THE SPRING RESEARCH AND MANUFACTURERS' ASSOCIATION

THE EFFECT OF LOW TEMPERATURE HEAT TREATMENT PARAMETERS ON THE FATIGUE PERFORMANCE OF CHROME-VANADIUM HELICAL COMPRESSION SPRINGS

by

M O'Malley B.Sc.

Report No 421

APRIL 1988

Report No 421

THE EFFECT OF LOW TEMPERATURE HEAT TREATMENT PARAMETERS ON THE FATIGUE PERFORMANCE OF CHROME-VANADIUM HELICAL COMPRESSION SPRINGS

SUMMARY

The Association has conducted an investigation into the effects of varying the low temperature heat treatment temperature on the fatigue performance of unpeened and shotpeened chrome-vanadium helical compression springs. The investigation also included a comparison of the effects of on-line versus batch heat treatment procedures.

The results indicate that, although statistically there is no difference between the fatigue properties of springs heat treated at the various temperatures and by the two types of treatment, there is a suggestion that optimum fatigue performance is obtained by batch heat treatment at 400°C.

APRIL 1988

CONTENTS

THE EFFECT OF LOW TEMPERATURE HEAT TREATMENT PARAMETERS ON THE FATIGUE PERFORMANCE OF CHROME-VANADIUM HELICAL COMPRESSION SPRINGS

1. INTRODUCTION

The low temperature heat treatment of cold coiled springs is a process widely practised in the spring industry since it has a beneficial effect on spring performance by relieving residual coiling stresses. Although the effect of low temperature heat treatment on springs produced from oil-hardened and tempered wire is not so great as that on springs coiled from patented cold drawn wire, where both the relief of residual wire drawing stresses and an ageing mechanism contribute to a significant increase in the elastic properties of the wire, the benefits of low temperature heat treatment are still significant. By optimising the low temperature heat treatment parameters, the springmaker can produce the best spring performance for his customer at the lowest cost.

For chrome-vanadium material, SRAMA's current recommendation of 350-450°C is based on industrial practice and assumes a batch treatment of 30 minutes at temperature. However, in order to speed spring production, manufacturers are now moving over to on-line heat treatment using shorter processing times but higher temperatures. It was, therefore, felt that an investigation should be undertaken to determine the effects of low temperature heat treatment on the fatigue performance of chrome-vanadium springs, and to compare the effects of batch heat treatment with on-line heat treatment. It was also felt that an assessment of the effects of low temperature heat treatment parameters on the spring performance after subsequent shot peening would be useful.

2. MATERIALS AND SPRING DESIGNS

The wire used for the investigation was 2.5 mm diameter BS 2803 730A65, ie a low chrome-vanadium grade. The specified chemical composition and tensile strength for this type of material are given in Tables I and II respectively, together with the actual composition and mechanical properties of the wire under test.

A batch of 200 springs was coiled to the design given in Table III. The springs were divided into 4 equal sets; 3 sets were given batch heat treatments of 300, 350 and 400°C for 30 minutes, and the fourth set was given an on-line heat treatment of 450°C for 5 minutes - this treatment being similar to current industrial practice. The furnace temperatures were checked by means of an independent, calibrated digital thermometer fitted with a roving thermocouple: for the batch treatments, the furnaces were within ± 5°C of the required temperatures, and for the on-line furnace, the temperature distribution was as illustrated in Figure 1.

After heat treatment the springs were all end ground, and then approximately half the number of springs of each set were shot peened using S230 shot, followed by stress relief of 220°C for 30 minutes. In order to ensure that the springs received identical shot peening treatments, the four sets were individually identified and then all peened together.

All the springs, both unpeened and shot peened, were prestressed repeatedly to solid prior to testing in order to stabilise them.

3. TESTING PROCEDURE

Springs for fatigue testing were individually load tested to determine the deflection necessary to produce the required stresses in the spring. Fatigue tests were carried out using the Association's single station forced motion fatigue testing machines.

A series of initial tests was conducted on a small number of both unpeened and shot peened springs using an initial stress level of 100 N/mm² and a range of maximum stress levels, in order to establish the most suitable maximum stress level for the bulk of the fatigue testing. The criterion used for deciding on this maximum stress level was that the fatigue lives for the majority of the springs would be between 10^5 and 10^7 cycles. The maximum stress levels thus established were 850 and 1100 N/mm² for the unpeened and shotpeened springs respectively.

Larger batches of springs from each of the four heat treatment sets were then fatigue tested, and the results of the testing are presented in Figures 2 and 3 for the unpeened and shot peened springs respectively.

4. DISCUSSION OF RESULTS

The test results were analysed using the Weibull method of analysis and the results of this analysis are given in Tables IV and V for the unpeened and shot peened springs respectively. A detailed description of the Weibull method of analysis is given in a previous report.(1)

The results of the analyses indicate that, statistically, there is no significant difference in the performance of the four sets of springs in the unpeened and shot peened conditions. This suggests that low temperature heat treatment parameters are not a major influence on the fatigue performance of chrome-vanadium material.

However, from examination of the figures quoted in Table IV for the B_{10} life of unpeened springs, it will be seen that there appears to be a definite improvement in the B_{10} life as the batch treatment temperature increases. It could be assumed, therefore, that low temperature heat treatment may have some influence in increaseing the minimum fatigue life of unpeened chrome-vanadium springs, although the scatter of the results eliminates the statistical validation of this assumption.

For the shot peened springs, it can be seen from Table V that there is only a slight increase in the B_{10} life as the batch low temperature heat treatment temperature increases. This is probably due to the fact that major improvements in the fatigue performance caused by the shot peening operation have masked the effects of the heat treatment differences. It was noted that the shot peening process reduced the amount of scatter on the results.

From these results for batch heat treatment of chrome-vanadium springs, 400°C appears to be the most suitable heat treatment temperature for producing optimum fatigue performance.

For the springs heat treated using the on-line method, it can be seen that their fatigue performance is not markedly different from that of the batch treated springs, indicating that this method of heat treatment will adequately stress relieve chrome-vanadium springs.

The overall findings of the work suggest that, for critical applications where shot peened chrome-vanadium springs would be operating in fatigue, the optimum performance would be obtained by batch stress relieving at 400°C; but neither variation in the low temperature heat treatment temperature away from this optimum nor using on-line treatment should adversely affect the fatigue performance to any great extent. For unpeened springs, on the other hand, variation in the heat treatment parameters away from the optimum could result in poorer fatigue performance.

5. CONCLUSIONS

1 The results of the testing indicate that, statistically, there is no difference in the fatigue performance of unpeened or shot peened chrome-vanadium springs when heat treated at various temperatures.

2 The results do suggest that, for unpeened springs, the optimum fatigue performance might be obtained by heat treating at 400°C although the improvement in fatigue performance is small.

3 The fatigue performance of springs heat treated using on-line methods was no different, statistically, from that of batch heat treated springs.

6 RECOMMENDATIONS

The results of this investigation suggest that springmakers may be able to utilise lower LTHT temperatures for chrome-vanadium springs. It would, therefore, be worthwhile extending this work to confirm the findings and to assess whether or not there is a similar effect on the fatigue limit for survival to 10^7 cycles, as any possible reduction in the low temperature heat treatment parameters could result in a worthwhile cost saving for the spring manufacturer.

7. REFERENCE

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

8. ACKNOWLEDGEMENT

The author wishes to thank Heath Springs Limited for their assistance in conducting these heat treatment trials.

TABLE I CHEMICAL COMPOSITION

	Composition (%)						
	C	Si	Mn	S	P	Cr	V
Specified	0.57- 0.72	0.15- 0.30	0.5- 0.9	0.025 max	0.03 max	0.35- 0.60	0.1- 0.3
Actual	0.70	0.19	0.51	0.015	0.016	0.54	0.23

TABLE II MECHANICAL PROPERTIES

Property	Specified	Actual
Tensile strength (N/mm^2)	1710-1860	1780
Limited Proportionality (N/mm^2)	-	720
0.05% Proof Stress (N/mm^2)	-	1635
0.1% Proof Stress (N/mm^2)	-	1680
0.2% Proof Stress (N/mm^2)	-	1705
Elongation (%)	-	6.0
Reduction in Area (%)	-	48.3

TABLE III SPRING DESIGN

Wire Diameter (mm)	2.5
Outside Diameter (mm)	20.0
Spring Index	7.0
Free Length after End Grinding, LTHT and Prestressing (mm)	33.6
Spring Rate (N/mm²)	20.6
Total Coils	5½
Active Coils	3½
Ends	Closed and Ground

TABLE IV RESULTS OF WEIBULL ANALYSIS OF UNPEENED SPRINGS

Heat Treatment	Weibull Slope	B10Life	95% Lower Confidence Limit on B10 Life
300°C for ½ hr	10.53	112,626	96,238
350°C for ½ hr	12.07	148,559	129,499
400°C for ½ hr	2.67	198,643	106,932
450°C for 5 minutes	36.74	112,204	107,256

TABLE V RESULTS OF WEIBULL ANALYSIS OF SHOT PEENED SPRINGS

Heat Treatment	Weibull Slope	B10 Life	95% Lower Confidence Limit on B10 Life
300°C for ½ hr	6.15	110,665	84,534
350°C for ½ hr	5.17	115,473	83,813
400°C for ½ hr	4.97	129,363	92,714
450°C for 5 mins	6.21	116,107	88,905

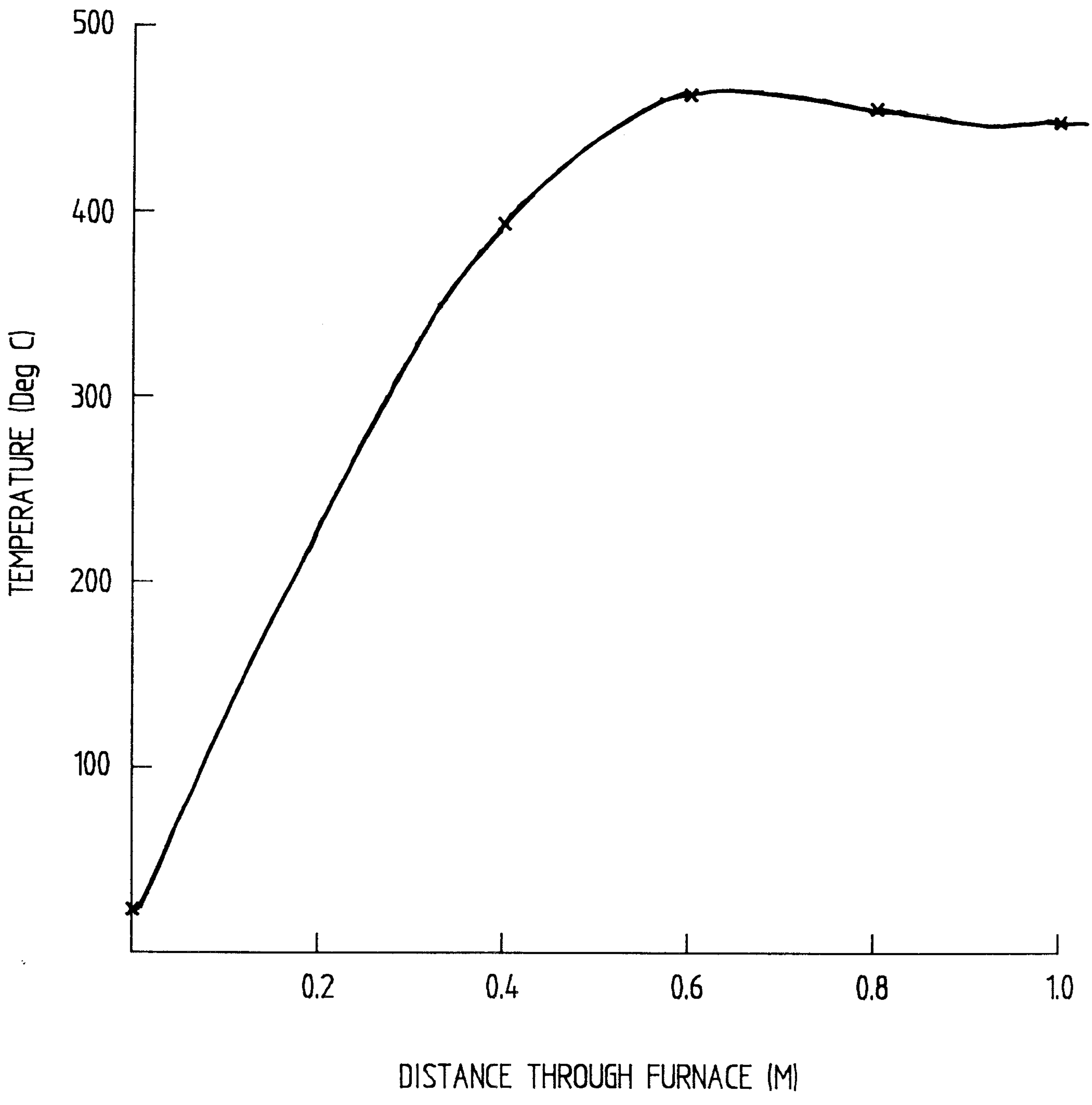

Fig 1: TEMPERATURE PROFILE FOR ON-LINE FURNACE

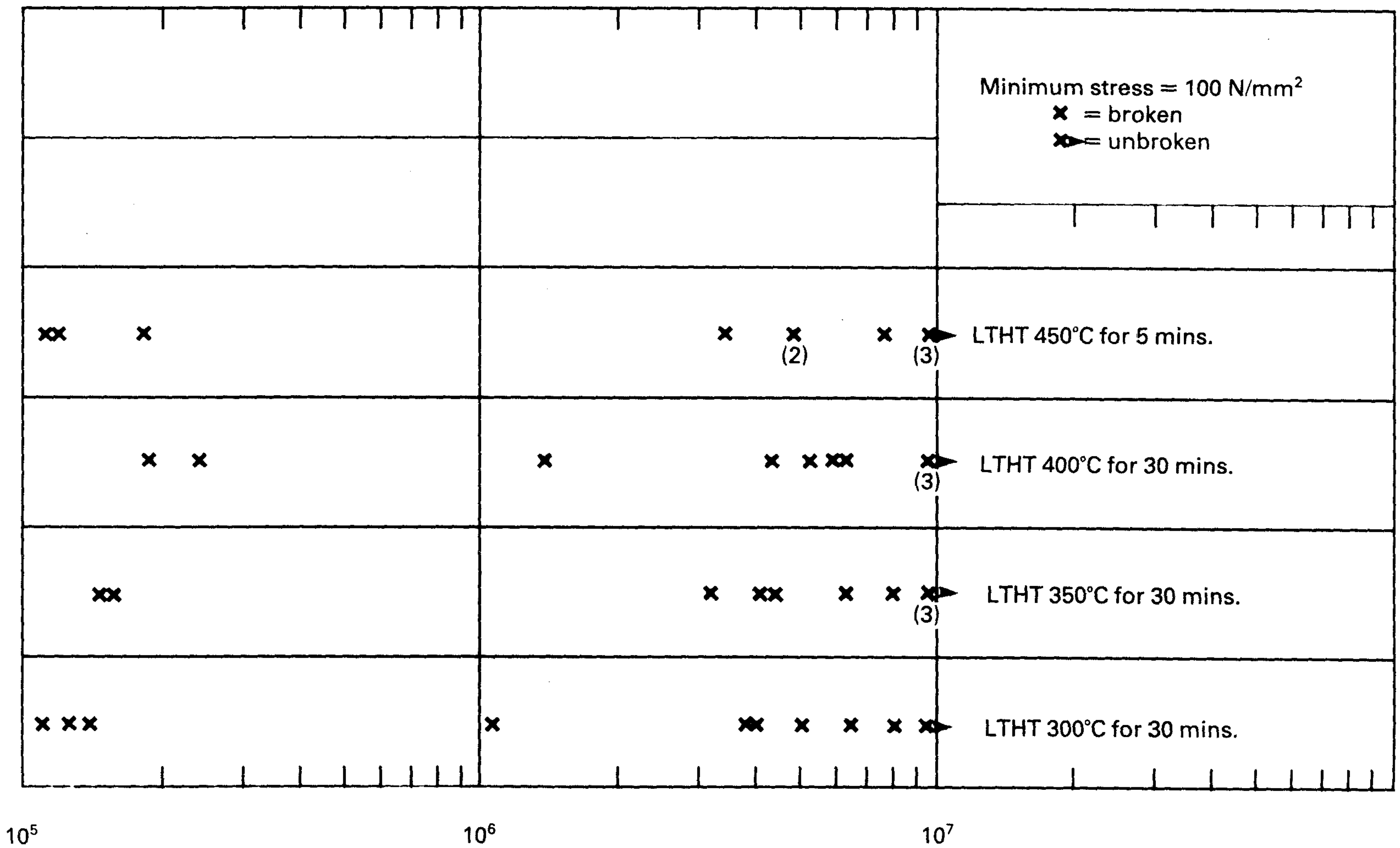

Fig 2: FATIGUE RESULTS FOR UNPEENED CHROME-VANADIUM COMPRESSION SPRINGS AT A MAXIMUM STRESS OF 850 N/mm^2

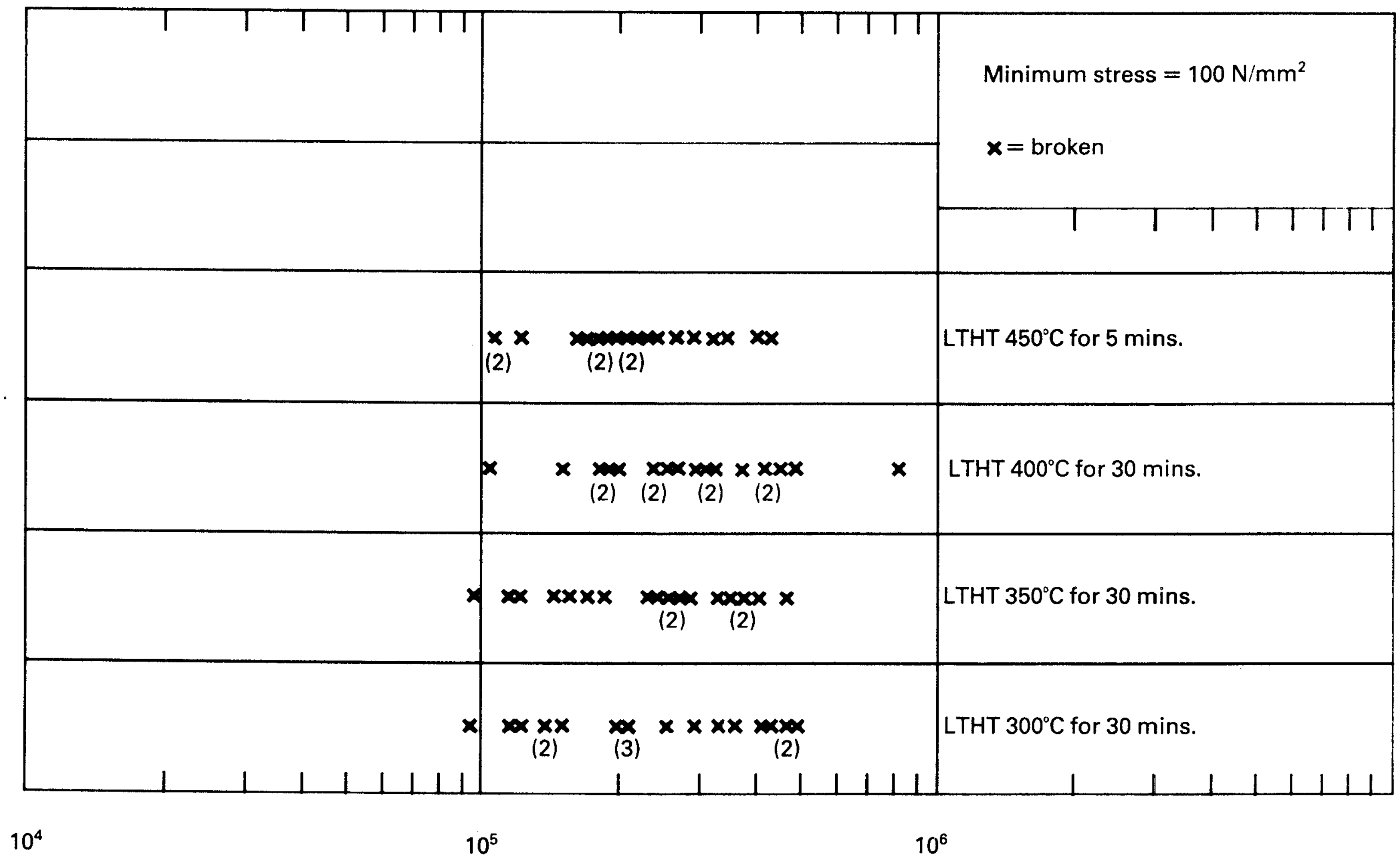

Fig 3: FATIGUE RESULTS FOR SHOT PEENED CHROME-VANADIUM COMPRESSION SPRINGS AT A MAXIMUM STRESS OF 1100 N/mm^2