THE SPRING RESEARCH AND MANUFACTURERS' ASSOCIATION

A COMPARISON OF THE EFFECTS OF SHOT PEENING AND GLASS BEAD PEENING ON THE FATIGUE PERFORMANCE OF HELICAL COMPRESSION SPRINGS

by

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SUMMARY

An examination has been conducted to examine the effects of various impact treatments on the fatigue performance of small compression springs made from 1.56 mm diameter patented cold drawn wire. The results indicated that the best performance was obtained by shot peening with S070 shot using a compressed air blasting process. Glass bead peening and peening using S110 shot in a Wheelabrator produced similar fatigue properties, which were lower than the improvement obtained by S070 shot, while aquablasting only produced a slight improvement over the anticipated performance of unpeened springs.

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FIGURES (cont.)

A COMPARISON OF THE EFFECTS OF SHOT PEENING AND GLASS BEAD PEENING ON THE FATIGUE PERFORMANCE OF HELICAL COMPRESSION SPRINGS

1. INTRODUCTION

Shot peening has become a well established method for improving the fatigue performance of springs. SRAMA has produced a wealth of data for shot peened springs examining the effects of various processing parameters, but generally this work has been conducted using springs made from material of 2 mm diameter wire or greater. It is known that shot peening can lead to underpeening (resulting from failure of the shot to pass through compression spring coil gaps), overpeening or excessive distortion of springs made from smaller diameter wire.

Other impact treatment processes are available which are claimed to overcome the above problems for smaller diameter materials, eg glass bead peening. The Association has previously compared such processes as dry honing and vapour blasting with conventional shot peening [(1)] using springs made from 2 mm diameter wire. The results of that investigation suggested that all three processes produced similar elevation in the fatigue properties over unpeened springs. However, it is almost twenty years since that investigation was conducted and it was felt that an update was required, given recent developments in the field of impact treatment processes. The Japanese have recently conducted an investigation [(2)] comparing the fatigue performance of shot peened springs with wet and dry bead peened springs and their results suggested similar performance for the three impact treatment processes.

This investigation has, therefore, been conducted to compare the effects of glass bead peening with conventional shot peening using both compressed air and wheelabrator methods with small steel shot on the fatigue performance of helical compression springs made from small diameter wire.

2. SPRING MATERIALS AND IMPACT TREATMENTS

2.1 Spring Material and Design

The work was conducted using helical compression springs made from 1.56 mm diameter patented cold drawn carbon steel to BS 5216 HD3 grade. Metallurgical examination of the wire showed it to be satisfactory, being free from wire defects and decarburization, having a microstructure of cold drawn pearlite with a hardness level of 540 Hv10.

A batch of 400 springs was coiled to the design details given in Table I. The springs were given a low temperature heat treatment of 350°C for 30 minutes after coiling.

2.2 Impact Treatment Processes

The springs were divided into 4 equal groups, each of which was given one of the following impact treatments:

a) Shot peened with cast S070 shot using a compressed air blasting process to an Almen A arc rise of 0.15 mm followed by stress relieving at 220°C for 30 minutes.

b) Shot peened using conditioned cut wire S110 shot in a Wheelabrator shot peener to an Almen A arc rise of 0.15 mm followed by stress relieving at 220°C for 30 minutes. This is the smallest shot size which can be satisfactorily used in a Wheelabrator type of machine.

c) Glass bead peened using 0.1/0.2 mm diameter beads by a compressed air blasting process to an Almen A arc rise of 0.15 mm followed by stress relieving at 220°C for 30 minutes.

d) Aquablasted, ie surface blasted by a suspension of alumina in water using a high pressure jet system. NB The aqua-blasting treatment removes the surface oxide film from the material, so producing a highly active, free surface which is highly susceptible to corrosion; thus it was necessary to coat the processed springs with a temporary protective in order to avoid any form of corrosion which could significantly affect the fatigue performance of the springs.

After impact treatment, the spring surface condition was examined using scanning electron microscopical techniques, as very little information is available regarding the appearance of shot peened surfaces; photomicrographs of the surface are presented in Figures 1 to 4 for the S070 peened, S110 peened, glass bead peened and aquablasted spring respectively. The S070 peened springs were found to have an adequately peened wire surface with even 100% coverage and with all traces of the wire drawing obliterated (see Figure 1). The S110 peening treatment had failed to obliterate all the wire drawing marks (see Figure 2) and the surface did not have the same peened appearance as the S070 peened material (compare Figures 1 and 2), suggesting that optimum peening parameters may not have been used. The shot may have been of insufficient hardness, or the shot velocity may have been too low to provide adequate peening of this high hardness material.

Similarly, the glass bead peening had failed to obliterate the wire drawing marks (see Figure 3). The aquablasting treatment had obliterated all traces of wire drawing with an even 100% coverage and had produced a surface topography similar in appearance to shot peening, but of a much finer character (see Figure 4).

All the springs were prestressed repeatedly to solid prior to testing in order to stabilise them.

3. EXPERIMENTAL PROCEDURE

The springs were fatigue tested using the Association's forced motion fatigue testing machines. The springs were tested from an initial stress level of 100N/mm² to various maximum levels so as to establish the approximate maximum stress level at which half the springs survived 10^7 cycles. Further testing was then conducted in order that a Probit analysis could be carried out to establish the fatigue limit in accordance with the procedure laid out in BS 3518: Part 5: 1966. A detailed description of the Probit method of analysis is provided in SRAMA report no 274.[(3)]

4. RESULTS AND DISCUSSION

The results of the fatigue tests are presented in Figures 5 to 8 for the S070 peened, S110 peened, glass bead peened and aquablasted springs respectively. From these fatigue data, Probit analyses were performed, the results of which are presented in Table II.

These indicate that the maximum improvement in fatigue performance was obtained by shot peening with S070 shot. In terms of $\sigma95$ stress level, the results for the springs peened using S110 shot and glass beads were essentially the same. However, a reduced scatter of the finite life results was obtained for the shot peened springs in comparison with the glass bead peened springs.

The poorer performance for these two sets of springs in comparison with those peened using S070 shot could be explained by the results of the SEM examinations, in that both the former processes failed to completely eliminate wire drawing marks which could act as initiation sites for fatigue cracks. Also, in failing to obliterate drawing marks it would seem reasonable to assume that the beneficial residual stresses normally induced in the surface layers by peening processes have not been generated to as high a degree by the S110 and glass bead peening as that obtained by the S070 peening where adequate surface coverage had been obtained.

The lowest fatigue performance of the four treatment processes was obtained for the aquablasted springs, the $\sigma 95$ stress level being only slightly above that which would be anticipated for unpeened springs. It would seem reasonable to assume that this slight improvement is due to the fact that the processing has improved the surface quality, thereby reducing the number of possible crack initiation sites, but it has failed to induce a significant beneficial residual stress system into the material surface layers, as would occur with the other peening treatments.

Some of the finite life samples of each of the impact treatment processes were examined using the Association's SEM in order to categorise the failure mode. All the springs examined had the characteristic features of fatigue failure having initiated at the wire surface at the inside coil position (ie the point of maximum stress) with either single or multiple fatigue fracture origins (see Figures 9-12). High magnification examination of the wire surface of the aquablasted springs adjacent to the fracture origin revealed slight traces of corrosion products (see Figure 13), which may account for the relatively poor performance of this batch of springs.

It can be seen from this work that the measurement of Almen A arc height may not necessarily give an accurate indication of the fatigue performance of shot peened springs. A more accurate prediction of fatigue performance may be obtained by establishing the level of the beneficial residual stress system in the spring after peening. An estimation of the level of stress imparted by peening could be obtained by means of free flat strip samples incorporated with the springs during treatment, which could then be easily analysed using established techniques of stress analysis eg centre hole drilling. SEM examination of the peening coverage, and subsequent surface quality, is a valuable addition to, and necessary part of, the ideal quality control procedure for the shot peening process.

The results of this investigation are in marked contrast to those obtained in the recent Japanese investigation[2] which found that bead peening and shot peening produced similar levels of improvement in fatigue performance. However, when comparing these two investigations, a number of factors should be taken into consideration which may have a bearing on the interpretation of results. The criterion chosen by the Japanese of 5×10^6 cycles for the fatigue limit differs slightly from the 10^7 cycle criterion used in this investigation. Also, the initial stress level used by the Japanese was higher than that used for this investigation and this would have some effect on the fatigue performance results. Finally, the Japanese work is based on the testing of a limited number of sample springs, so that the level of confidence which can be placed on the results is lower than that for the current investigation.

5. CONCLUSIONS

1. For springs made from small diameter patented cold drawn wire, the best improvement in fatigue performance is obtained by shot peening using a compressed air process with S070 shot which gave a $\sigma 95$ stress level of 875 N/mm^2.

2. Peening with S110 steel shot and glass bead peening improve the fatigue performance of small diameter wire springs, but not to as high an extent as the peening using S070 steel shot.

3. Aquablasting did not significantly improve the fatigue limit above that which would be anticipated for unpeened springs (ie approximately 700 N/mm^2), and so would not be recommended for carbon steel springs.

6. REFERENCES

1. Graves, G B and Heap, J M A "The Influence of Dry Honing and Vapour Blasting on the Fatigue Properties of Springs made from Patented and Cold Drawn Wire", SRA Report No 179, August 1970.

2. Anon, "A Study of the Shot Peening of Small Springs", Bane Ronbunshu, 1982, 27.

3. Desforges, J "Statistical Analysis of Fatigue Data produced from Compression Springs", SRAMA Report No 274, May 1977.

TABLE I SPRING DESIGN PARAMETERS

Material Type	BS 5216 HD3
Wire Diameter (mm)	1.56
Outside Diameter (mm)	12.09
Spring Index	6.75
Free Length After LTHT, End Grinding and Cold Prestressing (mm)	20.05
Total Coils	5 2/3
Active Coils	3 2/3
Spring Rate (N/mm)	13.7
Solid Stress (N/mm^2)	1310
Ends	Closed and Ground

TABLE II RESULTS OF PROBIT ANALYSES

Surface Treatment	Y = a + b X		Correlation Coefficient	Level of Significance	Fatigue Limit % survival	
	a	b			σ50	σ95
Shot Peened SO70	-14.20	0.014	0.9722	99%	990 ± 7	875 ± 10
Shot Peened S110	-11.79	0.013	0.6489	90%	945 ± 25	830 ± 38
Glass Bead Peened	-19.95	0.023	0.9753	99%	880 ± 6	810 ± 8
Aquablasted	-17.85	0.023	0.9517	99%	785 ± 6	710 ± 8

SEM PHOTOMICROGRAPHS

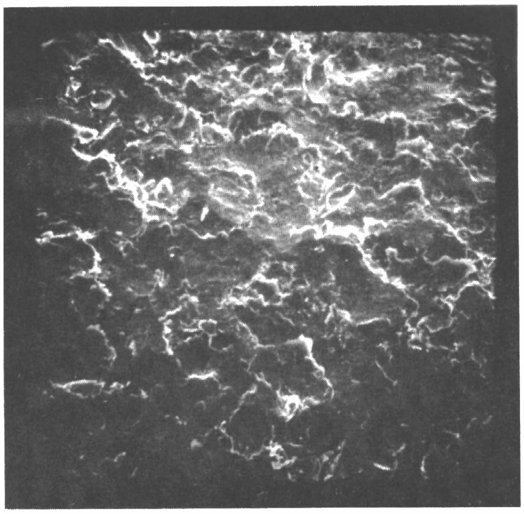

Figure 1 X 126

Surface of spring shot peened using S070 cast shot.

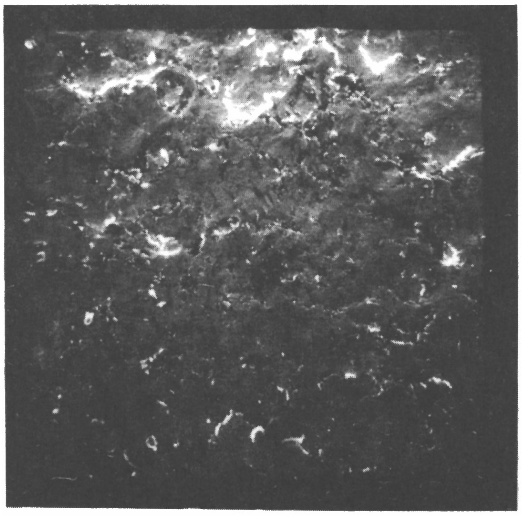

Figure 2 X 126

Surface of spring shot peened using S110 conditioned cut wire shot.

SEM PHOTOMICROGRAPHS

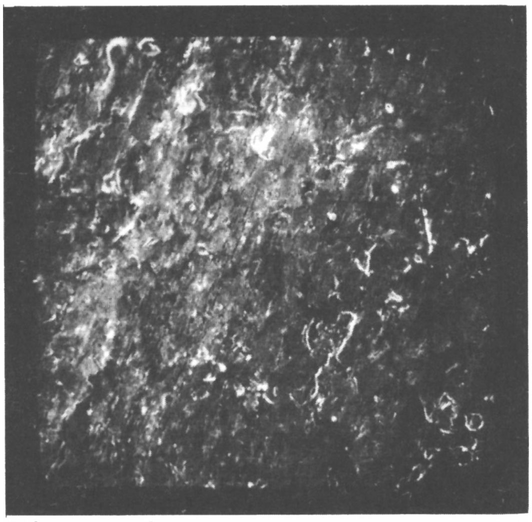

Figure 3 X 132

Wire surface of glass bead peened spring.

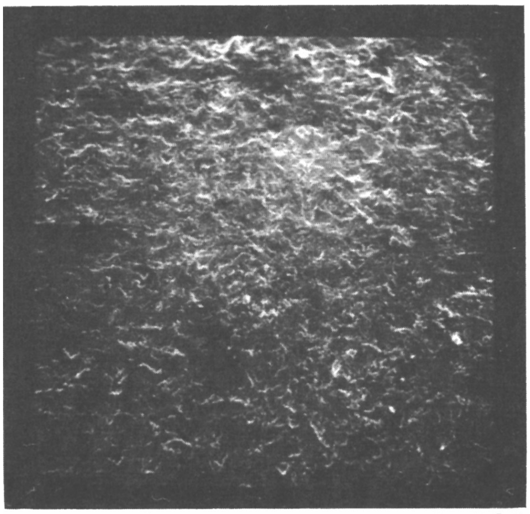

Figure 4 X 120

Wire surface of Aquablasted spring.

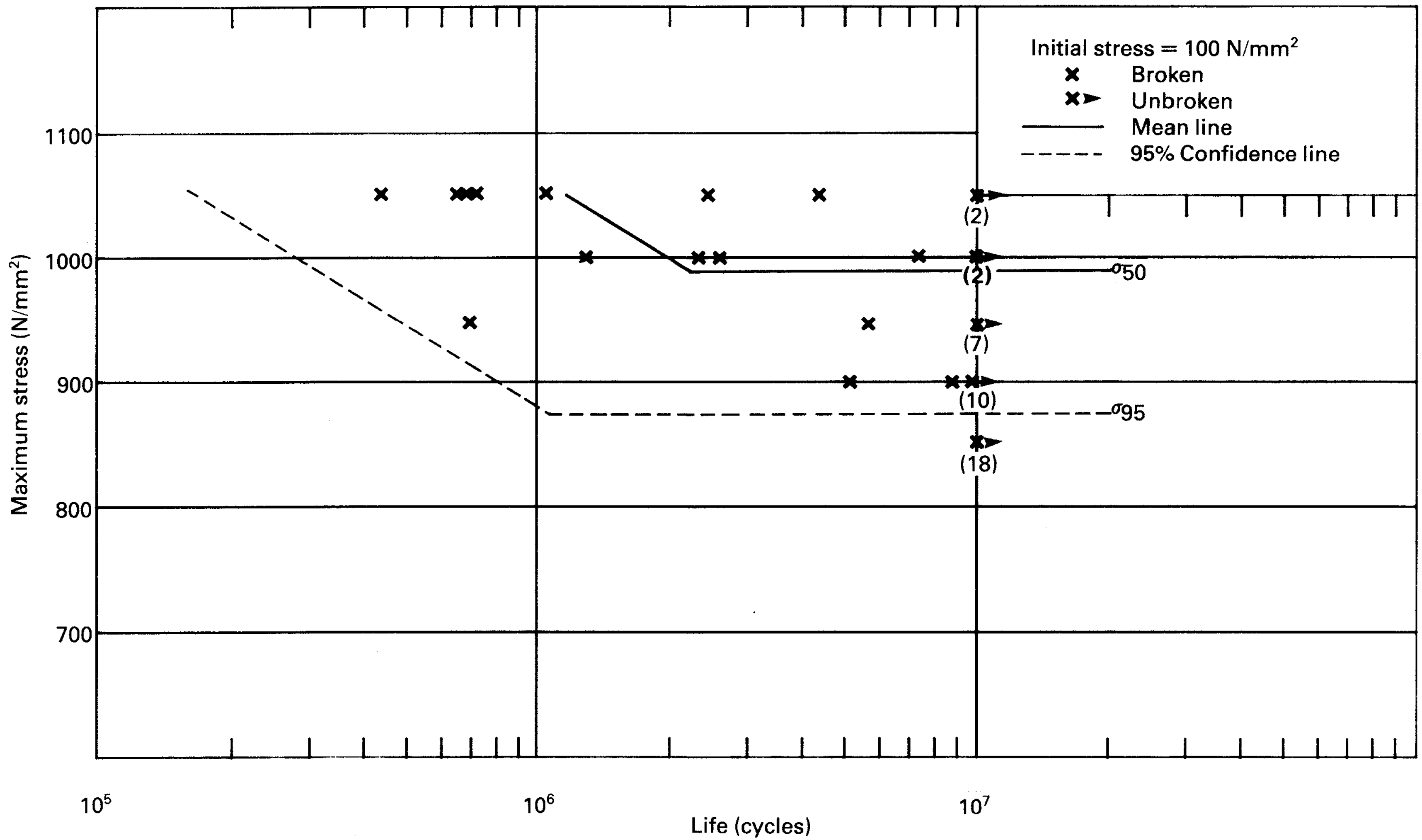

Fig 5: FATIGUE RESULTS FOR SPRINGS SHOT PEENED USING S070 SHOT

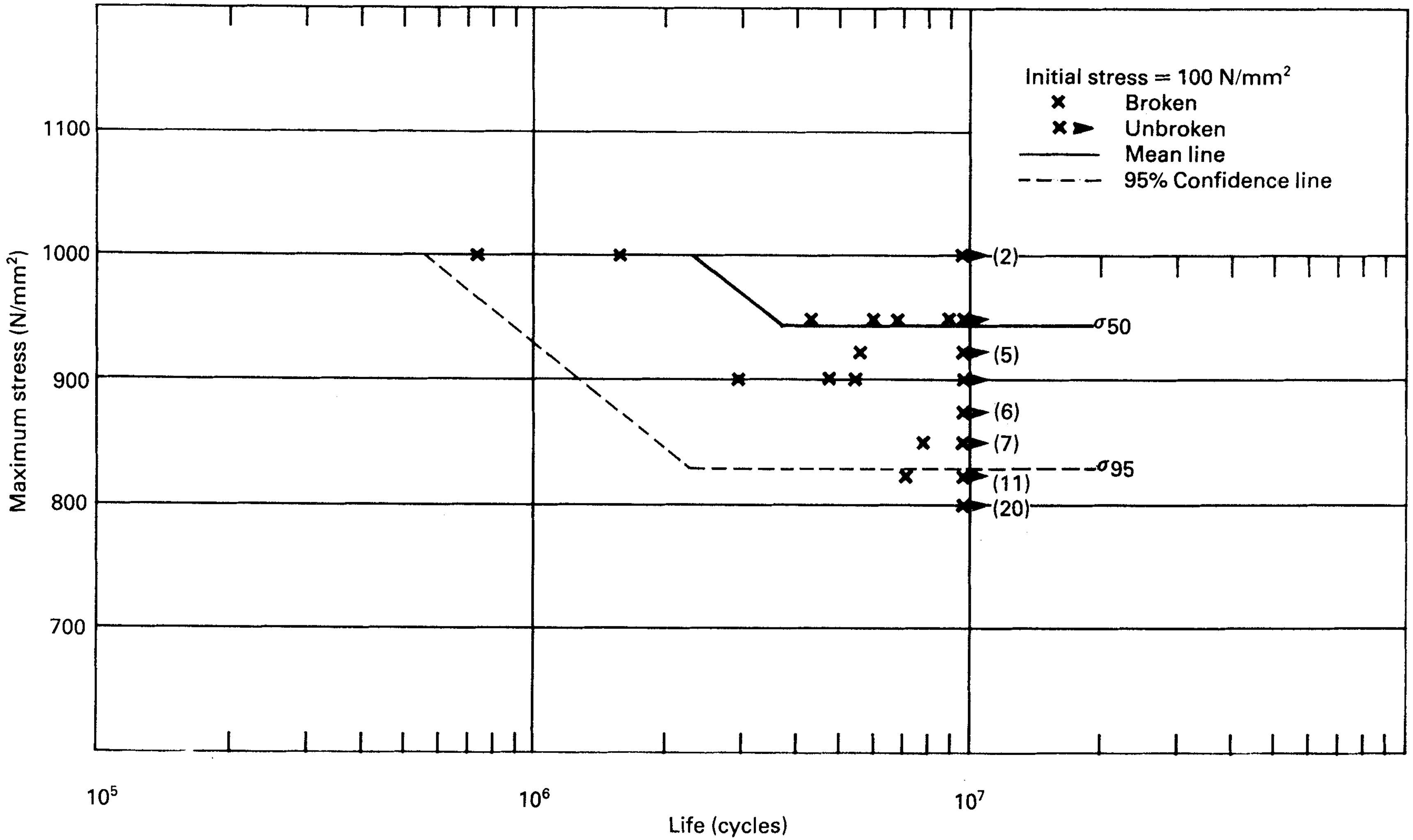

Fig 6: FATIGUE RESULTS FOR SPRINGS SHOT PEENED USING S110 SHOT

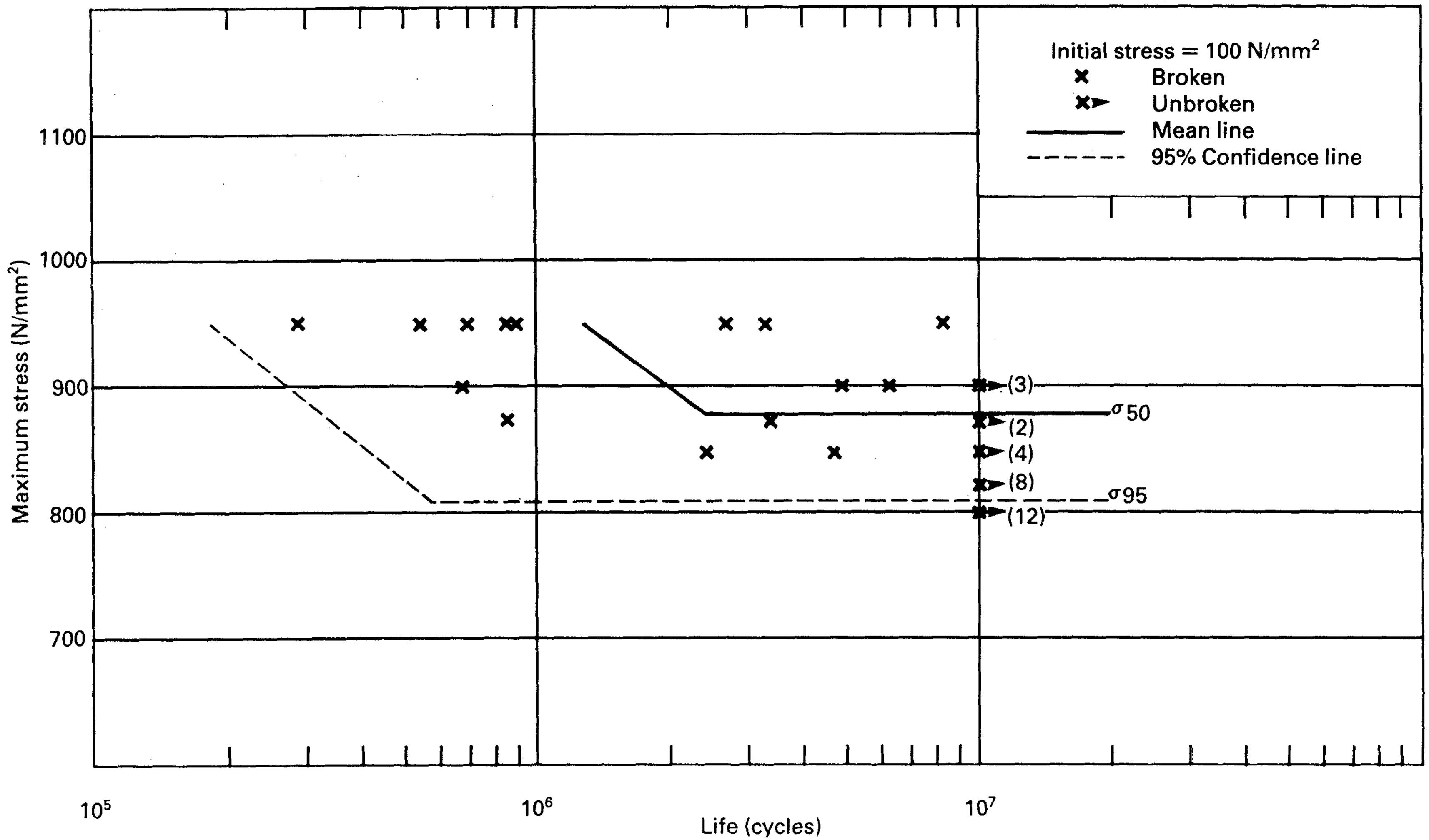

Fig 7: FATIGUE RESULTS FOR SPRINGS PEENED USING GLASS BEADS

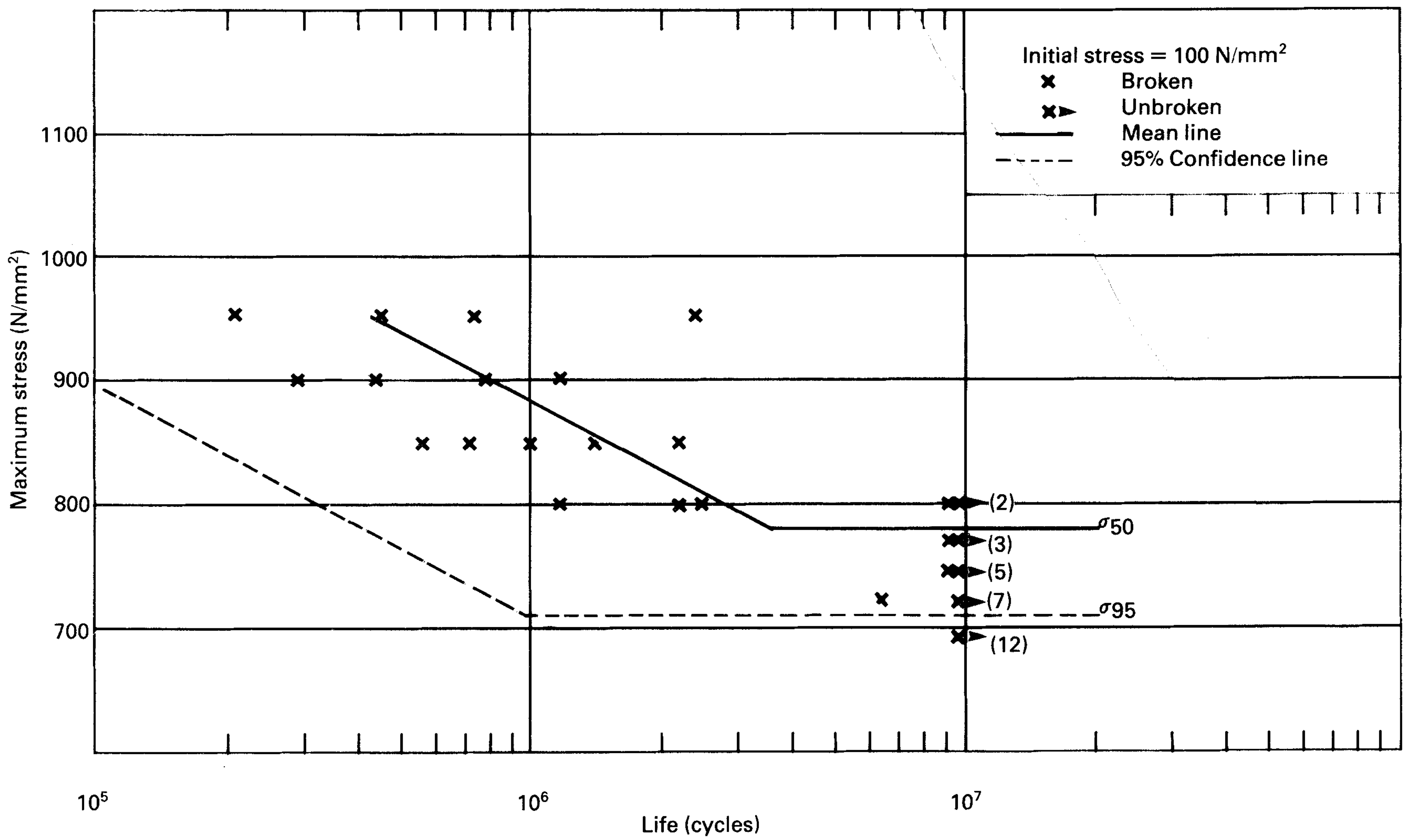

Fig 8: FATIGUE RESULTS FOR AQUABLASTED SPRINGS

SEM PHOTOMICROGRAPHS

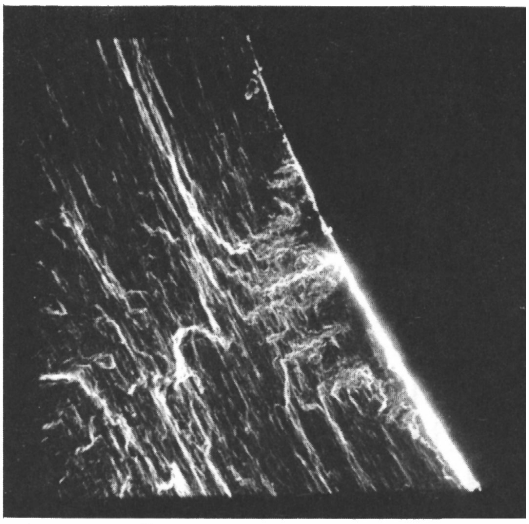

Figure 9 X 69

Typical fatigue fracture of spring shot peened using S070 shot.

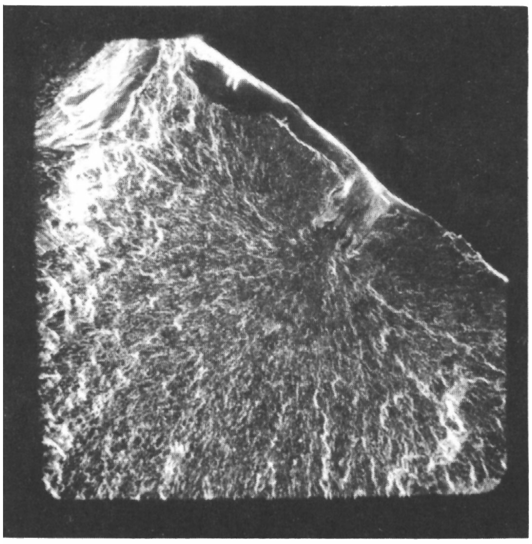

Figure 10 X 180

Typical fatigue fracture of spring shot peened using S110 shot.

SEM PHOTOMICROGRAPHS

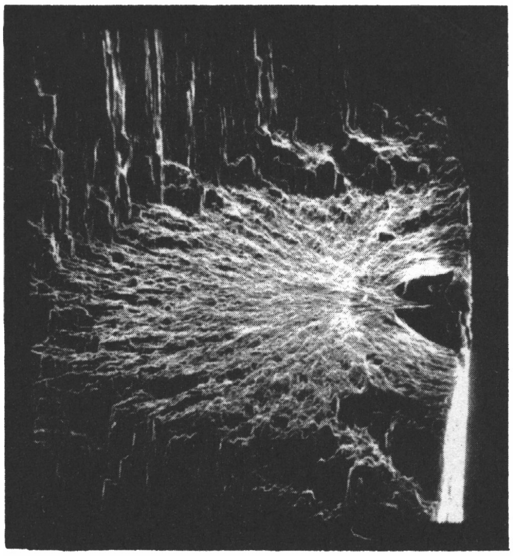

Figure 11 X 114

Typical fatigue fracture of spring peened using glass beads.

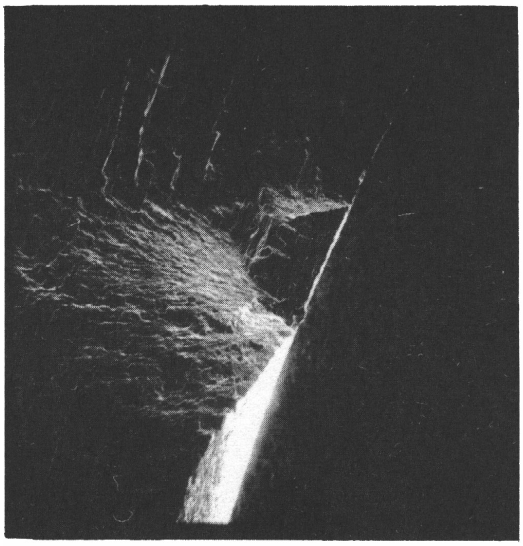

Figure 12 X 60

Typical fatigue fracture of Aquablasted spring.

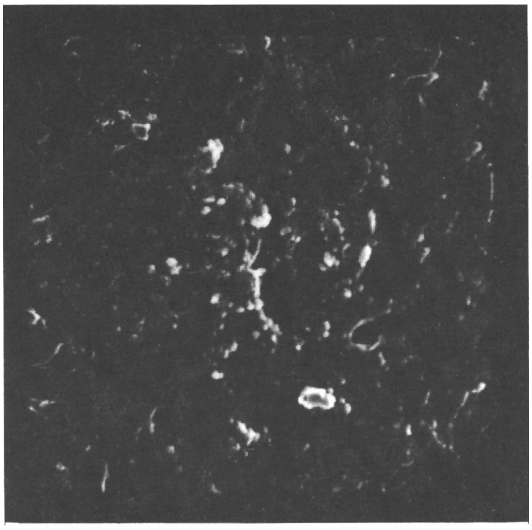

Figure 13 X 570

Wire surface of Aquablasted spring adjacent to fracture origin to show corrosion products.