File

OTTAWA June 25, 1945.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1895.

Metallurgical Examination of an Aircraft Crankcase Centre Section.

==========

(Copy No. 10.)

Bureau of Mines
Division of Metallic Minerals

Physical Metallurgy Research Laboratories

CANADA

DEPARTMENT OF MINES AND RESOURCES

Mines and Geology Branch

OTTAWA June 25, 1945.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1895.

Metallurgical Examination of an Aircraft Crankcase Centre Section.

==========

Origin of Sample and Object of Investigation:

A Pratt & Whitney aircraft engine crankcase centre section was submitted by Trans-Canada Air Lines, Winnipeg, Manitoba, on April 17, 1945, with a covering letter, File 3810-1, from J. T. Dyment, Engineering Superintendent. The centre section was considered defective because of fine cracks adjacent to the cylinder studs at right angles to the radii of the cylinder pads. The location and length of the cracks were listed in a sheet attached to the letter.

The crankcase centre section was stamped TCA50 15715-1. The cylinder pads were stamped with even numbers 2 to 14 on one side and odd numbers 1 to 13 on the other. The extent of the cracks in the centre section was indicated by centre punch marks.

(Continued on next page)

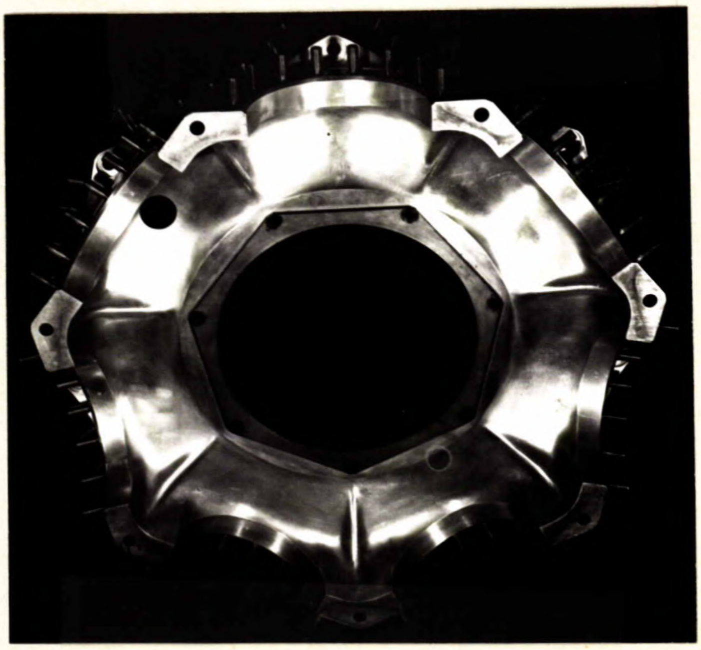
(Origin of Sample and Object of Investigation, cont'd) -

Request was made for a metallurgical investigation to determine:

1. Whether the cracks were caused by defective material.
2. Whether any relationship existed between the length and breadth of the cracks.
3. Whether the cracks would develop rapidly under service stresses.

The crankcase centre section as received is illustrated in Figure 1. The location of the cracks, indicated by punch marks, is shown in Figure 2. Figure 3 is a full-sized view of the crack between cylinder parts 3 and 4.

Figure 1.



PRATT & WHITNEY CRANKCASE CENTRE SECTION, TOP VIEW.

(Approximately 1/6 size).

-

Chemical Analysis:

The chemical analysis of the aluminium alloy, as determined by the Bureau of Mines laboratories, was as follows:

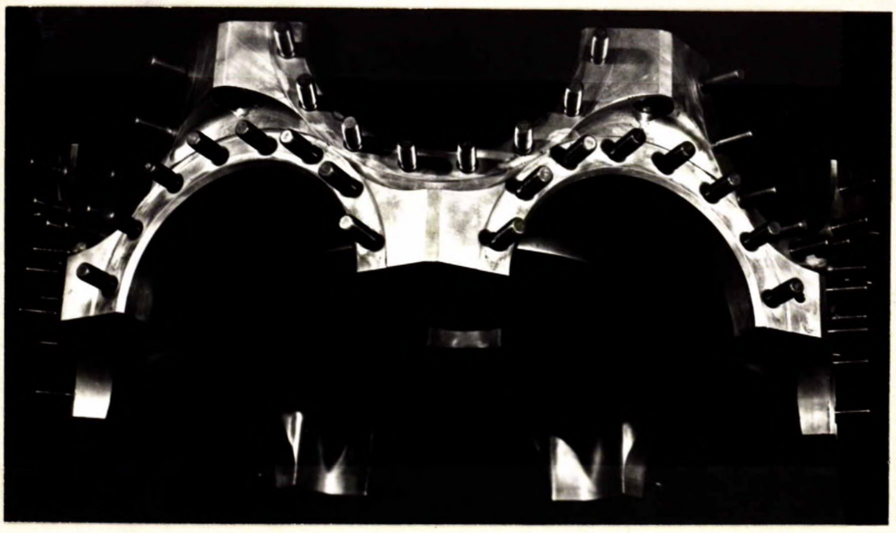
(Continued on next page)

(Chemical Analysis, cont'd) -

Element		Per Cent by Weight	Nominal Composition Alcoa A51S (Ac. 61S)
Copper	-	0.09	
Manganese	-	0.01	
Magnesium	-	0.62	0.6
Silicon	-	0.91	1.0
Iron	-	0.45	
Chromium	-	0.12	0.25
Titanium	-	0.04	
Aluminium	-	Remainder.	Remainder.

The chromium content is very slightly below the specified 0.15 per cent minimum.

Figure 2.



SIDE VIEW OF CRANKCASE CENTRE SECTION, SHOWING LOCATION OF CRACKS.

(Approximately 1/5 actual size).

Mechanical Tests:

Micro test bars (0.160-inch diameter, 0.80-inch gauge

(Continued on next page)

(Mechanical Tests, cont'd) -

length) were cut at various orientations. (Vertical means perpendicular to the parting plane of the forging dies. Transverse means parallel to the parting plane of the forging dies but at right angles to the main radius of the centre section. Longitudinal means parallel to the parting plane of the forging dies and along a main radius.)

The tensile properties as determined by micro test bars were as follows:

		Yield Strength, thousand p.s.i.	Ultimate Strength, thousand p.s.i.	Elongation, per cent
Vertical	1 -	43.5	47.0	18.0
	2 -	45.0	49.0	10.0
Average	-	44.2	48.0	14.0
Transverse	1 -	43.0	47.5	17.0
	2 -	43.0	47.5	12.0
Average	-	43.0	47.5	14.5
Longitudinal	1 -	44.0	47.5	13.0
	2 -	42.5	45.0	16.0
Average	-	43.2	46.2	17.0

The values for one full-sized test bar cut diagonally were:

42.1	44.3	11.0

Typical values for this alloy (Alcoa A51S-T) are:

40.0	47.0	20.0

Figure 3.

CRACKS BETWEEN STUDS
BETWEEN CYLINDERS 3 AND 4.

(Approximately to size).

-

Macrostructure:

The flow lines of the forging as they appear in a radial section are shown in Figure 4. Because of the symmetry of the crankcase centre section, the flow lines are similar in all radial sections. The area in which the cracks occurred is beside the stud on the face machined for the cylinder flange. It can be seen that this is an area of dead flow where the top and bottom flow lines diverge.

Figure 4.

X5/6, Tucker's etch.
GRAIN FLOW IN RADIAL SECTION.

Microstructure:

Sections through a number of the cracks were polished and examined microscopically. Figure 5 illustrates the nature of the cracks. This section was taken from between cylinder pads 4 and 5. This crack is about 3/8 of an inch deep. Figure 6 is a photomicrograph of a shallower crack (1/32-inch deep) between cylinder pads 7 and 8. Figure 7 is a photomicrograph of the same crack as in Figure 6 but at four times the magnification.

(Continued on next page)

(Microstructure, cont'd) -

Figure 7 illustrates the fine size of the constituents but shows the tendency of the cracks to follow the constituents.

Figure 5.

X18, Keller's etch.
DEEP CRACK BETWEEN CYLINDERS 4 AND 5.

Discussion of Results:

The chemical analysis is approximately nominal. The lower chromium content is without effect in this case.

(Continued on next page)

(Discussion of Results, cont'd) -

The tensile properties combine a high yield strength with low elongation. The elongation falls to particularly low values in directions perpendicular to the forging grain flow. The region where the cracks occur has not a favourable grain flow to resist tensile forces between adjacent cylinders.

Figure 6.

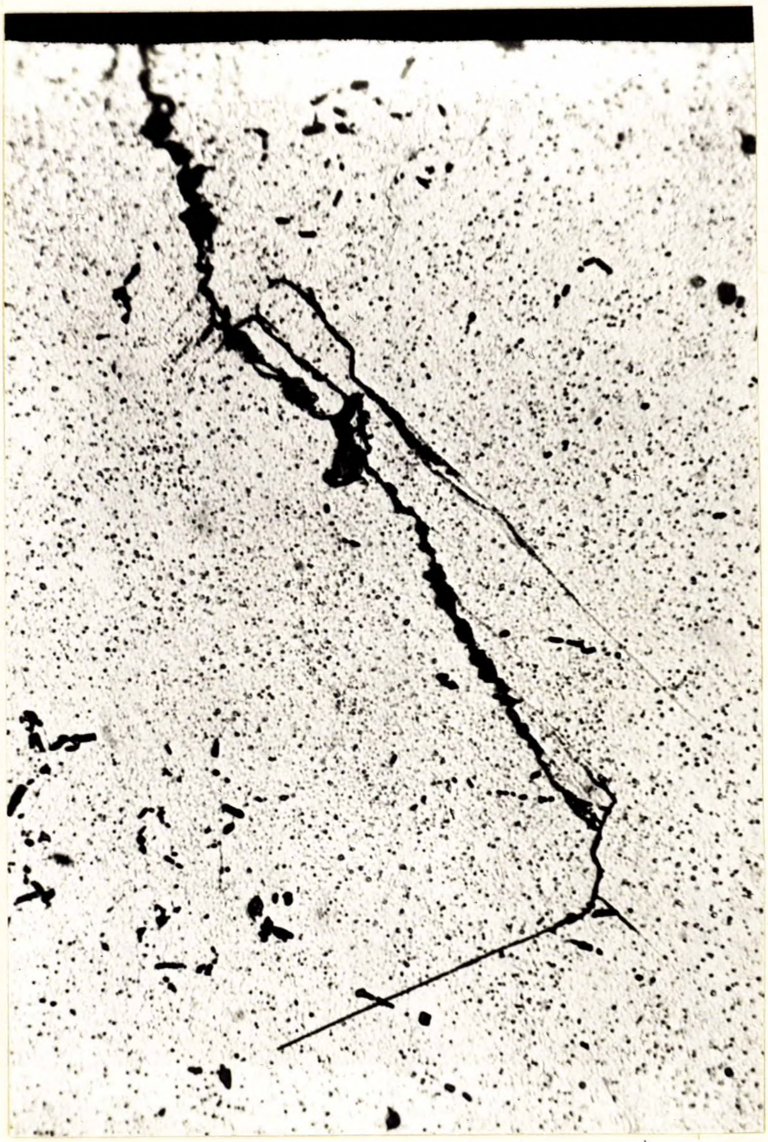
X150, etched in 0.5 per cent hydrofluoric acid.
CRACK BETWEEN CYLINDERS 7 AND 8.

At higher magnifications the cracks were seen to be jagged and perpendicular to the surface; characteristic of

(Discussion of Results, cont'd) -

fatigue cracks. The cracks penetrated to depths of less than one-quarter of the surface length. This lack of penetration would indicate concentration of the stress at the surface of the forging.

Figure 7.



X600, etched in 0.5 per cent hydrofluoric acid.

ENLARGED VIEW OF LOWER PART OF CRACK IN FIGURE 6.

-

The cracks appear to be caused by the following factors, listed in order of importance:

1. Long service life of 4,586 hours. This operating

(Discussion of Results, cont'd) -

time, which is possibly four times the normal, would lead to fatigue failure even with moderate stresses. This service life corresponds to about 250 million complete cycles of stress. Complete fatigue tests are mostly limited to 100 million cycles.

2. Stress concentration caused by the adjacent positions of cylinder hold-down studs for the front and rear rows of cylinders. This condition is illustrated by Figure 3 which shows the short distance between the studs. The geometry of the part, that is, the merging of one cylinder pad face into an adjoining one in the other row, does not appear to have had any effect because the cracks do not follow the demarkation line between the cylinder pad faces.

3. Properties of the material. The mechanical properties are slightly low but not enough to account for any unusual behaviour. The adverse grain flow in the region where cracking occurred brings the properties, particularly the elongation, to the lower end of the range. These can only be considered as subsidiary influences.

Conclusions:

The aircraft engine centre section developed shallow fatigue cracks at locations of stress concentration between adjacent cylinder studs after an extended service life. Redesign of the part to reduce the stress concentrations and substitution of an aluminium alloy of higher fatigue strength would be required if it is contemplated to operate all crankcases for this period.

The material showed no defects which would cause premature failure.

oooooooooo
oooooo
oo

JRS:MC.