THE SPRING RESEARCH & MANUFACTURERS' ASSOCIATION

THE CORROSION FATIGUE RESISTANCE OF PLASTIC COATED HELICAL COMPRESSION SPRINGS

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SUMMARY

In-air fatigue testing and corrosion fatigue testing have been carried out on uncoated BS 1408D R3 helical compression springs and S/N curves produced. Springs coated with four different plastics have also been subjected to corrosion fatigue testing. With compression springs having closed and ground ends the limiting feature of the spring coatings has been shown to be their effectiveness in protecting the area around the spring tip from the aggressive environment.

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1. INTRODUCTION

Plastic coatings are used extensively for coating many types of spring clips, mainly for a decorative effect(1). For protection purposes on helical compression springs, however, zinc or cadmium plating is normally used. Unfortunately, plating with these metals can lead to hydrogen embrittlement and sometimes early service failure. In an attempt to eliminate the problem of embrittlement, the use of plastic coatings has been investigated on helical compression springs for service in aggressive environments.

2. MATERIALS

In order to economise on material and to provide continuity, helical compression springs were manufactured from material remaining from an earlier investigation; for full details see J.W. Mee(2).

Springs were manufactured from BS 1408D R3 wire to the following dimensions:-

Wire diameter	2.64 mm
Spring mean diameter	24.0 mm
Free length	41.9 mm
Active coils	3.5
Total coils	5.5
Spring rate	9.8 N/mm
Closed and ground ends	

All of the springs, after coiling, were subjected to a low temperature heat treatment at 350°C for 30 minutes followed by end grinding and prestressing. The solid stress after prestressing was 1075 N/mm^2, which was equivalent to 60% of the tensile strength of the drawn wire.

Three thermosets(1) and one thermoplastic(1) coating were investigated, namely polyester, acrylic, epoxy and polyvinyl-chloride. The thermosets were applied by electrostatic spraying(1) and the thermoplastic by fluidised bed coating(1). The springs were supported from one end coil during coating. An attempt was made in some cases to use carbon fibre as a means of suspending the springs from the end coil, but without success. Very thin steel wire was therefore used as the means of suspension.

As with all springs having closed ends, the tip of the spring impinged on the first active coil. Penetration of the plastic at this point was not as complete as was desired and on prestressing the springs there was some evidence to suggest de-cohesion.

3. EXPERIMENTAL PROCEDURE

3.1 In-Air Fatigue Tests

Tests were conducted at a constant initial stress of 77 N/mm^2 to confirm the validity of the data published earlier by Mee(2) and to establish a base line for the purpose of subsequent comparison. This work was carried out on uncoated springs by varying the maximum stress applied and noting the number of cycles to failure, employing a forced motion machine at a speed of 25 Hz.

3.2 Corrosion Fatigue Tests

To determine the influence of a corrosive environment on the fatigue behaviour of springs, tests were conducted on uncoated springs at an initial stress of 77 N/mm^2, to provide a second base line for comparison purposes, and on springs coated with the various plastics under investigation. In all cases, the speed of testing was 25 Hz.

The corrosive environment was provided by simulated sea water having the composition(3): 23 g/l NaCl; 8.9 g/l Na_2SO_4; 9.8 g/l $MgCl_2$; and 1.2 g/l $CaCl_2$.

The springs were loaded in the fatigue testing machine and a perspex cabinet was placed over the test stations. A bath containing wicks was built on to the cabinet in such a way that the sea water dripped via the wicks onto the springs. The droplets of sea water were dispersed as soon as they reached the spring surface because of the cyclic motion of each spring. A constant head of sea water was maintained in the bath by means of a syphon system. The excess liquid, which collected in the bottom of the cabinet, was drained away via a plastic tube. The springs were encased in such a way that the operating conditions were approximately 100% relative humidity at a temperature of 28°C.

4. EXPERIMENTAL RESULTS

The S/N curves showing the two base lines, A for the in-air and B for sea water test results obtained with uncoated springs, are shown in Fig. 1. The fatigue behaviour of the plastic coated springs is also shown; it is evident that all failures occurred at endurances between the two base lines A and B, for uncoated springs tested in-air and in a corrosive environment respectively.

5. DISCUSSION

As can be seen from Fig. 1, fatigue testing uncoated carbon steel springs in a corrosive environment significantly reduced their endurance at all stress levels, the reduction being more marked at lower maximum stresses. Protecting the springs with a plastic coating gave some improvement in fatigue resistance at stress levels below about 800 N/mm^2 but, compared to the in-air fatigue data, the improvement was only marginal. For their protective function to have been considered really satisfactory, the plastic coated springs should have possessed lives similar to those for springs tested in air.

All the plastic coated springs which were corrosion fatigue tested failed at the point at which the coil tip impinged on the first active coil.

The poorest of the plastic coatings was the epoxy which exhibited the worst general condition after fatigue testing. The P.V.C., polyester and acrylic coatings showed generally good adhesion to the body of the spring; this is reflected in the somewhat better performance obtained from these coatings.

To measure the influence of testing speed on the corrosion fatigue behaviour of uncoated springs, a series of tests was undertaken at high stress levels, but at a speed of 8.3 Hz rather than 25 Hz as was used in the tests that provided the data presented in Fig. 1. These results are shown in Fig. 2, from which it can be seen that, under the conditions of testing employed, reducing the speed of testing by a factor of three (a 3-hour test compared to a 1-hour test) had no effect on the endurance. This would suggest that, within the range of test durations investigated, the cyclic stressing was the predominant factor during the simultaneous action of corrosion and dynamic stressing. However, for corrosion fatigue tests either of longer endurance or carried out at a slower testing speed, the influence of the corrosive effect may become the major factor in reducing corrosion fatigue resistance.

Some additional data are also presented in Fig. 2 for springs which were subjected to static corrosion conditions for one hour using the simulated sea water mentioned above. These springs were washed free of the corrosive medium and dried prior to fatigue testing in air. Their fatigue endurance was somewhat better than that of springs which were subjected simultaneously to corrosion fatigue testing but, because of the influence of corrosion causing stress raisers, their performance did not equal that of the un-corroded springs tested in air.

6. CONCLUSIONS

1. Since the fatigue data for the coated springs fall to the right of the data for uncoated springs (Fig. 1), there is some evidence that the coatings are beneficial. However, the extent of the possible improvement is masked by the problem of effectively coating the wire surfaces around the spring tip.

2. With the particular corrosion-fatigue test conditions employed, cyclic stressing appeared to be the major factor affecting endurance.

3. For spring designs in which the tip ends are not in contact with adjacent coils, PVC, acrylic and polyester coatings should offer useful protection to corrosive environments.

7. FURTHER WORK

It is suggested that the problem of obtaining a continuous coating of plastic under the tip of the spring should again be taken up with the producers and suppliers of the plastics.

8. REFERENCES

1. TIMMINS P.F. and others. "Plastic Coatings for Springs - A Literature Survey and Preliminary Work on the Fatigue Behaviour of Plastic Coatings on Helical Compression Springs". SRAMA Report No. 250, July 1975.

2. MEE J.W. "The Fatigue Properties of Springs Made from Patented Cold Drawn Wire to BS 1408D in 3 Ranges of Tensile Strength". <u>SRAMA Report No. 164</u>, June 1967.

3. BS 1391: 1952. "Performance tests for protective schemes used in the protection of light-gauge steel and wrought iron against corrosion"

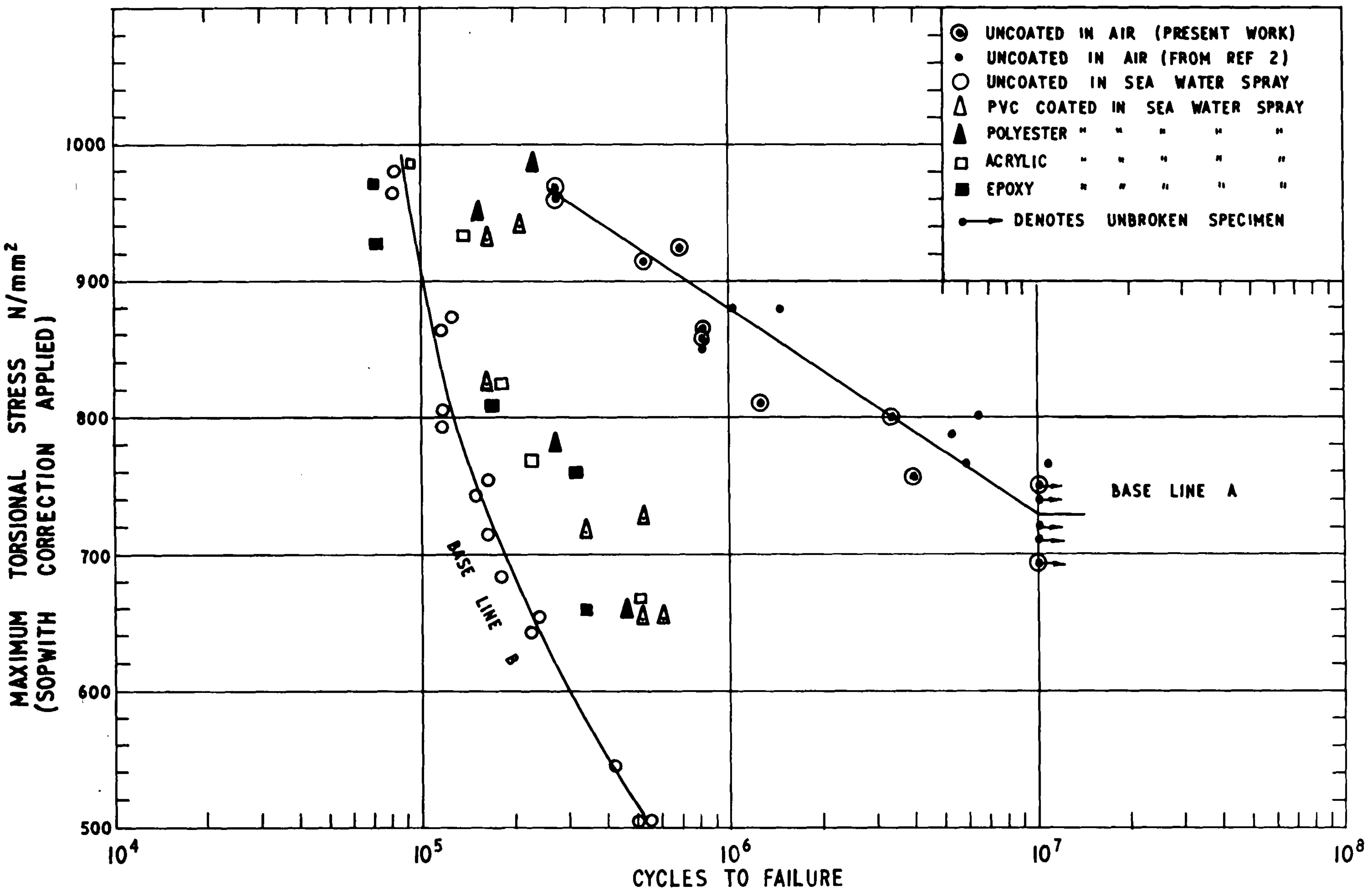

FIG. I INFLUENCE OF ENVIRONMENT ON THE FATIGUE RESISTANCE OF PLASTIC COATED AND UNCOATED BS 1408 D RANGE 3 WIRE HELICAL COMPRESSION SPRINGS.
(TESTS CARRIED OUT AT 8·3 Hz)

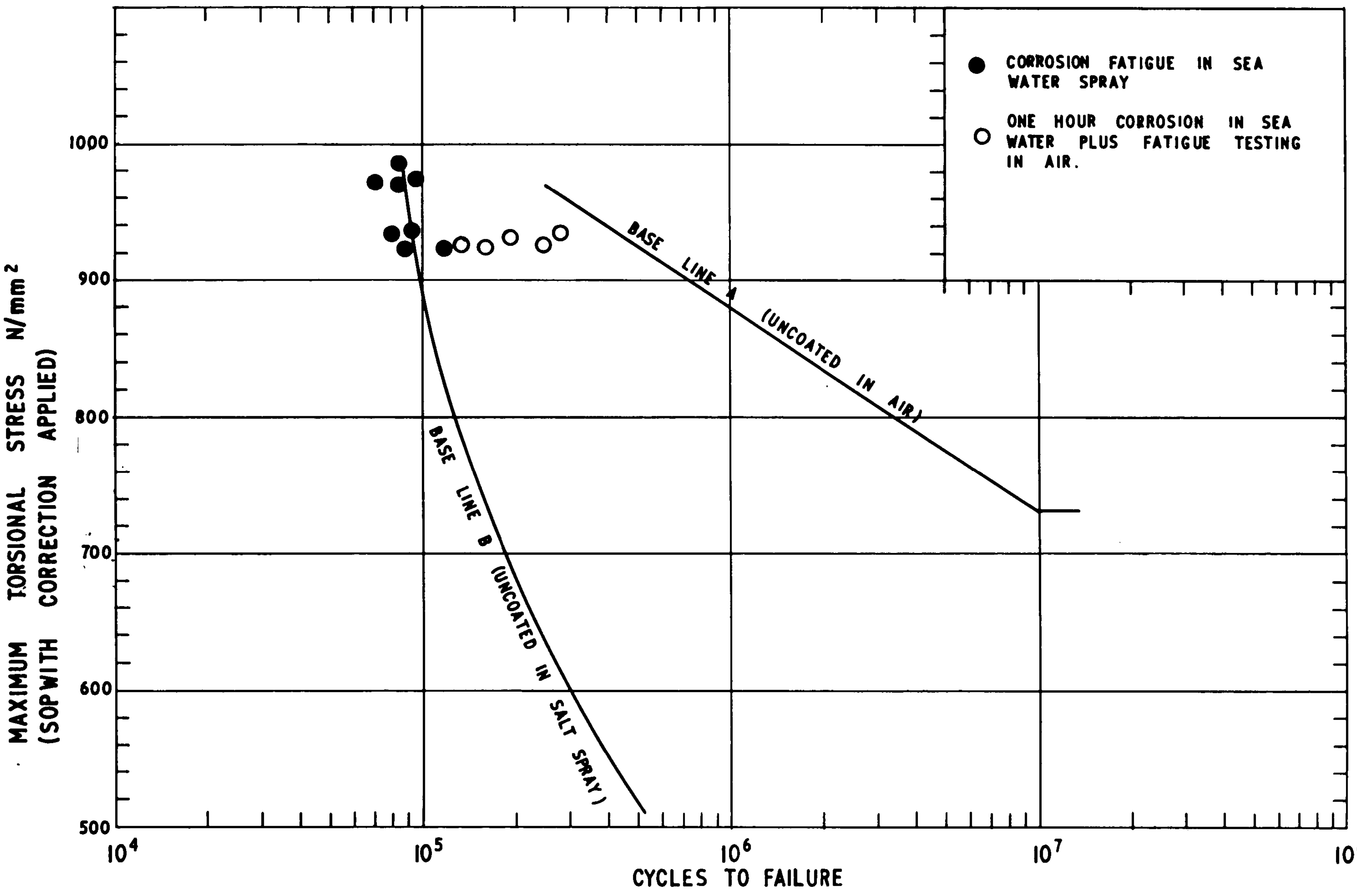

FIG. 2 CORROSION FATIGUE AND CORROSION PLUS FATIGUE DATA ON UNCOATED SPRINGS.
(TESTS CARRIED OUT AT 8·3 Hz)