CANADA

EFFECT OF SHOT PEENING PRIOR TO ELECTROPLATING ON THE FATIGUE PROPERTIES OF AN ALLOY STEEL

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EPARTMENT OF MINES AND
ECHNICAL SURVEYS, OTTAWA

MINES BRANCH
RESEARCH REPORT

R 23

PRICE 25 CENTS

SEPTEMBER 18, 1958

Mines Branch Research Report R 23

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ABSTRACT

The results of research into the effect of shot peening, prior to electroplating, on the fatigue strength of a modified SAE 3140 alloy steel are described in this report.

Eight S-N curves have been obtained on steel specimens with the following surface conditions: as-machined, shot peened, electroplated on a machined surface, and electroplated on a shot peened surface. These curves show that the specimens which were shot peened prior to electroplating with chromium, nickel or cadmium have materially higher fatigue properties than have specimens which were not shot peened before electroplating with these metals.

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INTRODUCTION

It has been shown by a number of investigators[1, 2, 3] that electroplating of chromium and other metals on carbon and alloy steel parts adversely affects their fatigue strength. This reduction in fatigue strength is attributed to the introduction of tension stresses on the surface of the electroplated parts. It is also well known that the introduction of hydrogen in the electroplating processes embrittles the steel unless the hydrogen is removed by baking the part after plating. Mattson and Almen[4] have shown that the endurance life and fatigue strength of steel are greatly improved by shot peening. In shot peening operations, under the intensive impact of a large number of small round steel balls, the shallow surface layer of the metal part (approximately 0.005 in. thick) undergoes substantial cold work. This cold work introduces compression macro-stresses into this outside surface layer and also closes up any submicroscopic fissures which would form a starting place for a fatigue crack.

It has been known for some time that ordinary electroplating reduces the fatigue strength of the plated part. However, it is only recently that any work has been done to offset the detrimental effect of electroplating on the fatigue properties of steel.

Prestressing the base metal in compression to overcome the residual tensional stresses of the electrodeposited coating has

recently been recommended by the engineers of Wright Air Development Center, Materials Laboratory, Dayton, Ohio, and incorporated in an amendment to United States Federal Specification QQ C-320, "Chromium Plating" (Electrodeposited).

In this investigation it was desired to obtain data on the fatigue properties of an alloy steel under certain surface finishes, namely: (a) machine finished; (b) shot peened; (c) electroplated with chromium on a machine finish and after shot peening; (d) electroplated with nickel on a machine finish and after shot peening; and (e) electroplated with cadmium on a machine finish and after shot peening.

The S-N fatigue curves were determined on R.R. Moore fatigue specimens. All of the electroplated specimens were baked at 390°F for five hours prior to testing on R.R. Moore rotating bending high-speed fatigue testing machines. This report will contain the results of tests on an alloy steel which is similar in composition to an SAE 3140 steel except that 0.17% molybdenum has been added to improve the depth hardening and impact properties.

CHEMICAL ANALYSIS

Atlas SPS-245 steel in the form of 5/8 in. diameter bars was used in this investigation. The composition of the Atlas SPS-245 steel and that of SAE 3140 steel are given below:

TABLE 1

Chemical Analysis (%)

	Atlas SPS-245 Steel	SAE 3140 Steel
Carbon	0.39	0.38-0.43
Manganese	0.74	0.70-0.90
Silicon	0.19	0.20-0.35
Phosphorus	0.035	0.04 max
Sulphur	0.015	0.04 max
Nickel	1.17	1.10-1.40
Chromium	0.51	0.55-0.75
Molybdenum	0.17	nil

HEAT TREATMENT

The 5/8 in. diameter bars were given the following heat treatment prior to machining the tensile and fatigue test specimens:

Oil quench from 1500°F,
Tempered 30 minutes at 1300°F.

MECHANICAL PROPERTIES

The results of tensile tests after the above heat treatment are given in Table 2.

TABLE 2

Mechanical Properties of Alloy Steel
(Atlas SPS-245 Steel)

Sample No.	Sample Size, in.	Area, sq. in.	Ultimate Tensile Strength kpsi	Yield Strength, kpsi	Elongation, % 4D	Reduction in Area, %
1	0.438	0.150	117.2	100.0	25.1	61.6
2	0.438	0.150	116.6	101.8	26.3	61.2
3	0.438	0.150	116.6	101.0	27.4	62.0
Average (3 tests)			116.8	100.9	26.3	61.6

FATIGUE TESTS

R.R. Moore fatigue specimens were machined from 5/8 in. diameter bars which had been heat treated to possess the mechanical properties given in Table 2. The R.R. Moore specimens were then tested with a machine finish, shot peened, electroplated with chromium, nickel and cadmium and also with the surface shot peened prior to electroplating with chromium, nickel and cadmium. The tests were all carried out in R.R. Moore high-speed rotating bending fatigue testing machines operated at 10,000 rpm. The results of these tests are given in Tables 3 to 10, inclusive, and the S-N fatigue curves are shown in Figures 1, 2, 3 and 4.

TABLE 3

Fatigue Properties of Modified SAE 3140 Steel, Machine Finished

Applied Stress, psi	Number of Cycles to Failure	Remarks
70,000	222,000	Broke
67,000	539,000	"
65,000	939,000	"
63,000	1,337,000	"
62,000	12,440,000	Unbroken
60,000	10,184,000	"

TABLE 4

Fatigue Properties of Modified SAE 3140 Steel, Shot Peened

Applied Stress, psi	Number of Cycles to Failure	Remarks
70,000	370,000	Broke
67,000	477,000	"
66,000	1,036,000	"
65,000	14,191,000	Unbroken
65,000	10,842,000	"

TABLE 5

Fatigue Properties of Modified SAE 3140 Steel, Chromium Plated

Applied Stress, psi	Number of Cycles to Failure	Remarks
65,000	132,000	Broke
60,000	269,000	"
55,000	574,000	"
54,000	724,000	"
52,000	13,636,000	Unbroken
50,000	10,159,000	"

TABLE 6

Fatigue Properties of Modified SAE 3140 Steel, Shot Peened and Chromium Plated

Applied Stress, psi	Number of Cycles to Failure	Remarks
70,000	182,000	Broke
68,000	207,000	"
67,000	155,000	"
66,000	396,000	"
65,000	13,443,000	Unbroken

TABLE 7

Fatigue Properties of Modified SAE 3140 Steel, Nickel Plated

Applied Stress, psi	Number of Cycles to Failure	Remarks
65,000	139,000	Broke
62,000	190,000	"
60,000	157,000	"
55,000	243,000	"
52,000	987,000	"
50,000	11,249,000	Unbroken

TABLE 8

Fatigue Properties of Modified SAE 3140 Steel, Shot Peened and Nickel Plated

Applied Stress, psi	Number of Cycles to Failure	Remarks
65,000	289,000	Broke
64,000	329,000	"
62,000	531,000	"
61,000	758,000	"
60,000	14,444,000	Unbroken

TABLE 9

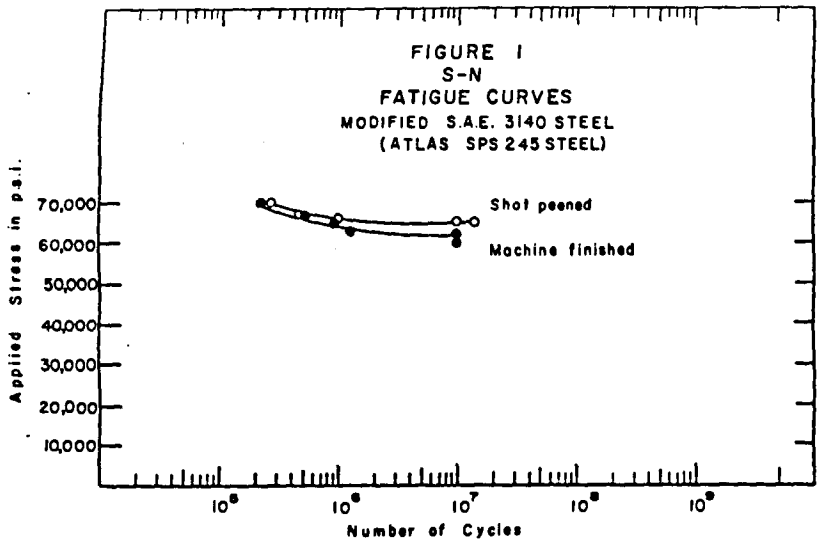
Fatigue Properties of Modified SAE 3140 Steel, Cadmium Plated

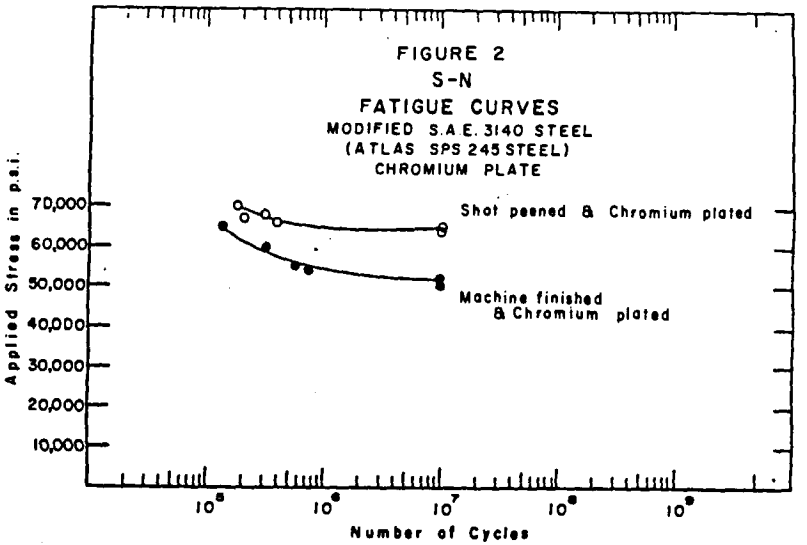
Applied Stress, psi	Number of Cycles to Failure	Remarks
65,000	98,000	Broke
60,000	211,000	"
55,000	1,080,000	"
54,000	1,321,000	"
53,000	14,230,000	Unbroken
52,000	10,039,000	"

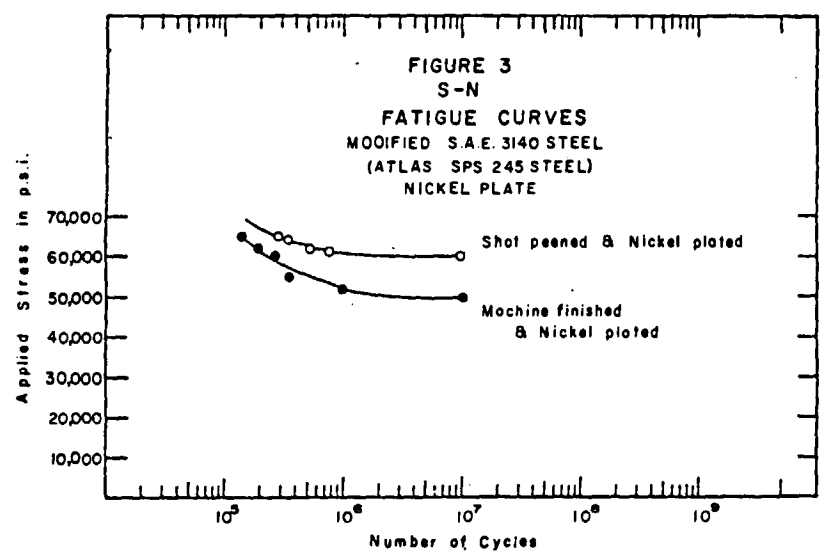
TABLE 10

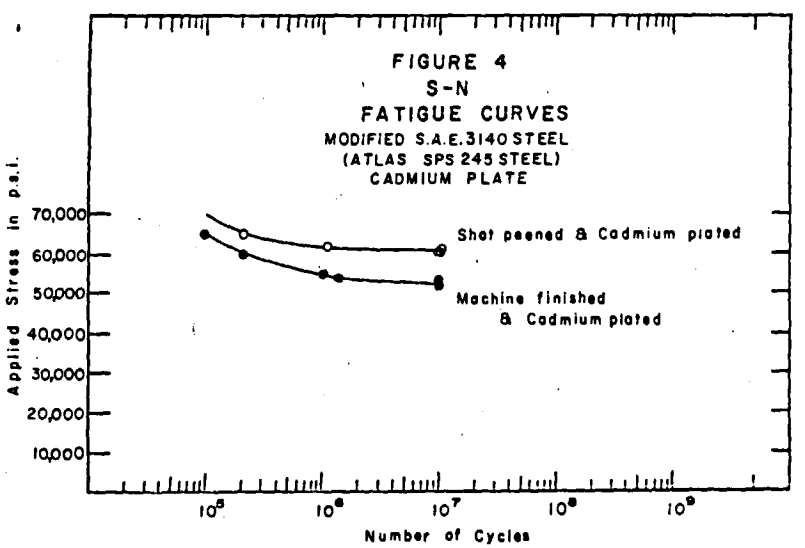
Fatigue Properties of Modified SAE 3140 Steel, Shot Peened and Cadmium Plated

Applied Stress, psi	Number of Cycles to Failure	Remarks
65,000	211,000	Broke
62,000	1,221,000	"
61,000	19,437,000	Unbroken
60,000	11,577,000	"









Figures 1 to 4 - Fatigue Curves

The fatigue strength values obtained in this investigation after machining, shot-peening and electroplating are summarized in Table 11.

TABLE 11

Fatigue Strength of Alloy Steel After Machining, Shot Peening and Electroplating

Fatigue Strength, psi	Finish of R.R. Moore Fatigue Specimens
62,000	Machined finish.
65,000	Shot peened.
52,000	Machined finish and chromium plated.
65,000	Shot peened and chromium plated.
50,000	Machined finish and nickel plated.
60,000	Shot peened and nickel plated.
53,000	Machined finish and cadmium plated.
61,000	Shot peened and cadmium plated.

It will be noted, in the above table, that the fatigue strength is lowered by 8,000 to 13,000 psi in electroplating chromium, nickel and cadmium on a machined surface. However, by shot peening prior to electroplating chromium, the fatigue strength is equal to that obtained by shot peening on a machined surface; and by shot peening prior to electroplating nickel and cadmium, fatigue strength increases of

10,000 and 8,000 psi, respectively, were obtained over those obtained on specimens electroplated with nickel and cadmium on a machined surface.

The beneficial effect of shot peening prior to electroplating with chromium, nickel and cadmium is clearly illustrated by an examination (see Table 12) of the number of cycles to failure obtained at a given stress in the damage zone.

TABLE 12

Number of Cycles to Failure at 65,000 psi

Surface Finish		Number of Cycles to Failure
Machine finish	-	939,000
Shot peened	-	14,191,000*
Chromium plated	-	132,000
Shot peened and cadmium plated	-	13,443,000*
Nickel plated	-	139,000
Shot peened and nickel plated	-	289,000
Cadmium plated	-	98,000
Shot peened and cadmium plated	-	211,000

*Unbroken

CONCLUSION

This investigation has shown that the endurance life and fatigue strength of steel which has been electroplated can be greatly increased by shot peening prior to electroplating. The tension stresses that are introduced in electroplating are overbalanced by numerically larger compression stresses introduced by shot peening.

It would therefore seem expedient to adopt this procedure of shot peening, prior to electroplating with chromium, nickel or cadmium, on critical steel components in aircraft and motor vehicles which are subjected to alternating stresses.

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