHS OF FRACTURE.

(Continued on next page)

(Macro-Examination, cont'd) -

Figure 5 shows a section of the spider which was given a macro etch, at 160° to 180° F. for 1½ hours, in a solution of 50 per cent HCl in water. It will be observed that the flow lines cut into the fracture which occurred along AB.

Figure 5.

SECTION OF SPIDER, MACRO-ETCHED.
(Approximately 1/3 actual size).

Chemical Analysis:

The steel was found to have the following composition:

		Per cent
Carbon	-	0.42
Manganese	-	0.74
Silicon	-	0.28
Phosphorus	-	0.015
Sulphur	-	0..018
Nickel	-	1.74
Chromium	-	0.80
Molybdenum	-	0.20
Vanadium	-	None detected.

Physical Tests:

Tensile, Izod, and hardness tests were carried out on test specimens machined from the forging. The following

(Physical Tests, cont'd) -

results were obtained:

Ultimate strength, p.s.i.	-	203,500
0.2 per cent proof strength, p.s.i.	-	198,400
Elongation, per cent in 1 inch*	-	6.0
Reduction in area, per cent	-	19.3
Brinell hardness	-	415
Diameter of test bar, in inches	-	0.282
Izod impact strength, foot pounds	-	10, 10, 10

(* Broke outside of gauge mark.)

A piece of steel, quenched in oil from 1525° F., drawn at 800° F., and quenched from the draw, was found to have an impact strength of 11 foot pounds.

Microscopic Examination:

A section of the steel was cut from the broken shaft at the point of fracture, mounted in bakelite, polished, and then examined under the microscope in the unetched condition. The steel was found to be fairly clean. The specimen was next etched in a solution of 4 per cent picric acid in alcohol and re-examined. Figure 6, a photomicrograph at X1000 magnification, shows the etched structure of the steel in the "as received" condition, the structure consisting of drawn martensite. Small areas of ferrite (the white constituent) are interspersed in this matrix. Figure 7 shows the etched structure of the steel after quenching in oil from 1525° F. and drawing at 800° F., the steel being quenched from the draw temperature. It will be observed that the free ferrite has been eliminated.

(Continued on next page)

(Microscopic Examination, cont'd) -

Figure 6.

X1000, picral etch.
STEEL IN THE "AS RECEIVED" CONDITION.

Figure 7.

X1000, picral etch.
CONDITION OF
STEEL AFTER HEAT TREATMENT.

Discussion of Results:

With the exception of the molybdenum content, the composition of the steel is within the limits specified for SAE 4340 steel. The molybdenum required by the SAE specification for this steel is 0.30 to 0.40 per cent. The lower molybdenum content may result in a tendency to temper brittleness; consequently, the steel examined should be quenched after the drawing operation. SAE Steel 4340 is regularly specified for this type of part and is an excellent general utility, tough strength alloy.

The fracture definitely is of the fatigue type. As surfaces always are weaker, the probability is, then, that failure originated from the two points AA and BB. However, it is not possible to say whether the fracture started from the outside or from the inside surface. In the absence or equality of stress raisers one would expect the former to be the case, as the outer fibres would be more heavily stressed. Shot-blasting of the spider would definitely improve its resistance to alternating stresses, as it would ensure a much better stress distribution.

The flow lines in the forging do not parallel the surface at the point of fracture. Fatigue life would have been improved had they done so, but in forgings of this type perfection in flow lines at all sections is not to be expected. The fatigue, therefore, is not attributed to poor forging practice. However, the deep tool marks shown in the inside surface would most certainly have acted as stress raisers, especially in such a hard material as the steel under examination, and may possibly have contributed to failure.

The ultimate strength, 0.2 per cent proof stress, and hardness values obtained from this steel are those that

(Discussion of Results, cont'd) -

would be expected after a quench in oil from about 1525° F. and a draw around 800°°F. The elongation and reduction of area are low for a steel of this composition and the postulated heat treatment, the first because the test specimen broke badly, the second probably because of the small-sized test specimen. The Izod values are also low. This is not due to temper brittleness, as a steel quenched from the draw had similar low impact properties.

The free ferrite revealed by the microscopic examination of the "as received" material is of the type that precipitates when the cooling rate is just under the critical value. This investigation shows that this free ferrite can be eliminated by a standard oil-quenching procedure. The free ferrite present would probably have an unfavourable effect on both the fatigue and the impact strengths.

Conclusions:

1. The composition of the steel used and the forging are considered as satisfactory.

2. The break was a characteristic fatigue fracture of the duplex type.

3. Rough machine grooves were found to be present in the broken forging shaft. These may have contributed to the failure.

4. The steel was not properly heat-treated.

Recommendations:

1. Machine practice should be checked, so as to eliminate deep tool marks.

2. The part should be shot-blasted.

3. The quenching rate should be increased in order that a uniform structure may be obtained.

NBB:PES.

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