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DEPARTMENT OF MINES AND RESOURCES BUREAU OF MINES CANADA

Ottawa, December 11, 1946.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 2151.

The Effect on the Fatigue Resistance of Shot Peening and Superpolishing the Machined Surfaces of SAE 4340 Steel Heat-Treated to C-34 Rockwell.

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Bureau of Mines

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Mineral Dressing and Metallurgy Division

Physical Metallurgy Mines and Geology Branch Research Laberatories

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Introduction:

The investigation was carried out to determine the effect of shot peening and superpolishing on the fatigue resistance of an SAE 4340 steel heat-treated to a hardness of C-34 Rockwell (321 Brinell). Rotating bending Krouse fatigue specimens of normal shape were tested (a) with smooth machine finish; (b) smooth machine finish and superpolished; (c) smooth machine finish, shot peened; (d) smooth machine finish, shot-peened and superpolished.

Material Studied:

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> The steel used in these experiments was Ultimo-4, 5/8-inch-diameter bars made by Atlas Steels Limited, Welland, Ontario. The results of chemical analysis and the specified range for SAE 4340 are given in Table I.

- Page 2 -

TABLE I. - Chemical Analysis.

		Specified, SAE 4340	As Found
		- Per Cent	e2
larbon	en	0.35-0.45	0.41
langanese	~	0.60-0.90	0.77
Silicon	•	0.15-0.30	0.23
Chromium	e.	0.60-0.90	0.56
Vickel	-	1.65-2.00	1.81
Volybdenum	6238	0.20-0.30	0,39

Rotating Bending Fatigue Tests:

The specimens were machined from heat-treated 5/8-inch diameter bars. The effective diameter of the fatigue specimen was 0.175 inch. Four fatigue determinations in all were carried out. The conditions in which the bars were tested are described below:

(a) Normal Krouse 2-inch-long x 0.175-inch diameter specimens (as shown in Figure 2) were prepared with a smooth machine finish. The surface roughness was 0.00025 inch.*

Figure 2.

UNPEENED KROUSE FATIGUE SPECIMEN.

(Approximately 2/3 size.)

(b) The specimens were given a superpolish surface

Note: All surface measurement made with a Brush Surface Analyser.

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- Page 3 -

(Rotating Bending Fatigue Tests, cont'd) -

finish by the following procedure:

i. Remove successive lathe cuts (on the radius) of 20, 10, 7, 4, 3 and 2 mils.

ii. Remove 2 mils by polishing with Armour's abrasive grit #150.

iii. Remove 2 mils by polishing with Behr-Manning emery paper, grit #1.

iv. Polish successively on emery papers Nos. 0, 00, and 000, twice as long as it was necessary to remove the scratches from the preceding paper. The material removed by these fine polishing papers should amount to a total of approximately 0.5 mil. The surface roughness was 0.00004 inch.

(c) The conditions of shot peening are given in Table III. Figure 3 shows a normal Krouse 2-inch x 0.175inch fatigue specimen after shot peening. The surface roughness was 0.00045 inch.

Figure 3.

SHOT-PEENED KROUSE FATIGUE SPECIMEN. (Approximately 2/3 actual size.)

(d) The superpolishing of the shot-peened specimens was carried out as described in (b), sections ii, iii and iv. The surface roughness was 0.00009 inch.

(Continued on next page)

Rea	ults	of	Rota	ting	Bondin	g P2	tia	uo 1	osta:~	3
									· · · · ·	

(Krouse Fatigue Specimens)

(<u>a</u>)	<u>Smooth</u>	Machine Finish, Unpeched		
	Test No.	Applied Stress, p.s.1.	Number of Cycles	Remarks
	1 2 3 4 5 6	80,000 75,000 72,000 71,000 70,000 90,000	380,500 481,400 593,800 10,056,400 10,125,000 161,100	Éroke. " No broals. Broke.

(b) Unpeased, Superpolished -

Test No.	Applied Stress,	Number of Cyclss	Romanks
1 2 3 4 5 6	80,000 81,000 82,000 83,000 85,000 90,000	10, 102, 000 10, 500, 000 10, 115, 000 2, 109, 700 1, 156, 000 390, 000	No break. n n Broke. n

(c) <u>Smooth Machine Finish</u>, <u>Shot-Peened</u> -

Test	Applied Stress,	Numbor of	Romezhn
<u>No.</u>	p.s.1.	Cycles	
1 2 3 4 5	82,000 83,000 84,000 85,000 90,000	10,508,000 11,254,000 475,000 535,000 290,600	No broak. Broko. Broko. M

(d) <u>Smooth Machine Finish</u>, <u>Shot Peened and Superpolished</u> -

Tost	Applied Stress,	Number of	Romarks
No.	p.s.i.	Gycles	
1 2 3	85,000 88,000 89,000	10,541,000 11,601,000 10,671,900	No break. n n
4	90,000	694,600	Broka,
5	95,000	239,000	n

S-N fatigue curves embodying the above results are shown in Figure 4, Page 8.

Heat Treatment:

The steel bars 5/8 inch in diameter were heated up to 1525° F. for 45 minutes in a controlled-atmosphere furnace, and then quenched in oil. The bars were then tempered for 45 minutes at 1100° F.

Mechanical Properties:

After the above heat treatment, the steel had the following mechanical properties:

TABLE II.

TT + fwota atrease n s f	5	158,000
aVield stress, p.s.i.	# 7	150,000
Elongation. % 4/2702	£1.0	18.0
Reduction in area, per cent	180	59 " O
Brinell hardness (3,000-kg. load)		32].
Rockwoll hardness (converted)	6 9	C-34
Diamoter of tensile bar, inches	21 V	0,282
₽±1,63×1.4% (\$1,54%)=0,0+1,4%,0,00,0,0,0%,0,4%,0,0%,0,0%,0%,0%,0%,0%,0%,0%,0%,0%,0%,0	-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1	₩2% ₽ ₩2 21124 - HMB MB2592 BAHMB 49-3994 97-1994 24-1975 2202 2207 27-0

* Yield 0.2 per cent offset.

Microscopic Examination:

The nital-etched structure of the steel after being heat treated to Rockwell G-34 is shown in Figure 1, a photomicrograph at X1000 magnification.

> (Figure 1 follows,) (on Page 5.)

(Microscopic Examination, contid) -

Figure 1.



X1000, etched in 2 per cent nital.

SAE 4340 STEEL.

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Shot Peening Data:

Shot size Opening of shot feed Shot type Intensity Coverage Portion peened Handling under blast

Time of Exposure - 1/2 minute. Type of machine - Compressed air. Air pressure - 40 lb. (gauge). Air pressure Gear setting Weight of shot per minute

SAE P-28. -----

1/4 inch.
Pangborn White Iron Shot.
0.012-inch Almen Strip. Considered ample. - Test section only; ends masked. - Mechanically rotated at 286 r.p.m. and moved by hand longitudinally. - 2 = 286 r.p.m. - 980 grans.

Summary of Fatigue Tests:

In Table III is given a summary of fatigue values obtained in this investigation, and also the results of similar tests conducted by U.S. Army Air Force, Material Command, Wright Field, on SAE X4340 steel heat-treated to Rockwell C-34.

TABLE III.

		Fatigue S Wright Field	tress, p.s.i. Burcau of Mines
		energian and a construction and a second structure and the structures	ኇጟጞኯ፟፟፟ጟኯኯኯጟጟጟኯ፟ቚ፝፝፝፝፝፝፝፝፝፝፝ቚቚጞቔቘጞ፟ዸ፟ኯፙጟኯ፝ቔቔቚዀኯዹዀጚፙኯዸፙፙዀኯፙኯኯኯኯኯኯኯኯኯኯኯኯኯኯኯኯ ፟ኇጟጞኯ፟፟ጟኯኯጟጟኯኯ፟ቚቔቔቔጞዸኯፙጞኯቜቔቔኯኯኯዹዀኯፙኯኯኯኯኯኯኯኯኯኯኯኯኯኯኯኯኯኯኯኯኯኯኯኯኯኯኯኯኯኯኯ
Smooth machine finish	63	72,000	73,000
Superpolished	62	82,000	82,000
Shot-peened	6 23	79,000	83,000
Shot-peened and superpo	lishoć	89,000	89,000

Discussion of Results:

The combined treatment of shot-peening and superpolishing gave the most favourable results. This may be due to the reduction of stress-concentration points or a more uniform distribution of the compressive stress at the surface. The fatigue strength of superpolished and shotpeened specimens is approximately the same. It will be noted that the results obtained in these Laboratories are in close agreement with values obtained at Wright Field.

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(Figure 4 follows,) (on Page 8.)



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