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O T T A W A May 26th, 1943.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1417.

Examination of Four Steel Axle Shafts.

(Copy No. 14.)

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

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

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REPORT

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Source of Material and Object of Investigation:

On April 21st, 1943, Dr. C. W. Drury, Director of Metallurgy, Army Engineering Design Branch, Department of Munitions and Supply, Toronto, Ontario, submitted four steel axle shafts for determination of their chemical compositions, physical properties, and microstructure. Two of these, the smaller in diameter, were said to be representative of present production; the two larger-diameter shafts were suggested as replacements, as the smaller shafts were said to be failing in service approximately half an inch outside the side gear. An opinion on the relative properties of the larger and smaller shafts was requested (Requisition No. 520, A.E.D.B. Lot Nos. 307 to 310).

The samples submitted were all new shafts and were tagged as follows:

No.		Size
C19SR 4235	-	1$\frac{3}{4}$"OD x 47" long.
C19SR 4234	-	1$\frac{1}{2}$"OD x 30" long.
C19SR 4234	-	1$\frac{1}{4}$"OD x 27" long.
C19SR 4235	-	1$\frac{1}{4}$"OD x 42" long.

For purposes of identification the above shafts will be referred to herein as Nos. 1, 2, 3 and 4 respectively.

Chemical Analysis:

	PER	CENT							
Shaft	C	Mn	Si	P	S	Cr	Ni	Mo	V
No. 1	0.35	0.66	0.22	0.011	0.012	0.59	1.58	0.28	N.D.
No. 2	0.43	0.69	0.26	0.019	0.012	0.64	1.61	0.29	N.D.
No. 3	0.34	0.62	0.19	0.027	0.017	0.61	1.79	0.32	N.D.
No. 4	0.34	0.62	0.20	0.024	0.018	0.57	1.78	0.32	N.D.

N.D. - None detected.

Heat Treatment and Physical Properties:

According to published charts of the Climax Molybdenum Company, the following physical properties can be reasonably expected for SAE 4340 steel when quenched in oil at 1500 to 1550° F. and drawn at the indicated temperatures:

		800° F.	900° F.	1000° F.
Ultimate stress, p.s.i.	-	218,000	200,000	180,000
Yield " , p.s.i.	-	198,000	180,000	160,000
Reduction in area, per cent	-	49	50	52
Elongation, per cent in 2 inches	-	16	18	19
Brinell hardness	-	420	385	360
Izod impact, ft.lb.	-	20	32	47

The shafts examined had the following physical properties in the "as received" condition:

		No. 1	No. 2	No. 3	No. 4
Ultimate stress, p.s.i.	-	189,500	210,500	214,800	211,500
Yield " , p.s.i.	-	174,000	170,000	199,300	173,300
Reduction in area, per cent	-	54.5	47.5	52.0	54.0
Elongation, per cent in 2 inches	-	8.0@	12.0@	13.5	13.0@
Brinell hardness	-	352	388	415	415
Izod impact, ft.lb.	-	42, 45	20,17,16	13,14,14	15,17,16

@ Broke outside middle third.

Full sections of the shafts were heated up to 1525° F., and after being held at temperature for one hour per inch of cross-section they were quenched in oil, drawn at 1000° F., and

(Heat Treatment and Physical Properties, cont'd) -

again quenched in oil from the draw temperature.

After this heat treatment the steels had the following physical properties:

		No. 1	No. 2	No. 3	No. 4
Ultimate stress, p.s.i.	-	168,000	185,000	169,500	169,750
Yield point, p.s.i.	-	158,750	172,500	160,000	161,000
Reduction in area, per cent	-	58.5	62.5	58.0	58.0
Elongation, per cent in 2 inches	-	17.5	16.0	20.0	18.5
Brinell hardness	-	341	375	341	352
Izod impact, ft.lb.	-	59,60,59	37,35,35	51, 55	42,43,47

Microscopic Examination:

Specimens of each shaft in the "as received" condition were polished and then were examined under the microscope in the unetched condition. The steels were all found to be fairly clean. The steels were then etched in a solution of 4 per cent picric acid in alcohol and re-examined. Figures 1, 2, 3 and 4 are photomicrographs, at X1000 magnification, showing respectively the etched structures of steel shafts Nos. 1, 2, 3 and 4. The structure consists of drawn martensite.

Discussion of Results:

The composition of the four steel shafts was fairly close to the range specified for SAE 4340 steel with the exception of the carbon contents of two of the steel shafts, which were just under the specified limit. All shafts examined had high tensile and fairly low impact properties except Shaft No. 1 which was fairly tough but weaker. The impact strength, of course, could be increased at the expense of the tensile strength by drawing at a higher temperature.

CONCLUSIONS:

Experimental heat treatment tests on the shafts showed that the impact strength of these steels could be increased by a suitable heat treatment. If a lowering of tensile and yield can be tolerated, a marked increase of impact strength can be effected.

Torsion properties are directly relative to tensile properties. In the absence of definite information as to the type of failure, it is difficult to make any set recommendations. However, the SAE 4340 steel used should give good service if the design is satisfactory. If the failure is of the impact type, that is, if the fracture is non-duplex and shows little distortion, the steel should be drawn at a higher temperature and used in the softer, tougher form. If the fracture is duplex (indicating fatigue failure), or if there is marked evidence of distortion (indicating straight failure in tension), a higher-strength material is required. This can be effected by increasing the shaft section or by using a higher strength steel.

In so far as the suggested alternative shaft is concerned, there are, of course, advantages in using a large shafting, if the fracture indicates that failure occurred in torsion. If failure is in fatigue or in impact, this change of design may not be effective and an improvement in steel properties or in stress distribution (such as can be effected by shot blasting) may be necessary. The tests showed that the higher carbon steel in Shaft No. 2 had higher tensile and yield strengths when drawn at the same temperature as the other shafts, although the impact properties were somewhat lower.

However, by heat treatment adjustments, practically similar physical properties can be obtained in the four

(Conclusions, cont'd) -

steels examined. The question of the desirability of the increase in shaft size is, therefore, one of design only. As has been mentioned above, the important point, from the metallurgical standpoint, is whether tensile strength or whether resistance to shock is required. The nature of the failure should indicate the optimum heat treatment.

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Figure 1.

X1000.

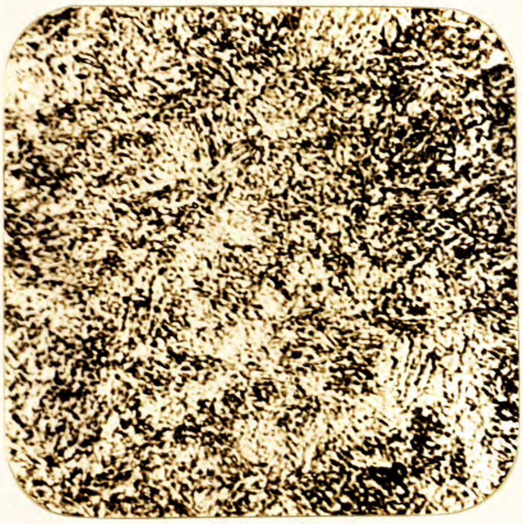
SHAFT NO. 1.

Figure 2.

X1000.

SHAFT NO. 2.

Figure 3.



X1000.

SHAFT NO. 3.

Figure 4.

X1000.

SHAFT NO. 4.

(All specimens etched 4 per cent picral.)

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