THE SPRING MANUFACTURERS' RESEARCH ASSOCIATION

The Effect of Industrial Processing and Surface Treatments on the Fatigue Strength of Hot-Formed Springs

First Progress Report

Report No. 147

by

J.W. Mee, A.Met., A.I.M.

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(War Office Contract No. 70/GEN/9496)

First Progress Report
(The Research Programme)

Summary

The present programme of research is a continuation of previous work carried out for F.V.R.D.E. A total of 165 springs in 11 batches will be manufactured from En 45 silicon manganese acid O.H. steel. The springs will be fatigue tested to determine the effect of: shot-peening, carbon restoration, carbon restoration and shot-peening, low-temperature heat treatment after scragging, scragging to limited stress levels, use of black bar material, variation of silicon content, and variation of spring index.

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1. INTRODUCTION

A programme of research has been planned in order to extend the scope of the earlier work which was carried out in collaboration with the War Office (F.V.R.D.E.) In the earlier research, the effect of carbon restoration and shot-peening on the fatigue properties of hot-formed springs made from silicon manganese (En 45) steel and carbon steels (En 42 and En 44) was investigated. The S.M.R.A. determined the fatigue properties of 54 different batches of springs, the metallurgical examination of which was carried out by F.V.R.D.E. From the results, reported by the War Office(1) and by the S.M.R.A.(2) it was evident that to obtain maximum fatigue strength :

a) there should be no stress raisers in the bar material, i.e. ground bar should be used,

b) there should be no decarburisation of the finished spring; this can be achieved by carbon restoration prior to hardening,

c) shot-peening must be carried out under controlled conditions to produce a high peening intensity.

The main limitations of the results obtained were, firstly that the shot-peening treatment applied was not sufficiently intensive, secondly, by contract requirement the fatigue tests were discontinued at 0.5×10^6 cycles which prevented a clear determination of fatigue limit and thirdly, that only one cast of each type of steel was investigated.

These limitations will be overcome in the present research programme. The shot-peening will be more intensive than before, the fatigue tests will be continued to 10^7 cycles and two casts of steel will be employed.

The shot-peening will be carried out to an intensity of 0 015 to 0 022 in arc-rise on Almen 'A' strips.

To compare the effect on fatigue properties of carbon restoration and shot-peening of springs made from both black and ground bar, one batch of black bar springs will be included in the programme.

Variation in cast analysis, particularly silicon, may affect the degree of decarburisation during coiling and during heating for coiling and therefore, change the required carbon restoration conditions. One batch of springs will be made from ground bar with a higher silicon content than the main cast and near to the upper limit for En.45.

Spring index may affect the fatigue properties and this factor will therefore be investigated at 3 levels. As a new fatigue testing machine will be available for test springs of a greater mean diameter than that used in the earlier research higher indexes than before are included in the programme.

Tests carried out by Pope and Andrew[3] showed that, compared with scragging a spring solid, a higher solid stress could be achieved by scragging to a limited stress and applying a low temperature heat-treatment to raise the elastic limit to a level at or above the stress at which the spring would not set if compressed solid. A limited number of tests on railway buffer springs[4] indicated that a higher fatigue life might be obtainable on fully scragged springs if they were low temperature heat-treated after scragging In the present research the treatment will first be applied to a batch of ground bar carbon restored springs to determine its effect on the fatigue limit The effect of limited scragging to two levels of stress followed by low temperature heat treatment will then be investigated

2. OBJECTS OF THE RESEARCH

Springs made from ground bar En.45 silicon manganese acid open hearth steel will be fatigue tested and the results will be used as a basis of comparison to determine the effect of the following variables on fatigue limit.

(a) Shot-peening
(b) Carbon restoration prior to hardening
(c) Carbon restoration and shot-peening
(d) Low temperature heat treatment after scragging carbon restored springs

(e) Limited prestressing (at 2 levels) and low temperature heat-treatment of carbon restored springs

(f) The use of black bar material for carbon restored and shot-peened springs

(g) The use of a higher silicon content ground bar for carbon restored and shot-peened springs

(h) Change of index of carbon restored and shot-peened springs

3. SCHEDULE OF SPRINGS

3 1 Spring Designs

The 3 spring designs are given in Table I

3 2 Spring Manufacture

A complete schedule of the manufacturing procedure for each batch of springs is given in Table II

Samples of bar material will be taken from cast A black bar and ground bar and cast B ground bar (3 samples 1 foot long from each) to check for decarburisation and surface defects.

Control bars, 1 foot long, will be heated with the spring bars for batches 3 to 11 in the coiling furnace (5 control bars per batch) and despatched with the springs for carbon restoration.

Coiling of all the springs will be from a temperature of 900°C

Descaling by lightly shot-peening will be carried out on all the springs after coiling and on the control bars. Springs and control bars for carbon restoration will be oiled for protection from corrosion during transit.

Carbon restoration conditions will be determined by Birlec Ltd from metallographic examination of the control bars. Carbon restoration and hardening from 915°C will be in a batch type "sealed quench" furnace Partial tempering will follow immediately at 250°C for 1 hour. The springs will then be returned to the springmaker for full tempering and subsequent processing.

Hardening of springs which are not to be carbon restored will be from a reheating furnace at 915°C into oil.

Tempering of all springs will be for 1 hour at 480 - 490°C.

Scragging of batches 6 and 7 will be to the appropriate loads for stresses of 60 and 70 tonf/in^2 respectively. All other springs will be fully scragged.

Low temperature heat treatment after scragging, (250°C for 1 hour) will be applied to batch nos. 4, 6 and 7. Shot-peening of batch nos. 2, 5, 8, 9, 10 and 11 will be to an intensity of 0.015 to 0.022 in arc-rise on an Almen 'A' strip and using 0.030 to 0.040 in. diam conditioned cut-wire shot. Three Almen tests will be taken with each batch of shot-peened springs.

Protection of finished springs will be by phosphating to D.T.D.934, by baking at 150 - 210°C for 4 hours and oiling.

3.3 Reserve of Material

To facilitate the manufacture of complete replacement of all the batches of springs, a reserve of material is being held in billet form

4 THE TESTING PROGRAMME

4.1 Examination of bar stock

Samples of the 3 types of bar stock to be used will be examined for decarburisation and surface defects before the springs are manufactured.

4.2 Load testing of springs

For testing on the radial fatigue testing rig each spring will be load tested to obtain the test lengths for an initial stress of 5 tonf/in^2 and the particular maximum stress required. Load testing will not be necessary on springs which are to be tested on the new resonance fatigue testing machine as the initial and maximum stresses will be determined dynamically.

4.3 Fatigue testing

Batches of springs will be fatigue tested as far as possible in numerical order. A fatigue limit will be obtained for each batch with at least two springs unbroken at 10^7 cycles at stresses near to but below the fatigue limit.

4.4 Examination of broken springs

Metallurgical examination of selected springs and control bars will be undertaken as the fatigue test on each batch of springs is completed.

5. REFERENCES

1. F.V.R.D.E. Report No. M56M, 11th April, 1962
2. C.M. Somerton and J.W. Mee, S.M.R.A. Report No. 135, July 1962
3. J.A. Pope and J.E. Andrew, Coil Spring Journal No. 14, March 1949, pp 6 - 13.
4. J.W. Mee, Coil Spring Journal No. 27, June 1952, pp.32-34.

Table I Designs of test springs

	Design 1*	Design 2	Design 3
Bar diam 'd' in	1.04	1.04	1.04
Spring mean diam 'D' in	3.5	4.52	5.77
Spring index 'c' = $\frac{D}{d}$	3.37	4.35	5.55
Correction factor 'K'	1.51	1.36	1.26
Effective coils 'n'	13.5	7	4
Length free in.	20.28	13.32	10.2
Length solid in.	15.08	8.32	5.2
Solid stress tonf/in^2	80	80	80

*Also the design of earlier F.V.R.D.E. springs

Table II Spring Manufacturing Schedule

Spring Design	No. 1									No. 2	No. 3
Material	Cast 'A' - Ground Bar							Cast 'A' Black Bar	Cast 'B' Ground Bar	Cast 'A' Ground Bar	
Details of manufacture											
Batch No	1	2	3	4	5	6	7	8	9	10	11
Heat to 900°C and coil	x	x	x	x	x	x	x	x	x	x	x
Descale by light shot-peen	x	x	x	x	x	x	x	x	x	x	x
Reheat at 915°C for hardening	x	x									
Carbon restore at 915°C			x	x	x	x	x	x	x	x	x
Oil harden	x	x	x	x	x	x	x	x	x	x	x
Partial temper at 250°C for 1 hour			x	x	x	x	x	x	x	x	x
Fully temper at 480-490°C for 1 hour	x	x	x	x	x	x	x	x	x	x	x
Scrag solid	x	x	x	x	x			x	x	x	x
Scrag to 60 tonf/in^2						x					
Scrag to 70 tonf/in^2							x				
L T H T at 250°C for 1 hour				x		x	x				
Shot-peen		x			x			x	x	x	x
Phosphate, bake and oil	x	x	x	x	x	x	x	x	x	x	x
Number of springs	15	15	15	15	15	15	15	15	15	15	15

Cast A - En.45 with 1.7 - 1.8% Si

Cast B - En.45 with 1.9 - 2.0% Si