OTTAWA June 21st, 1943.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1434.

Examination of a Pitted Hoover Airscrew Blade.

(Copy No. 13.)

Bureau of Mines
Division of Metallic
Minerals
-
Physical Metallurgy
Research Laboratories

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
Mines and Geology Branch

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Origin of Problem and Object of Investigation:

In a letter (File No. 902-5-1(AMAE-DAI)) dated May 31st, 1943, Air Commodore A. L. Johnson, for Chief of the Air Staff, Department of National Defence, Air Service, Ottawa, Ontario, requested the examination of Hoover Airscrew Blade No. 1185, which showed two areas of surface pitting.

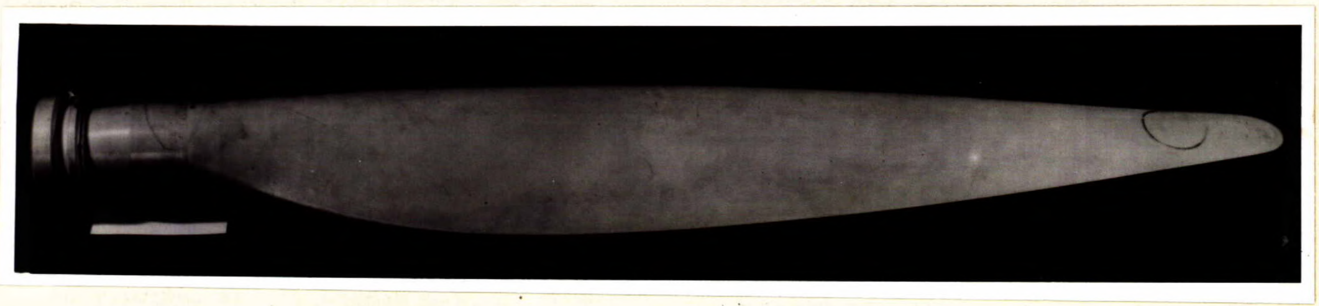
It was requested that the nature of this pitting be determined in order to confirm whether this condition is indicative of more serious defects in the material. It was also stated that similar surface defects were found on some other blades, which were being quarantined pending the results of this examination.

1434
4cc.
J. W.M.

Description of Sample:

Figure 1 shows the airscrew blade as submitted. The areas of surface pits are marked, one on the tip and one on the shank of the blade.

Figure 1.



AIRSCREW BLADE AS SUBMITTED.

(Approximately 1/8 size).

Figure 2 shows the appearance of the pitted area on the shank of the blade.

Figure 2.

SURFACE PITS ON SHANK PART OF THE BLADE.

(Approximately 1/2 size).

Chemical Analysis:

		Per cent
Copper	-	4.45
Manganese	-	0.74
Iron	-	0.56
Silicon	-	0.39
Titanium	-	0.027
Chromium	-	0.001
Magnesium	-	None detected.
Nickel	-	None detected.
Zinc	-	None detected.

Metallographic Examination:

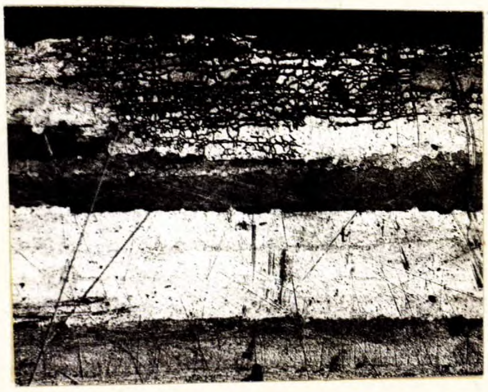
Macroscopic examinations of cross-sections of the blade cut through the pitted areas and etched in Tucker's reagent (15% HF, 45% HCl, 15% HNO_3 + 25% H_2O) showed no signs of any defects in the material.

Microscopic examination showed that the examined surface pits were due to corrosion. Figures 3 to 8 show definitely the intercrystalline character of the corrosion failure.

(Figures 3 to 8 follow,)
(on next page.)

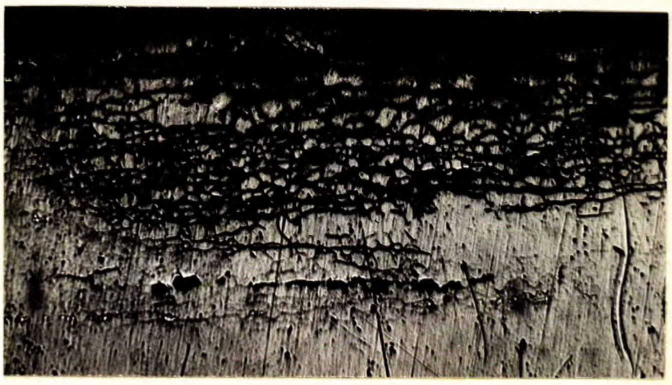
(Metallographic Examination, cont'd) -

Figure 3.



X100, Keller's etch.®

Figure 4.



X200, unetched.

-

Figure 5.

X100, unetched.

Figure 6.

X200, unetched.

-

Figure 7.

X200, unetched.

Figure 8.

X200, unetched.

-

® Keller's etch: 1 per cent HF, 1.5 per cent HCl, 2.5 per cent HNO_3, and 95 per cent H_2O.

Discussion of Results:

Chemical analysis showed that the propeller blade was made from 25ST aluminium alloy.

Macroscopic examination proved that the material showed no segregations, inclusions, or other non-uniformity of the material.

Microscopic examination shows that the surface pits are due to intercrystalline corrosion attack. This type of corrosion is a most dangerous one, because the surface pits are mostly very small and therefore difficult to detect, while the corrosion proceeds along the grain boundaries deeply into the material.

Intercrystalline (or intergranular) corrosion causes a gradual loosening of the grains on dissolution of the intercrystalline matter. This fistular granulation of the material below the surface causes considerable reduction of mechanical properties, especially of the fatigue strength, and after sufficient progress of the corrosive attack the material suddenly breaks.

Intercrystalline corrosion occurs usually after quenching at too low temperatures which are just sufficient to start visible precipitation. These initial precipitates are generally located in the grain boundaries, whereas a coarser and more uniform precipitation occurs throughout the crystal grains at higher quenching temperatures.

Some of the age-hardenable aluminium alloys, especially if copper-bearing, may suffer intercrystalline attack in a corrosive environment when in a condition which is characterized by a very fine precipitate in the grain

(Discussion of Results, cont'd) -

boundaries.

It was found* that the susceptibility of duralumin-type alloys to intercrystalline corrosion is purely the result of heat treatment and may be caused by:

a) abnormally large drop in temperature between removal from furnace and quenching;

b) slow quenching speeds, as in hot water or oil; or

c) reheating the solution-treated alloy over 120° C. (248° F.).

Unfortunately, each of these factors is helpful to production methods. b) and c) can be avoided, but a) cannot be entirely eliminated as there is inevitably some delay in moving the metal from the furnace to the quenching tank. The designer of a heat-treatment plant must know the maximum delay permissible in quenching, in order that suitable handling equipment may be installed. Such information is not generally available, however, as the published work on intercrystalline corrosion has been mainly of an academic nature, lacking the positive practical data necessary for the control of industrial heat-treatment operations.

Prolonged exposure tests* showed that light alloys which are susceptible to intercrystalline attack can be adequately protected against mildly corrosive atmospheres by suitable surface treatment, such as anodic oxidation following by painting.

Other investigations** showed that the influence of

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* J. C. Arrowsmith and G. Murray - "The Influence of Delayed Quenching during Solution Heat-Treatment on the Resistance of Duralumin to Intercrystalline Corrosion," - SHEET METAL INDUSTRIES, vol. 16, No. 188 (Dec. 1942), pp. 1879-1884, 1910.

** H. L. Logan - "Effect of Quenching Rate on Susceptibility to Intercrystalline Corrosion of Heat-Treated 24S Aluminum Alloy Sheet," - JOURNAL OF RESEARCH, National Bureau of Standards, vol. 26 (April 1941), pp. 321-329, Research Paper RP1378.

(Discussion of Results, cont'd) -

the quenching rate becomes greater with the increase of the copper content.

The practical conclusion from the above information is that the time interval from the removal of the material from the heating bath or furnace until it is completely immersed in the quenching medium should be as short as possible; in any event, it should not exceed a few seconds.

Once the material is damaged by intercrystalline corrosion it cannot be recovered or protected from further attack.*

CONCLUSIONS:

1. Intercrystalline corrosion attack has pitted the propeller blade.

2. Such intergranular attack occurs as a result of non-optimum heat treatment. With proper heat treatment, corrosion occurs as simple surface pitting, a much less serious condition.

3. Material subject to intergranular corrosion, the most serious type of corrosive action, will always corrode in this fashion. Such corrosion is likely to occur in marine atmospheres unless unusual protection procedures are adopted.

4. The literature indicates that material subjected to intercrystalline attack possibly can be reclaimed by first removing the corroded areas by filing and subsequently putting a heavy protective cover on the material.

It is not thought that this procedure would be

* G. Sachs and K. R. Van Horn, "Practical Metallurgy" -- Published by Amer. Soc. for Metals, Cleveland, Ohio, 1940. Page 108.

(Conclusions, cont'd) -

advisable in the present case. The safer practice would appear to be to scrap the propellers.

5. Every effort should be made to eliminate alkalic corrosive agents, such as cleaning solutions, etc., from the fabrication plant and to maintain closer control on heat-treatment operations.

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JWM:GHB.