THE SPRING RESEARCH AND MANUFACTURERS' ASSOCIATION

FATIGUE TESTING OF CLOCK TYPE SPRINGS

Report No 383

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SUMMARY

A number of clock type springs of differing designs have been fatigue tested in order to determine the effect of stress level on fatigue life.

The results obtained indicate the need for caution when deciding acceptable stress levels for a given fatigue life. In addition, it was found that material surface condition can have a greater effect on spring fatigue life than material edge condition.

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1. INTRODUCTION

The designer of clock type springs has to date been severely limited in his ability to design a clock type spring for a specified life because of the lack of fatigue data for this type of spring.

The biggest hurdle which had to be overcome to enable any data to be produced was the lack of suitable commercially available clock spring fatigue testing equipment. For this reason SRAMA undertook the design and manufacture of a purpose built machine (1) incorporating modern load measurement technology.

With the successful installation and commissioning of this machine this difficulty was removed and as a consequence this project has been undertaken, the object of which is to determine the fatigue performance of a range of commercially available springs.

2. SPRINGS TESTED

From various sources, twenty springs were obtained for testing. Eleven of these were of random design while the remainder were of one specific design. All springs employed identical end fixing arrangments (see Figs 1 and 2) albeit that the centre mandrel diameter varied for several of the random springs. Table 1 gives all details of the spring designs.

The springs were all tested in a 'cage', fitted to the machine, which would contain the spring fragments on failure. All springs were tested such that the spring material occupied as closely as possible 50% of the available area encompassed by the ouside diameter. Adjustment of the outside diameter to fulfill this requirement was accomplished by altering the position of the pins within the test cage defining the springs outside diameter.

3. PROCEDURE

Preliminary stress values were chosen so that with the fatigue test results it would be possible to produce an S-N curve for the clock springs for a minimum stress of 200 N/mm^2, and stress ranges of 1000, 1300 and 1600 N/mm^2. As testing progressed, and samples were received, there were several cases of springs not being able, even when wound up solid, to give the torque necessary to set up these stress ranges. Several springs therefore had to be tested at lower stress levels. For this reason, an additional stress range of 800 N/mm^2 was introduced for the minimum stress of 200 N/mm^2. In addition, four of the random design springs could only give a torque corresponding to a maximum stress of 650 N/mm^2. To test these springs from the minimum stress of 200 N/mm^2 would involve a very low stress range of 450 N/mm^2. These four springs were therefore tested from a minimum stress of 50 N/mm^2 over a stress range of 600 N/mm^2 up to a maximum stress of 650 N/mm^2.

For each spring, for the minimum and maximum stresses at which it was to be tested, the values of torque were calculated from the equation:

$$T = \frac{\sigma b t^2}{6}$$

The spring was then set up in the test machine for the specified test range. Values of A_1 and A_2 (Fig 3) were noted which correspond to the calculated torques of T_1 and T_2. As can be seen from Fig 3, the torque supplied by a clock spring on wind up in greater than that on wind down, due to friction between the turns. The spring was therefore wound up by a further amount and unwound, the torques T_3 and T_4 being recorded at positions A_2 and A_1 (Fig 3). This then allows values of the hysterises in the spring due to friction to be calculated. At position A_1 this is $H_{1-4} = T_1 - T_4$ and at position A_2, $H_{2-3} = T_2 - T_3$. To obtain true values of deflection which will set up the calculated values of torque T_1 and T_2, allowing for hysterises, the spring was then wound up to a torque of $T_2 + 0.5 \times H_{2-3}$ and then unwound to a torque of $T_1 - 0.5 \times H_{1-4}$. Values of angle of rotation of A_3 and A_4 were noted for these torque values (Fig 3).

Testing was then commenced by winding the springs up to the first deflection position A_3 and setting the machine to automatically cycle through an angle of $(A_3 - A_4)^{\circ}$.

The failure detection circuit consists of a system which compares the maximum value of torque registered every cycle with a preset value (set to be just less than T_2) and which stops the test should this preset value not be registered within a specified time period. Therefore, when a spring fails and the torque it gives is reduced, the machine will automatically switch off and hold the cycle count.

4. RESULTS AND DISCUSSION

The fatigue test results are summarised in Table II along with details of stress levels and mode of failure. Fig 4 shows a plot of maximum stress against fatigue life for those springs tested from a minimum stress of 200 N/mm^2.

The overall lives of springs 1 to 11 were much lower than anticipated, an important result when it is considered that many of these springs were multiple origin fatigue failures rather than defect induced failures.

It is however noticeable that the ratio of mandrel diameter to strip thickness (d/t in Table I) is not less than the maximum value of 15 to 25 recommended for avoiding excessive stress levels in the inner turns of the spring. The ratio of strip length to strip thickness (L/t in Table I) is within the maximum value of 15000 over which excessive frictional effects can be induced.

Springs 12 to 20 exhibited increased lives more typical of what was expected and in addition tend to exhibit a normal fatigue trend on the S-N curve despite the fact that the exact failure origin could not be determined in many cases.

It had been envisaged that the majority of the failures would occur in the inner fixing zone due to the stress concentrating effect of the fixing bend. However, none of the springs failed at this point, the majority of the failures occurring well into the active portion of the spring.

A further notable finding was that all failures had initiated on the tensile face of the material rather than on the edge of the strip suggesting that the importance of edge condition may have been overestimated. Figure 5 shows a typical fatigue fracture surface - several transverse cracks running across the springs tensile surface. Figures 6 and 7 show respectively a surface pit and drawing mark, both of which are possible fracture initiation sites. Figure 8 shows surface damage, probably post failure, which has obscured the failure origin.

Hardness tests, the average results of which are given in Table I, were carried out on one spring of each design. Surprisingly the values obtained show no obvious correlation with fatigue life, ie the harder materials do not necessarily exhibit a greater fatigue life.

Consideration of all the results obtained seems to imply that when producing fatigue data for clock type springs it is not possible to compare unlike springs on an S-N curve. Differences in spring design in terms of heat treatment, surface quality and material type may affect fatigue life.

5. CONCLUSIONS

1. Based on the fatigue lives obtained, designers should be very cautious when deciding upon acceptable operating stress levels for a given operating life. In general, typical operating stress levels in clock springs produce very low fatigue lives (average 17,000 cycles).

2. Correctly manufactured inner fixing points of the type used (shown in Fig 1) will not fail in fatigue applications. In addition, failure at the outer fixing point of the type used (Fig 2) is unlikely due to its inherent low stress condition.

3. The importance of material edge condition may previously have been overestimated - material surface condition can have a more pronounced effect on spring fatigue life.

4. In the absence of design data for clock springs and in the light of the information produced by this study, manufacturers or users of clock springs would be advised to life test sample springs for fatigue performance before going into volume production.

6. REFERENCES

1. Rushton, C J, "Clock Spring Fatigue Testing Machine". SRAMA Report No 368.

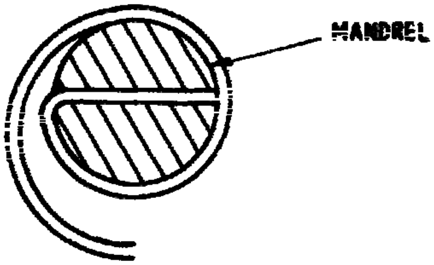

FIG. 1. INNER FIXING POINT.

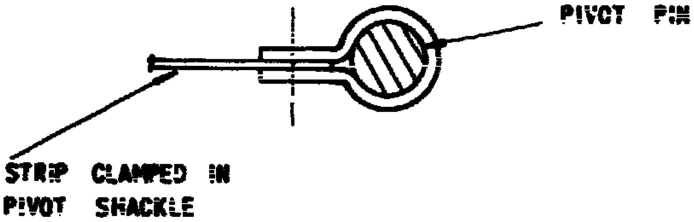

FIG. 2. OUTER FIXING POINT.

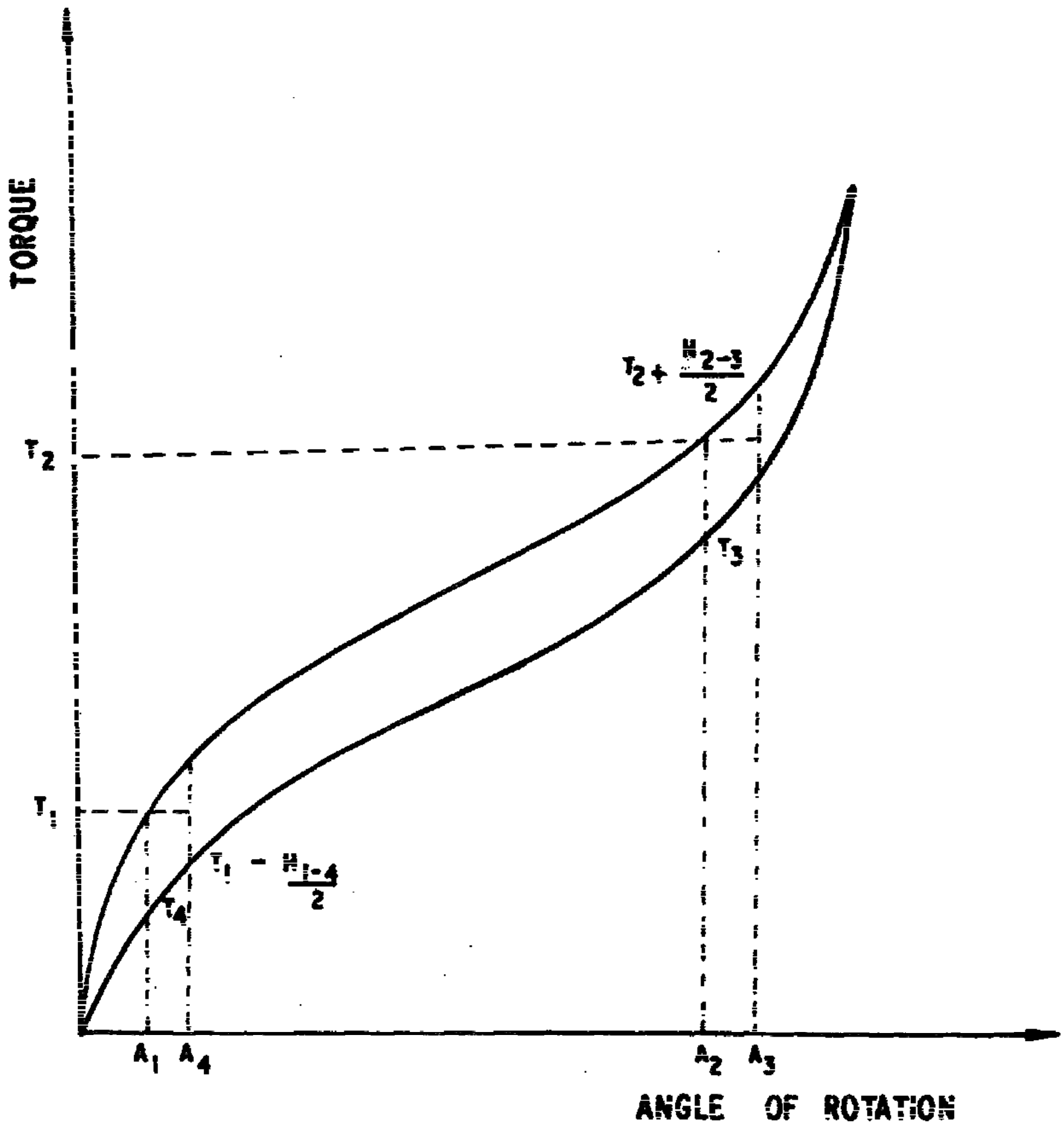

FIG. 3. CLOCK SPRING TORQUE CURVE.

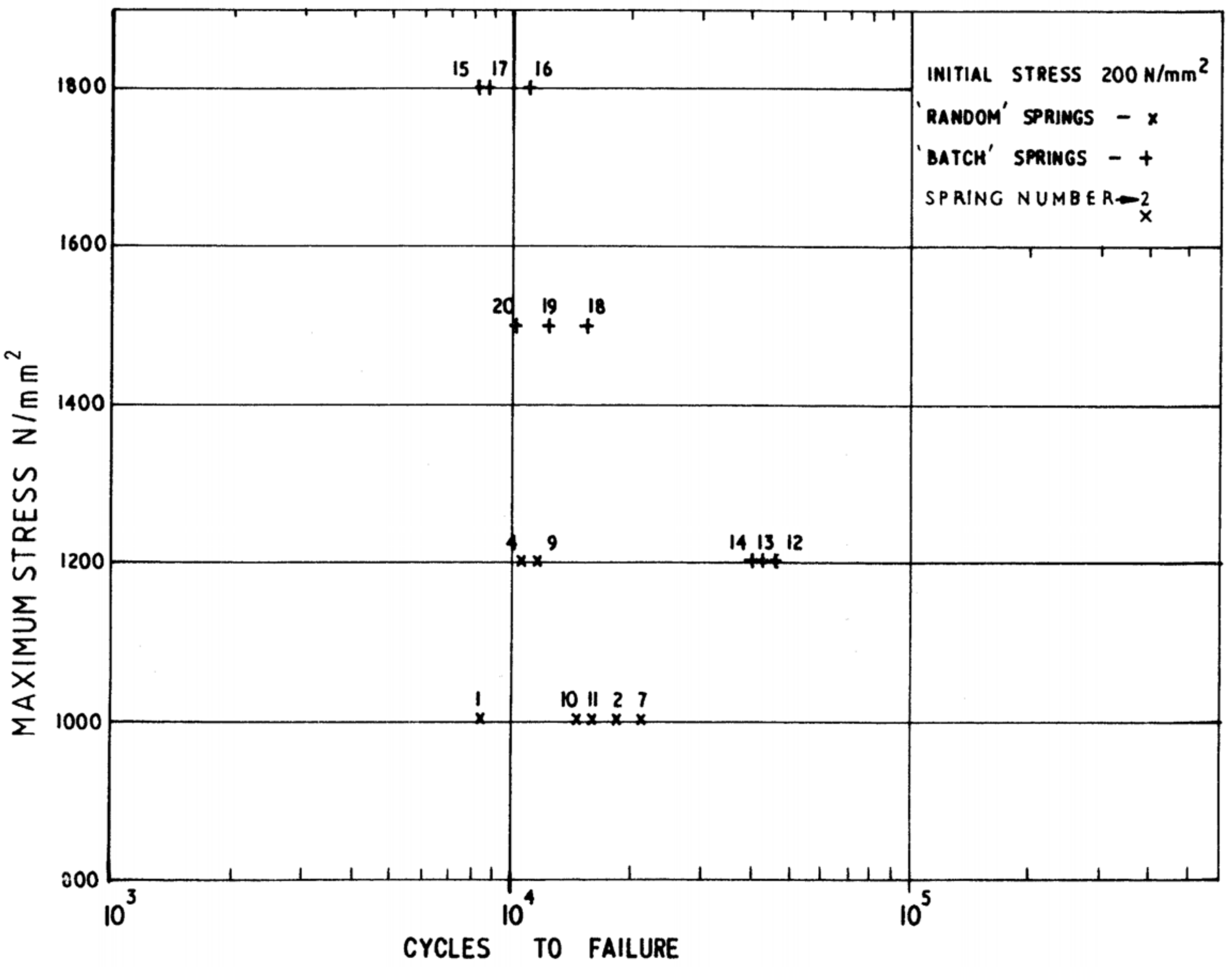

FIG. 4. PLOT OF MAXIMUM STRESS/ LIFE FOR CLOCK SPRINGS.

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Fig 5 Mag x 55

Typical fracture surface.

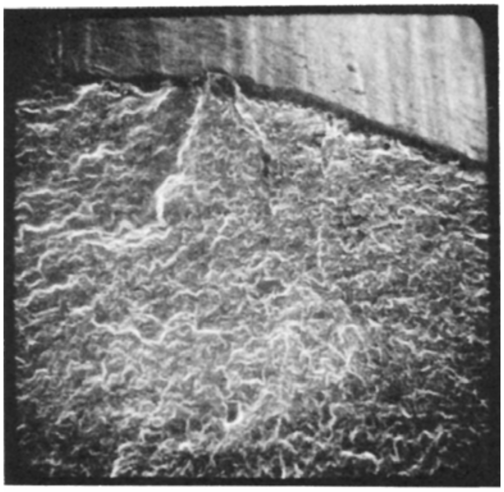

Fig 6 Mag x 160

Failure due to surface defect (pit).

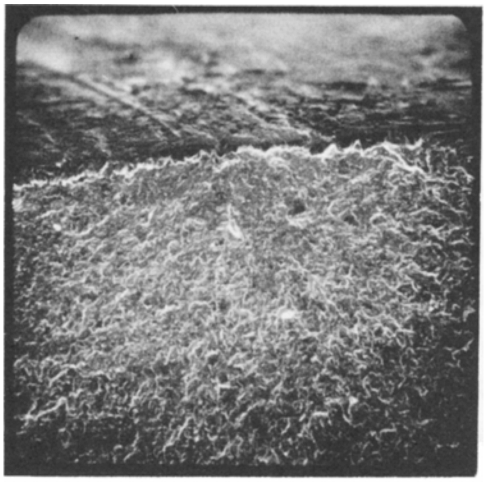

Fig 7 Mag x 145

Failure due to drawing mark.

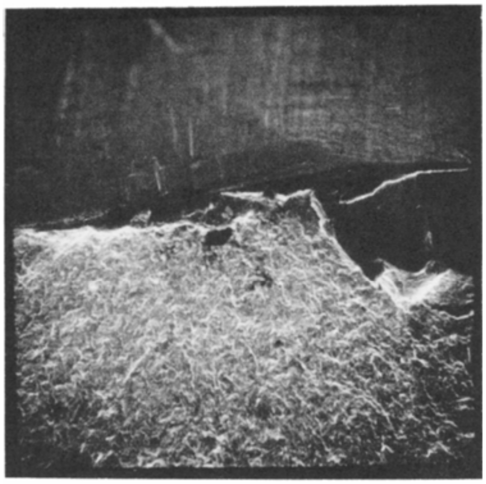

Fig 8 Mag x 160

Failure due to surface damage.

TABLE I SPRING DESIGN DETAILS

Spring No	Section Size (mm)		Caged Dia D_o (mm)	Mandrel Dia d (mm)	$L/_t$	$\frac{d}{t}$
	b	t				
1	44.5	1.19	216	19.4	12816	16.3
2	44.5	1.19	216	19.4	12816	16.3
3	44.5	1.19	168	31.8	7536	26.7
4	38.1	1.70	219	50.8	6158	29.9
5	18.0	0.76	151	19.6	15220	25.8
6	18.0	0.76	151	19.6	15220	25.8
7	44.5	2.03	219	45.8	4365	22.6
8	38.1	1.25	127	25.4	3886	20.3
9	31.8	2.64	127	31.8	851	12.0
10	44.5	2.03	219	44.5	4376	21.9
11	28.6	2.03	260	52.6	6170	25.9
12	27.0	1.59	181	30.0	4942	18.9
13	27.0	1.59	181	30.0	4942	18.9
14	27.0	1.59	181	30.0	4942	18.9
15	27.0	1.59	181	30.0	4942	18.9
16	27.0	1.59	181	30.0	4942	18.9
17	27.0	1.59	181	30.0	4942	18.9
18	27.0	1.59	181	30.0	4942	18.9
19	27.0	1.59	181	30.0	4942	18.9
20	27.0	1.59	181	30.0	4942	18.9

TABLE II FATIGUE TEST RESULTS

Spring No	Stress Range	Life (Cycles)	Mode of Failure	Hardness Value (HV 10)
1	200-1000	8400	M	448-466
2	200-1000	18660	M	435-450
3	50- 650	32774	M	464-473
4	200-1200	10628	D	431-452
5	50- 650	6869	M	285-323
6	50- 650	6098	M	483-638
7	200-1000	21081	M	403-425
8	50- 650	4058	M	387-405
9	200-1200	11103	D	390-411
10	200-1000	14849	G	405-417
11	200-1000	16210	G	530-563
12	200-1200	45646	P	433-435
13	200-1200	41139	G	-
14	200-1200	40498	D	-
15	200-1800	8355	D	-
16	200-1800	10996	D	-
17	200-1800	8446	M	-
18	200-1500	15889	D	-
19	200-1500	12501	D	-
20	200-1500	10525	P	-

M = Multiple origin fatigue failure

D = Fracture intiated on tensile surface close to dressed edge - post failure damage obscurred origin

G = Fracture origin associated with groove on spring tensile surface, possible drawing mark, close to dressed edge

P = Fracture origin associated with pit on tensile surface close to dressed edge