THE SPRING RESEARCH AND MANUFACTURERS' ASSOCIATION

THE EFFECTS OF CORROSION PROTECTIVE SURFACE COATINGS ON THE PERFORMANCE OF SHOT PEENED SPRINGS

Report No 430

by

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SUMMARY

A further investigation has been conducted to examine the effect of corrosion protective surface coatings on spring performance, particularly with regard to the effects on shot peened springs. It was found that none of the coatings detrimentally affected the fatigue performance of the springs. However, the corrosion resistance of some of the coatings, in the face of neutral salt spray, was reduced from that experienced previously with unpeened springs.

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1. INTRODUCTION

Recent SRAMA Reports (Refs 1,2,3) have examined several of the new paint, plastic and metallic corrosion protective coatings which are currently available. The reports covered the environmental and neutral salt spray testing of both unpeened and shot peened test panels and unpeened spring samples. Fatigue testing of unpeened spring samples was also carried out and this found that the majority of the coating systems examined had detrimental effects on the fatigue performance of the springs. However, a significant proportion of springs are shot peened to improve their fatigue performance in service and, as most of the coatings previously investigated can be applied to shot peened springs, an investigation was required to assess whether or not the application of such coatings had any adverse effects on the fatigue performance of shot peened springs.

2. COATINGS EXAMINED AND EXPERIMENTAL TECHNIQUES

The investigation was conducted using compression springs made from 4 mm diameter chrome-vanadium wire to BS 2803 735A50 grade: full details of the spring design are given in Table I. Metallurgical examination having shown the material to be satisfactory with regard to freedom from defects and decarburization, microstructure and hardness level, the complete batch of springs was shot peened using S230 shot, followed by a post peening stress relief of 220°C for 30 minutes. The various coatings (listed in Table II) were then applied to batches of 16 springs, one batch of springs being left uncoated for comparative purposes. Full details of the coatings are provided in the previous reports (Refs 1,2,3).

It was noted that the cadmium plated springs coated by the springmaker had a slightly "crazed" appearance to the coating which suggested that the plating bath parameters may not have been optimum. A second set of springs was therefore coated by a commercial plater and used in the tests for comparative purposes.

2.1 Coating Thickness Checks

The thickness of each coating type was measured on transverse microsections by means of a metallurgical microscope fitted with a calibrated eyepiece graticule. In all cases, the coating was found to be present on 100% of the wire surface. The thickness measurement results are presented in Table III.

2.2 Fatigue Testing

Fatigue testing was carried out using the Association's forced motion fatigue testing machines. Initial testing was conducted using the uncoated springs to establish a suitable stress level for the remainder of the testing. The criterion chosen for establishing this test stress level was that the uncoated springs should have a mean life of approximately 10 million cycles, this being a suitable life for comparative purposes as any adverse or beneficial effects of the coating processes would be manifest by either early failure or survival beyond 100 million cycles respectively. Thus, for an initial stress level of 100 N/mm^2, the maximum stress level to meet the testing criterion was established as 1060 N/mm^2.

Fatigue tests were then carried out between these 2 stress levels on a batch of 12 uncoated springs and on 8 springs covered with each of the various coating systems.

2.3 Neutral Salt Spray Testing

Corrosion testing to the requirements of ASTM B117-73 was carried out using the Association's Liebisch STR400 salt spray test cabinet. All the springs were prestressed to solid prior to the commencement of testing, as the majority of shot peened springs operating in fatigue would be prestressed to stabilise them prior to operation. The prestressing process should also help to highlight any problems with the coating such as poor adherence or cracking of the coating at the end tip due to flexing.

The criterion adopted as the definition for coating failure was the first appearance of red rust on the spring, be it under the end coil or on the active coils of the spring.

3. RESULTS AND DISCUSSION

The results of the fatigue testing are presented in Figure 1. They were analysed using the Weibull method of analysis, the results of which are given in Table IV. A detailed description of the Weibull method of analysis is given in a previous report (Ref 4).

The results of the analysis suggest that two processes have significantly improved the B10 fatigue performance of the springs, ie epoxy painting and Ivadising. The improvement obtained with the latter process could be ascribed to the fact that all components receive a bead-peening treatment after Ivadising; the springs can therefore be regarded as having received a duplex peening treatment, which can lead to improved fatigue performance.

The results of the analysis also suggest that none of the processes significantly reduced the fatigue performance of the springs, although it was noted that the scatter of the results for the majority of the plated springs was slightly less than for the unplated springs. However, it will be seen from examination of Figure 1 that, for 3 of the coating systems (namely electroplated zinc, Dacromet and Deltatone), none of the springs survived beyond 10 million cycles, suggesting that these coating systems may have had a slightly detrimental effect on the fatigue performance of the shot peened springs.

It is interesting to compare the fatigue results of this work with those of the previous investigation on unpeened springs, (Ref 1) which found that, with the exception of Ivadising, all the coating processes reduced the fatigue performance of the springs. This suggests that the improvements in fatigue performance imparted by shot peening act to counter the detriment to fatigue performance caused by the surface treatments; it is assumed that this maintenance in performance is due to the beneficial residual surface stress system produced by the shot peening.

The results of the neutral salt spray tests are presented in Figure 2. It will be noted from these data that the springs cadmium plated by the springmaker had markedly lower corrosion resistance than their commercially plated counterparts (and lower than anticipated for this type of coating), suggesting that the former had not been correctly plated.

The coatings can be grouped as follows in terms of the protection offered against corrosion by neutral salt spray (1 = worst, 4 = best):

1. Xylan, epoxy paint, phosphated and epoxy paint, phosphated and electro-cathodic paint.

2. Mechanically plated zinc, mechanically plated aluminium/zinc, electro-plated zinc, Dacromet.

3. Electroplated cadmium, phosphated and Deltatone, mechanically plated tin/zinc, Deltatone.

4. Galvano-Aluminium, Ivadising.

Comparing the neutral salt spray test results of this work with those of the previous investigations on unpeened springs (Refs 1,2,3), it will be seen that shot peening has significantly reduced the corrosion resistance of the following coatings, possibly due to poorer keying of the coating on the peened surface:

Xylan, epoxy paint, phosphated and epoxy paint, phosphated and electro-cathodic paint, electroplated cadmium, Deltatone and Galvano-Aluminium.

For the other coating systems, the corrosion resistance with regard to neutral salt spray was similar for both the unpeened springs tested previously and the shot peened springs tested in this investigation.

4. CONCLUSIONS

1. None of the surface coatings examined had any significant detrimental effect on the fatigue performance of shot peened springs.

2. Coating with epoxy paint and Ivadising both produced a significant improvement in the fatigue performance of the shot peened springs.

3. The corrosion resistance of some of the coatings was significantly reduced over that obtained using coated, unpeened springs. The coatings in question were Xylan, epoxy and electrocathodic paint, electroplated cadmium, Deltatone and Galvano-Aluminium.

5. REFERENCES

1. Reynolds, L F, "Evaluation of New Surface Coatings for Corrosion Protection of Unpeened Springs", SRAMA Report 381, May 1985.

2. ________, "Evaluation of Paint and Plastic Coatings for Springs", SRAMA Report 400, August 1986.

3. ________, "Further Evaluation of New Surface Coatings for Springs", SRAMA Report 414, November 1987.

4. Desforges, J, "Statistical Analysis of Fatigue Data Produced from Compression Springs", SRAMA Report 274, May 1977.

TABLE I SPRING DESIGN PARAMETERS

Spring Parameter	
Wire Diameter (mm)	4.06
Outside Coil Diameter (mm)	32.20
Spring Index	6.93
Free Length After LTHT, End Grinding and Prestressing (mm)	53.40
Total Coils	5.92
Spring Rate (N/mm^2)	30.86
Solid Stress (N/mm^2)	1165
Ends	Closed and Ground
Low temperature heat treatment	400°C for 30 Minutes

TABLE II IDENTIFICATION OF COATING CODES

Coating Details	Code
Uncoated	U/C
Xylan	X
Epoxy Paint	E
Phosphated and Epoxy Paint	E (P)
Phosphated and Electrocathodic Paint	EL (P)
Electroplated Zinc	Zn 3
Electroplated Cadmium*	Cd 3 (1)
Electroplated Cadmium+	Cd 3 (2)
Mechanically Plated Zinc	Zn
Mechanically Plated Tin/Zinc	Sn/Zn
Mechanically Plated Aluminium/Zinc	Al/Zn
Dacromet	DAC
Deltatone	DEL
Phosphate and Deltatone	DEL (P)
Ivadised	IVAD
Galvano-Aluminium	GAL

* = Springs electroplated by springmaker with plating facilities

+ = Springs commercially electroplated

TABLE III <u>COATING THICKNESS MEASUREMENT RESULTS</u>

Coating Identification	Coating Thickness (mm)		
	minimum	mean	maximum
X	0.010	0.024	0.036
E	0.111	0.136	0.193
E (P)	0.024	0.050	0.074
EL (P)	0.010	0.025	0.040
Zn 3	0.014	0.020	0.022
Cd 3 (1)	0.018	0.025	0.036
Cd 3 (2)	0.006	0.014	0.020
Zn	0.004	0.010	0.016
Sn/Zn	0.014	0.016	0.020
Al/Zn	0.005	0.014	0.021
DAC	0.006	0.010	0.014
DEL	0.006	0.012	0.020
DEL (P)	0.010	0.012	0.020
IVAD	0.016	0.020	0.026
GAL	0.010	0.018	0.025

TABLE IV **RESULTS OF WEIBULL ANALYSIS**

Coating Code	Weibull Slope	B_{10} Life	95% Confidence on B_{10} Life
U/C	0.93	157,278	30,949
Sn/Zn	1.25	120,752	27,968
Zn	1.05	124,084	21,761
Zn 3	2.92	142,681	76,160
DEL	1.81	185,222	67,100
Cd 3 (2)	0.67	212,782	13,494
DEL (P)	1.80	221,549	80,175
DAC	6.62	241,551	183,059
E (P)	2.63	269,429	133,985
X	2.58	282,526	138,862
Cd 3 (1)	5.41	284,027	202,386
Al/Zn	1.06	422,310	75,181
EL (P)	2.13	430,795	182,109
GAL	1.84	449,071	165,264
E	1.18	711,662	149,477
IVAD	1.45	1,582,040	445,293

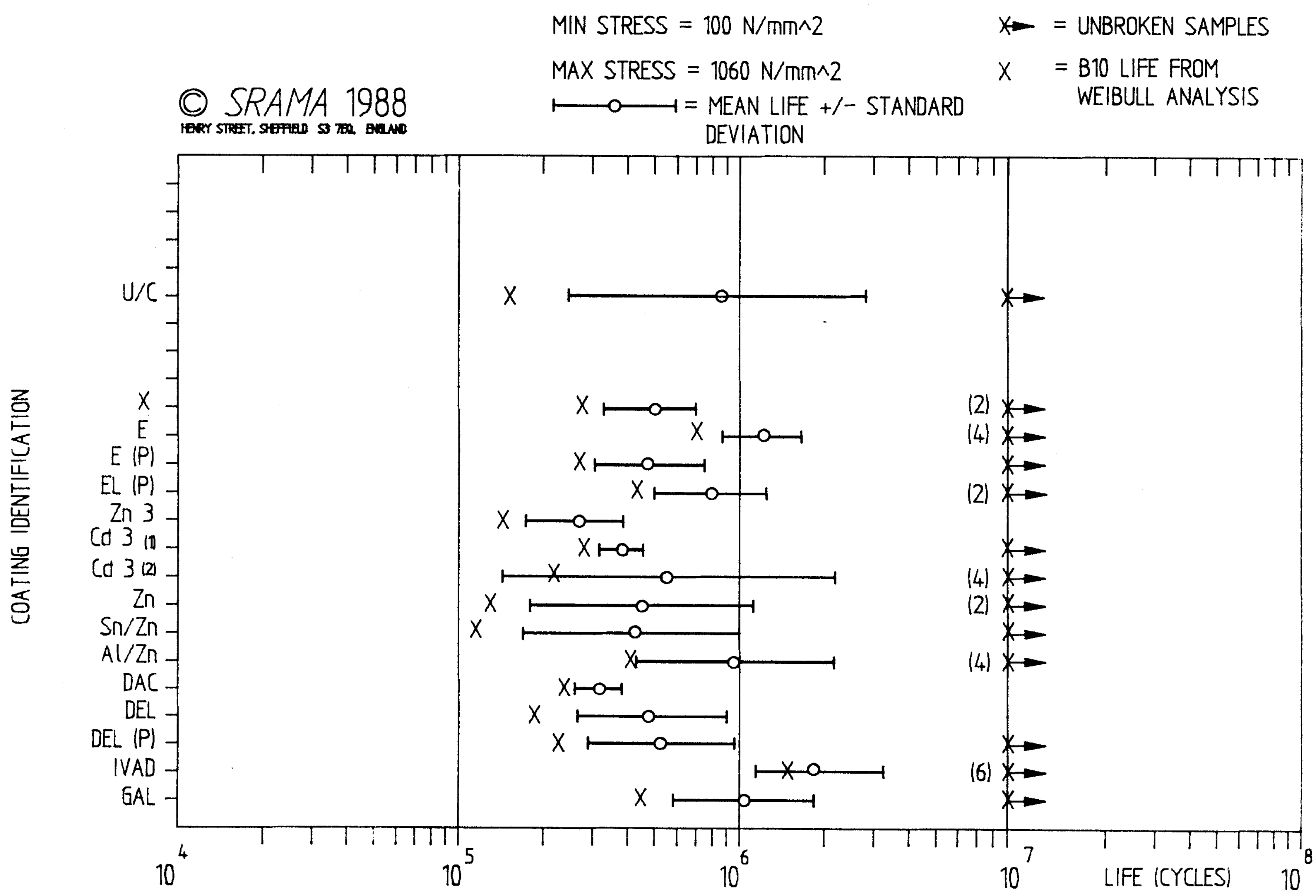

FIGURE 1 FATIGUE PROPERTIES OF SURFACE COATED SHOT PEENED SPRINGS

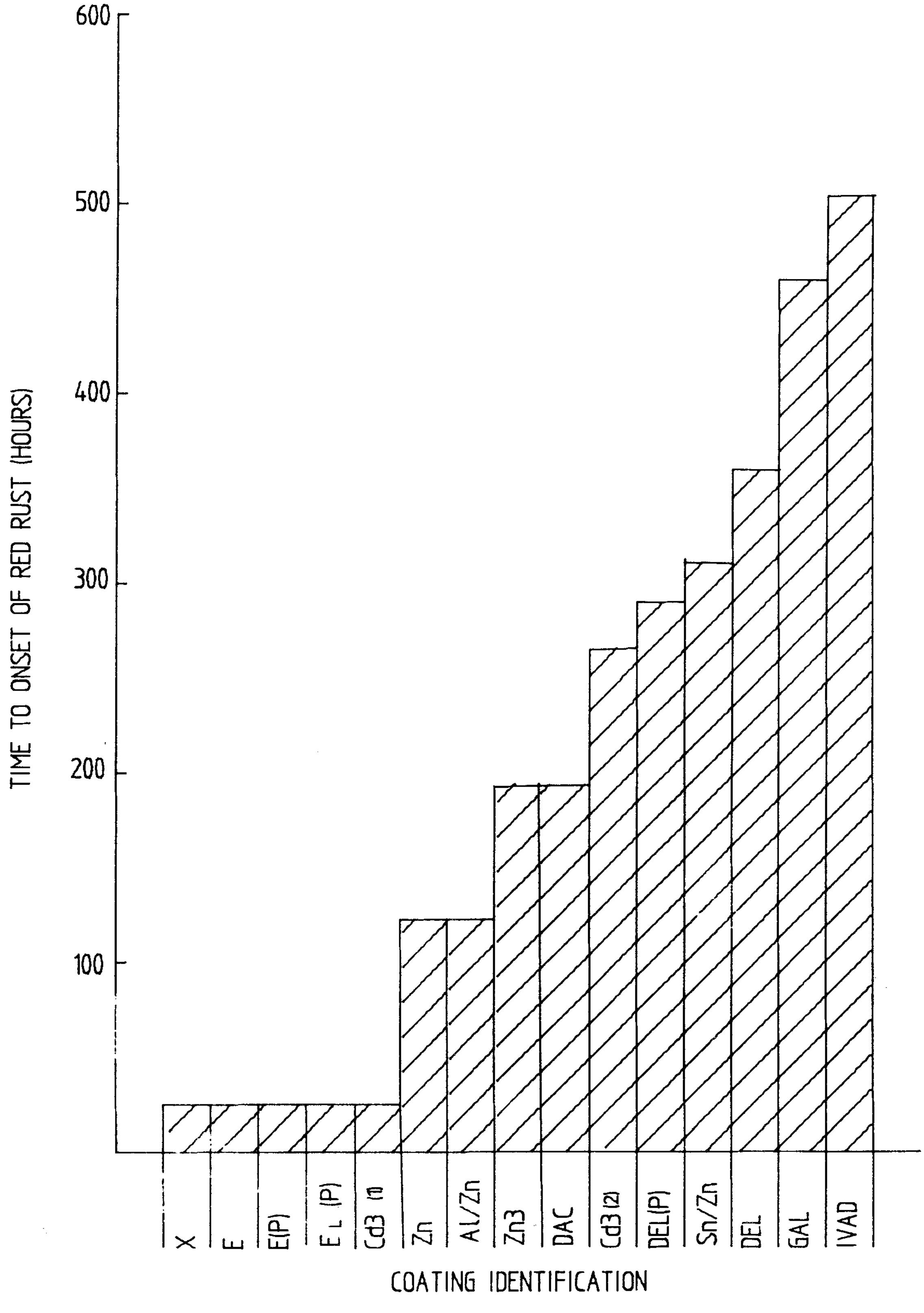

FIGURE 2 RESISTANCE OF COATINGS ON SPRINGS TO NEUTRAL SALT SPRAY