THE SPRING RESEARCH ASSOCIATION

A Note on the Influence of Corrosion on the Fatigue Properties of Peened Springs made from 4mm Diameter S202 Wire

Report No. 182

by

T.Key
and
G.B. Graves, A.Met., A.I.M.

November 1970

THE SPRING RESEARCH ASSOCIATION

Report No: 182

A NOTE ON THE INFLUENCE OF CORROSION ON THE FATIGUE PROPERTIES OF PEENED SPRINGS MADE FROM 4 mm DIAMETER S202 WIRE

SUMMARY

An investigation has been carried out into the fatigue properties of springs made from 4 mm diameter S202 wire subjected to a corrosive environment for periods of 1 to 20 days. Test stresses were selected above and below the fatigue limit obtained on clean springs so that any change in properties would be immediately recognisable.

(November 1970)

CONTENTS

Report No: 182

A NOTE ON THE INFLUENCE OF CORROSION ON THE FATIGUE PROPERTIES OF PEENED SPRINGS MADE FROM 4 mm DIAMETER S202 WIRE

by

T. Key

and

G. B. Graves, A. Met., A.I.M.

1. INTRODUCTION

Data are available on the fatigue properties of materials fatigue tested in dry air (1) (2) (3), and also in a corrosive media (4) (5).). However, it would be desirable to know if a particular wire or spring, which had inadvertently corroded during manufacture or storage, would perform satisfactorily under dynamic conditions in a non-corrosive environment.

To this end a number of peened springs were taken and subjected to a corrosive atmosphere for periods of 1 to 20 days after which they were fatigue tested in dry air. Fatigue testing was also carried out on un-corroded springs to allow comparisons to be made.

2. EXPERIMENTAL WORK

2.1 Test Springs

A batch of 60 springs made from 4 mm diameter S202 wire was used.

The spring dimensions were as follows:-

Free length	50 mm
Total coils	5.5

Active coils	3.5
Wire diameter	4.0 mm
Mean diameter	28 mm
Rate	33 N/mm (188 lbf/in)
Solid stress	925 N/mm^2 (60 $tonf/in^2$)
Approximate weight	45 grams

All the springs were peened to 018/022 A2 and then protected with Croda Aquamove B immediately after manufacture; all were free from any corrosion.

A number of these un-corroded springs were used subsequently to obtain a datum S/N curve using an initial stress of 100 N/mm^2 (6.5 $tonf/in^2$).

2.2 Corrosion Treatment

The remaining 32 springs were then cleaned and divided into batches of eight. Each batch was then subjected to a corrosive environment in a humidity cabinet for 1, 5, 11 or 20 days and subsequently dried. The humidity cabinet contained distilled water and the environment was controlled at 100% relative humidity; cycling the temperature between 42°C and 48°C gave conditions of evaporation and condensation on the springs. All the springs were weighed before and after corroding, then stored in a freshly prepared desiccator until required for fatigue testing. The springs were weighed so that any change in mass could be detected. The springs were also visually examined to determine the percentage coverage of corrosion.

2.3 Fatigue Testing

Seven un-corroded springs were fatigue tested to provide S/N curve data from which two test stresses of 850 N/mm^2 (55 $tonf/in^2$) and 750 N/mm^2 (48.6 $tonf/in^2$) were chosen so that any change in the fatigue properties of the corroded springs would be immediately recognisable.

3. RESULTS

Fig. 1 shows, in the form of an S/N curve, the fatigue behaviour of un-corroded helical compression springs manufactured from S202 wire. Using an initial stress of 100 N/mm^2 (6.5 $tonf/in^2$) a fatigue strength of

785 N/mm^2 (51 tonf/in^2) at an endurance of 10^7 cycles is indicated when tested in dry air.

Figs. 2 to 5 illustrate the influence of corrosion on the endurance of springs when subjected to maximum stress levels of 750 and 850 N/mm^2 (48.6 and 55 tonf/in^2).

Table I gives the individual lives of corroded springs and Table II the changes in weight of the springs after being corroded for 1 to 20 days in a humidity cabinet. An estimate of the percentage area affected by corrosion is also given. These data are shown graphically in Fig. 6.

4. DISCUSSION

It is well known that the fatigue behaviour of a material is influenced by its surface condition since practically all fatigue failures start at the surface. Any component, therefore, which suffers from the effects of corrosion resulting in the formation of corrosion pits, which act as stress raisers, will be adversely affected when subjected to dynamic stressing. Although the reduction in fatigue properties of materials subjected to corrosive attack and subsequently stressed dynamically is not as severe as in those materials which are simultaneously subjected to both corrosion and fatigue[5], the use of corroded spring material for dynamic applications should be avoided.

Examination of the fatigue data produced from corroded springs clearly shows a reduction in endurance. For instance, after one day's corrosive treatment the endurance of four springs stressed to 850 N/mm^2 (55 tonf/in^2) ranged from 170 000 cycles up to the endurance of un-corroded springs at 1 500 000 cycles, on average a reduction in fatigue life of 50%. Increasing the period of corrosion progressively reduced the scatter in the endurance as well as reducing the overall life of the springs, such that after 20 days of corrosion treatment, resulting in 70% of the spring area being corroded, the range of endurances recorded was 117 000 to 189 000 cycles, a reduction of some 90% of the fatigue life compared with that for uncorroded springs

The effect of corrosion was even more marked on springs stressed at 750 N/mm^2 (48.6 tonf/in^2), which is just below the fatigue limit of un-corroded springs. Again the loss in fatigue resistance was progressive with increase in duration of corrosive treatment, until after 20 days the endurance of 150 000 to 320 000 cycles was little better than that for springs stressed to the higher level of 850 N/mm^2 (55 tonf/in^2).

It should be noted that these results apply to shot peened springs where, due to the residual compressive stress system present in the surface of the spring, the influence of corrosion pits, to act as stress raisers and thereby reduce fatigue resistance, may be less than with unpeened springs [(6)]

5. CONCLUSIONS

1. Even the slightest amount of corrosion on springs is detrimental and adversely affects their fatigue performance. A few days' corrosion on springs stressed at 850 N/mm^2 (55 tonf/in^2) reduces the fatigue resistance by 90%.

2. Springs stressed to levels near the fatigue limit show a larger reduction in endurance as a result of corrosion, than do more highly stressed springs.

6. RECOMMENDATIONS FOR FUTURE WORK

It is not known whether the fatigue properties of corroded unpeened springs could be restored by subsequent shot peening or what benefits, if any, would result from re-peening shot peened springs which had suffered from corrosion. Both these topics could form the basis for future work in this field.

7. REFERENCES

1. Springs; Materials/Design/Manufacture. SRA, 1968.
2. The Mechanical and Physical properties of the B.S. En Steels. Woolman, J. and Mottram, R.A. Vol 1 1964, Vol 2 1966, Vol 3 1969, Pergamon Press.
3. Proc. International Conf. on Fatigue of Metals. Inst. Mech. Eng., 1956.
4. Met. Reviews. Gilbert, P.T. 1956, <u>I</u>, pp. 379-417.
5. Mechanical Metallurgy. Dieter, G.E. p. 320, McGraw-Hill, 1961.
6. Gould, A.J. and Evans, U.R. J.I.S.I., 1948, 160, p. 164.

TABLE I FATIGUE RESULTS FOR CORRODED S202 SPRINGS

Time in Humidity Cabinet (Days)	Maximum Torsional Stress (Corrected) (N/mm^2)	Cycles to Failure	Condition B - Broken UB - Unbroken
1	850 (55 $tonf/in^2$)	747 000	B
		1 584 000	B
		171 000	B
		315 000	B
	750 (48.6 $tonf/in^2$)	7 947 000	B
		12 519 000	UB
		12 465 000	UB
		189 000	B
5	850(55 $tonf/in^2$)	126 000	B
		189 000	B
		144 000	B
		288 000	B
	750 (48.6 $tonf/in^2$)	15 000 000	UB
		225 000	B
		15 000 000	UB
		333 000	B
11	850 (55 $tonf/in^2$)	108 000	B
		9 000	B
		171 000	B
		180 000	B
	750 (48.6 $tonf/in^2$)	9 369 000	B
		9 369 000	UB
		324 000	B
		324 000	B
20	850 (55 $tonf/in^2$)	180 000	B
		189 000	B
		117 000	B
		126 000	B
	750 (48.6 $tonf/in^2$)	153 000	B
		216 000	B
		171 000	B
		324 000	B

TABLE II WEIGHT VARIATION AND ESTIMATE OF CORRODED AREA OF SPRINGS AFTER CORROSION TREATMENT

SPRING NUMBER FOR EACH SERIES	WEIGHT VARIATION AFTER INDICATED NUMBER OF DAYS (grams)			
	1 DAY	5 DAYS	11 DAYS	20 DAYS
1	+0.003	+0.036	+0.103	+0.150
2	+0.003	+0.039	+0.049	+0.161
3	+0.003	+0.035	+0.008	+0.103
4	-0.001	+0.035	+0.084	+0.091
5	+0.001	+0.024	+0.101	+0.129
6	+0.002	+0.033	+0.075	+0.135
7	NIL	+0.032	+0.034	+0.127
8	-0.007	+0.028	+0.083	+0.076
Weight Variation Average	+0.0005	+0.033	+0.067	+0.121
% Area Corroded Average	25.0	35.0	65.0	70.0

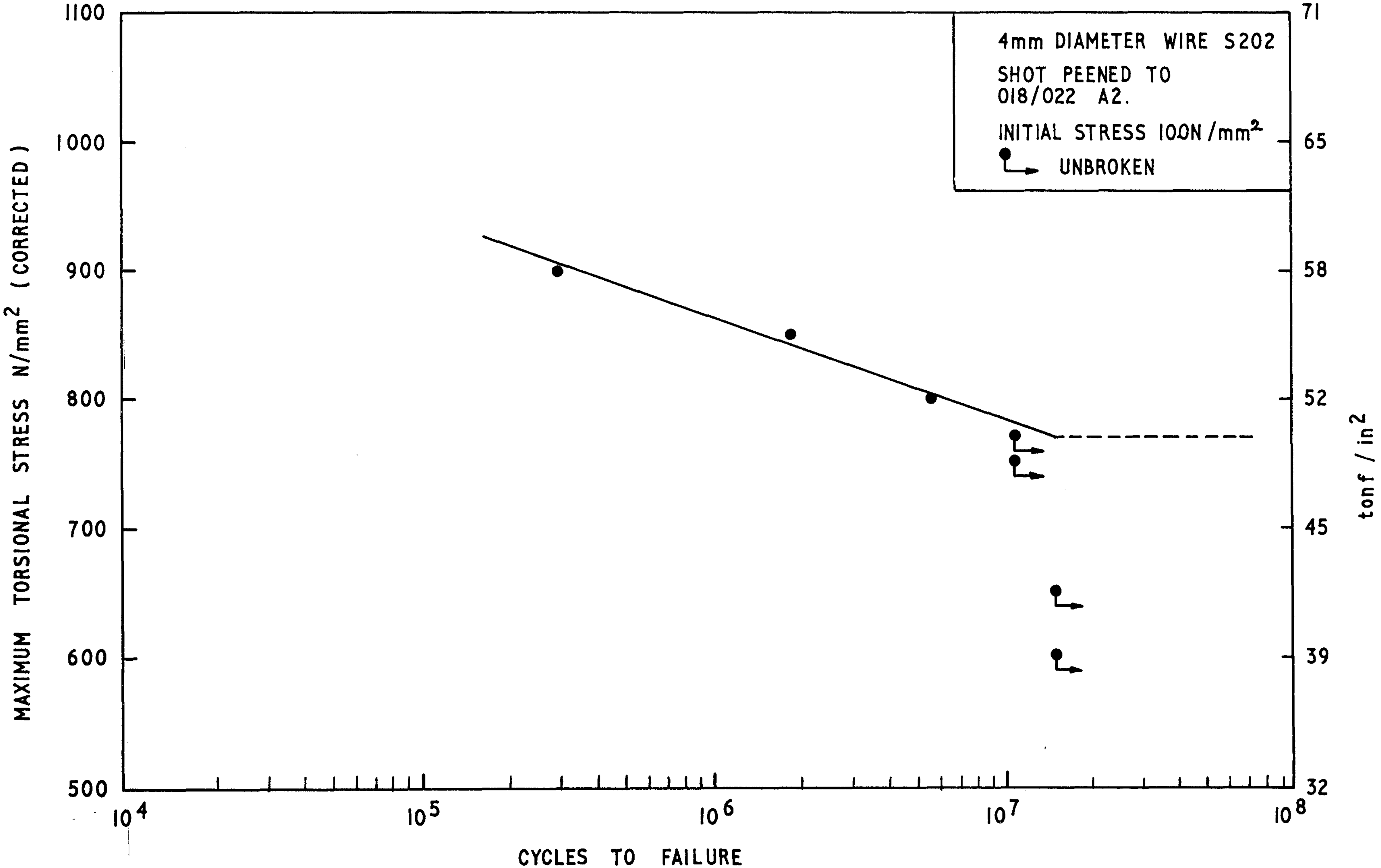

FIG. 1. S/N CURVE FOR SPRINGS MADE FROM 4mm DIAMETER S202 WIRE

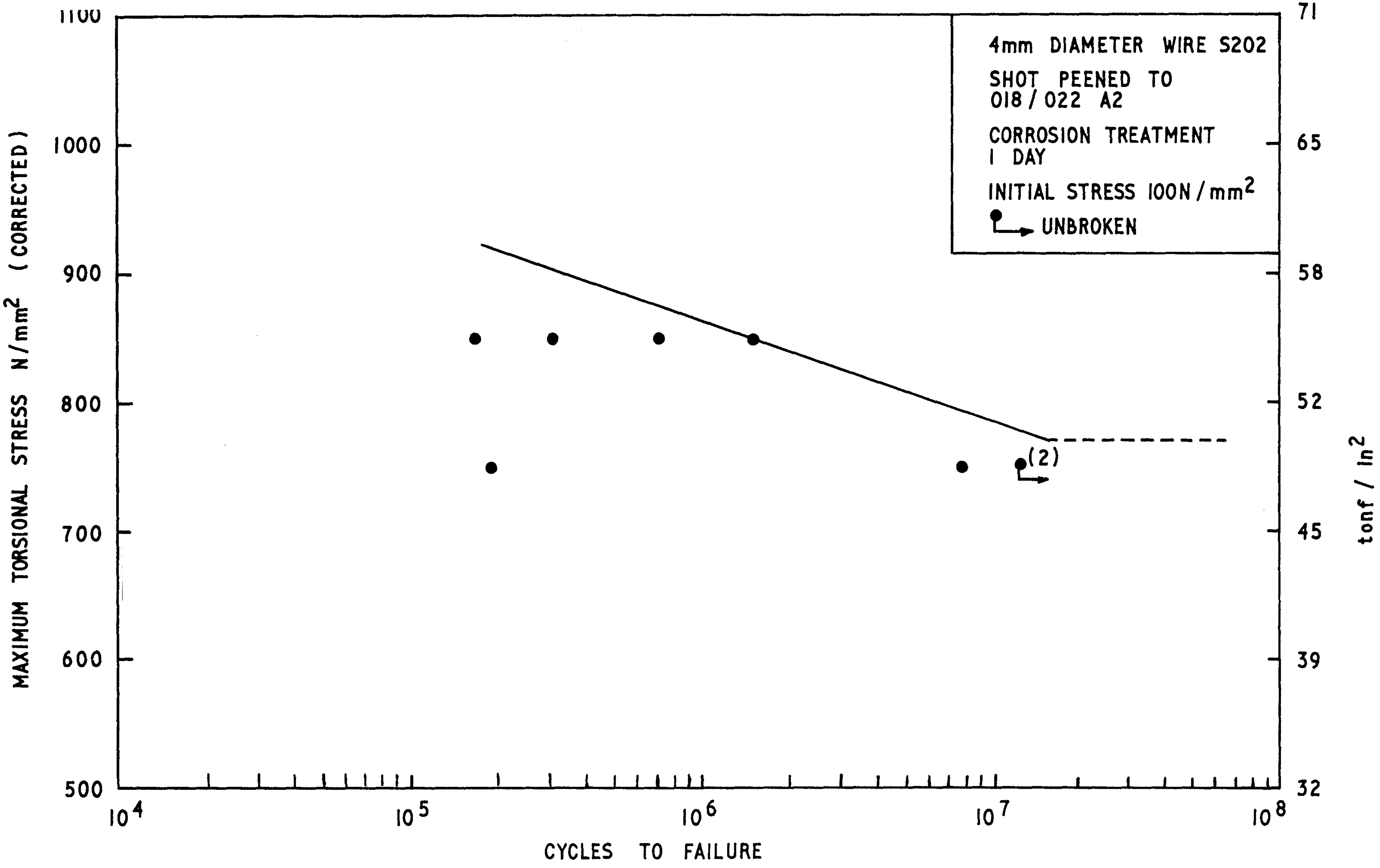

FIG. 2. FATIGUE RESULTS OF SPRINGS AFTER 1 DAY IN HUMIDITY CABINET

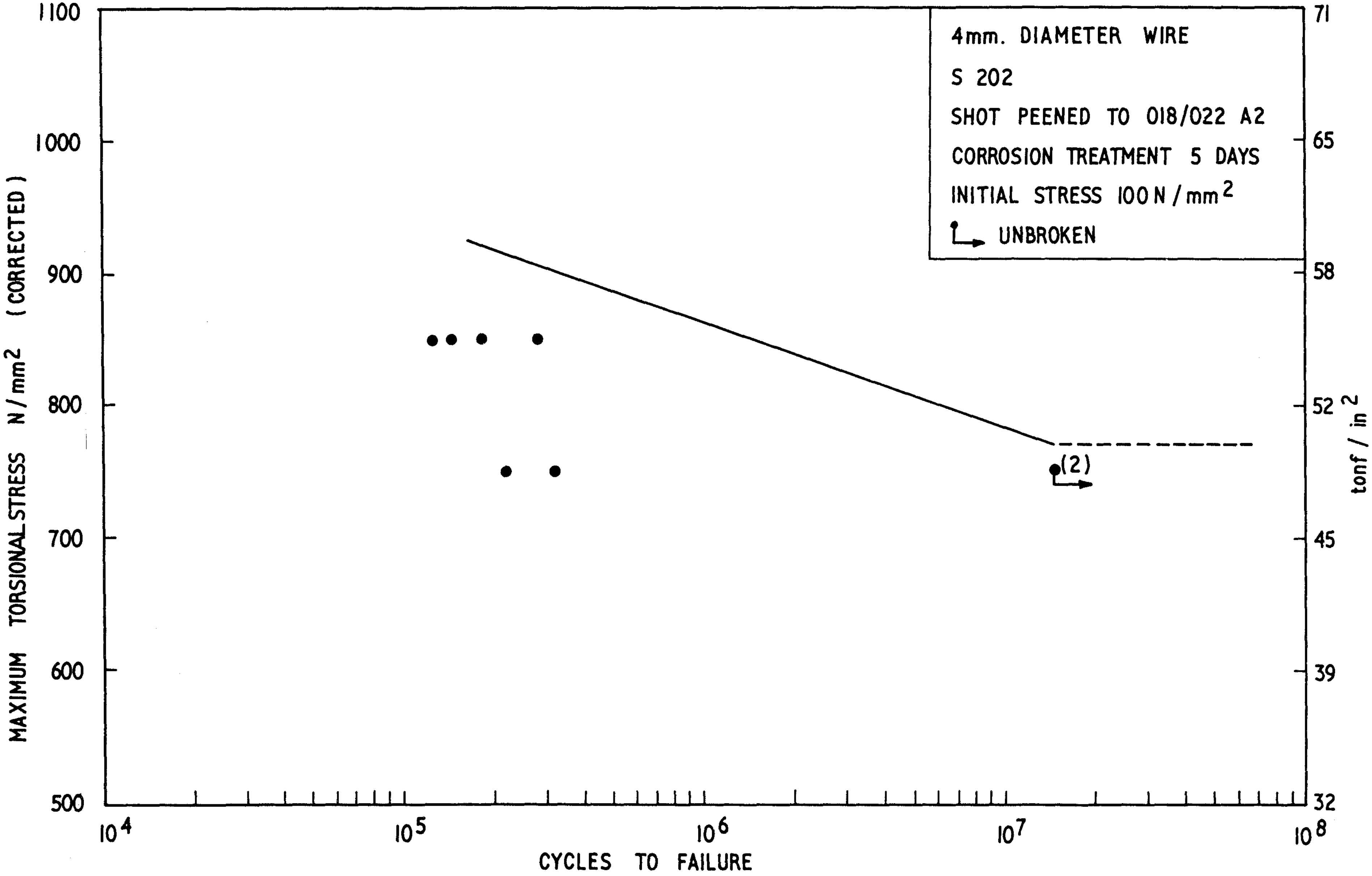

FIG. 3. FATIGUE RESULTS OF SPRINGS AFTER 5 DAYS IN HUMIDITY CABINET

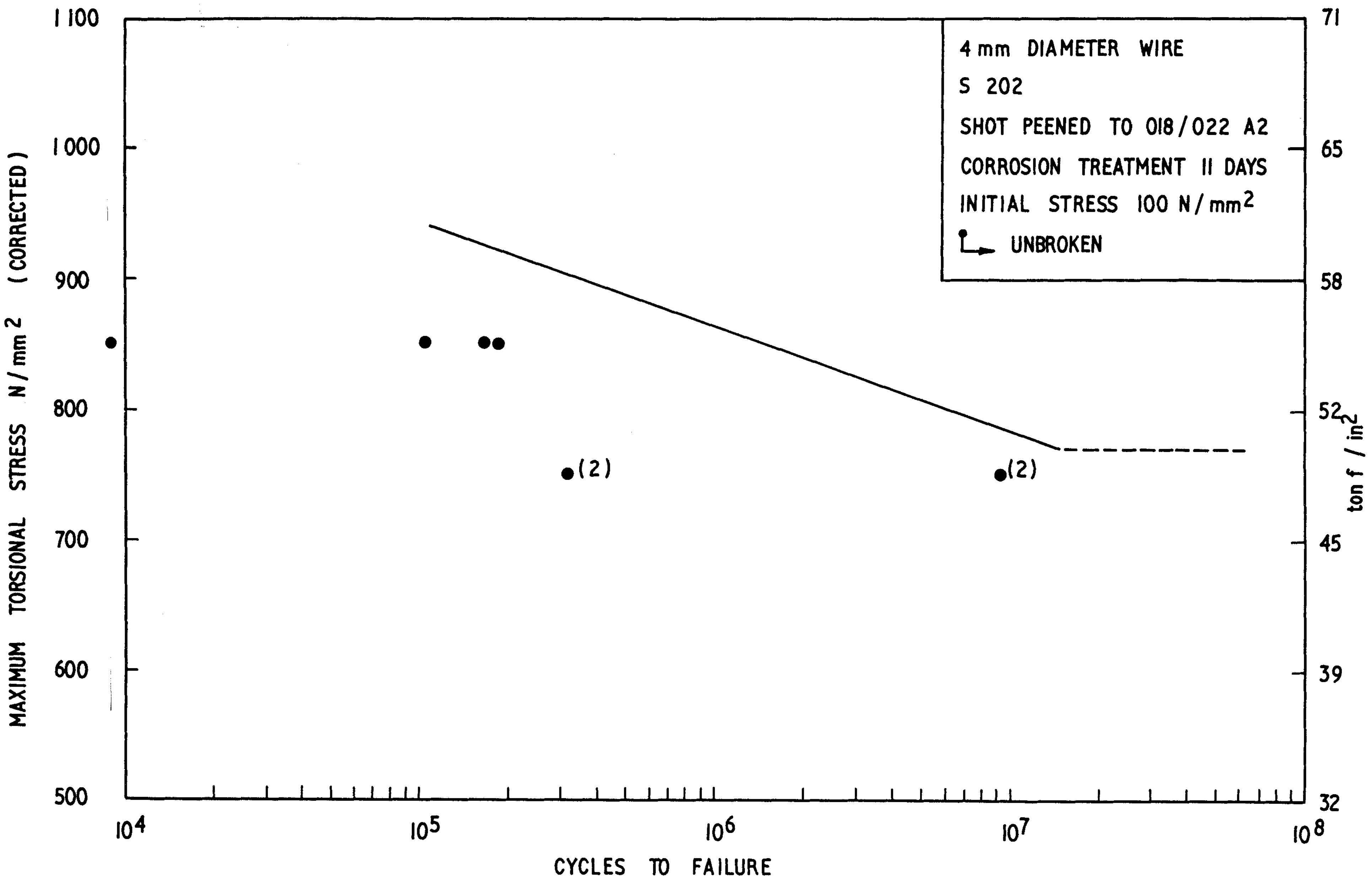

FIG. 4. FATIGUE RESULTS OF SPRINGS AFTER 11 DAYS IN HUMIDITY CABINET

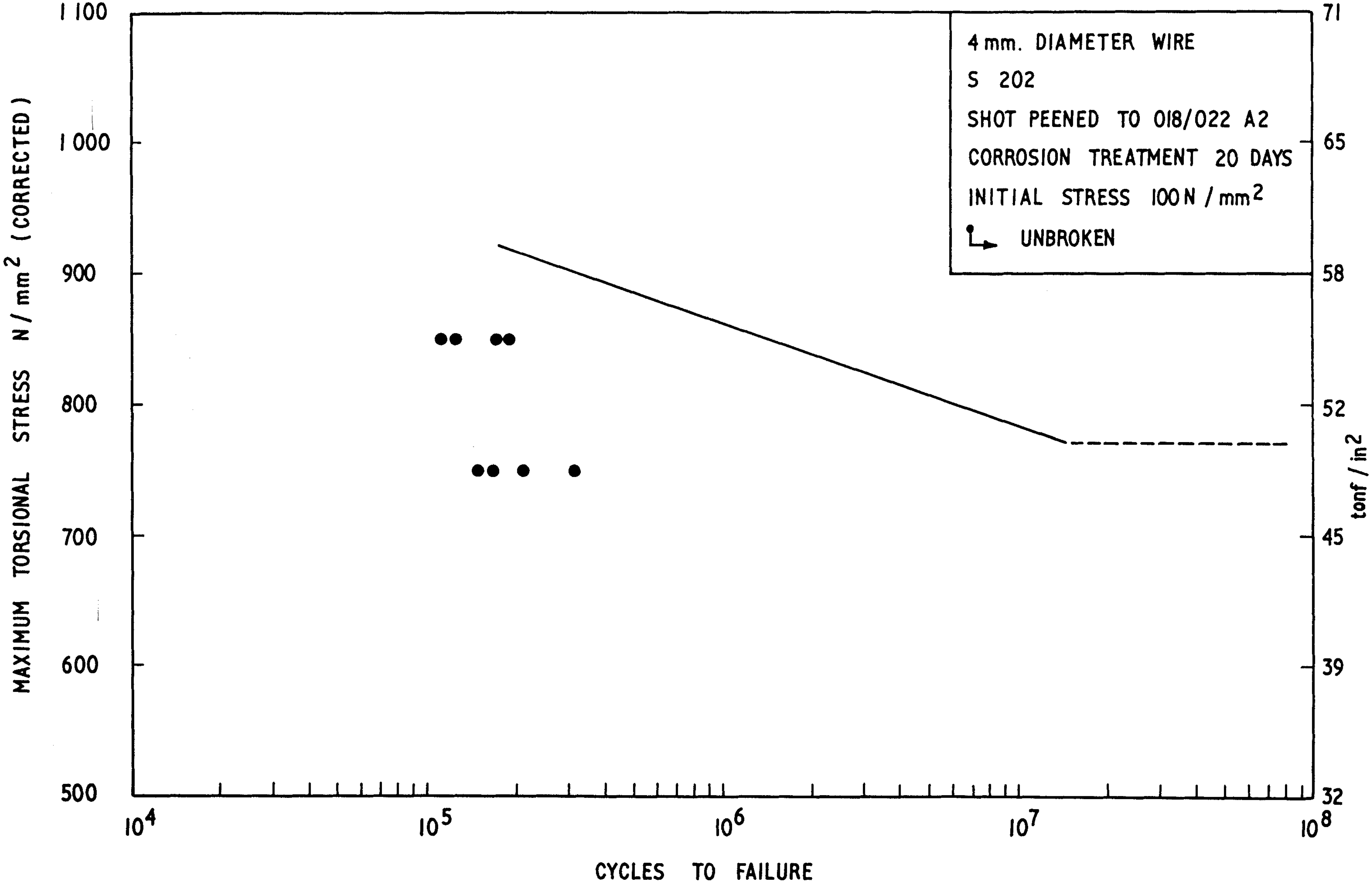

FIG. 5. FATIGUE RESULTS OF SPRINGS AFTER 20 DAYS IN HUMIDITY CABINET

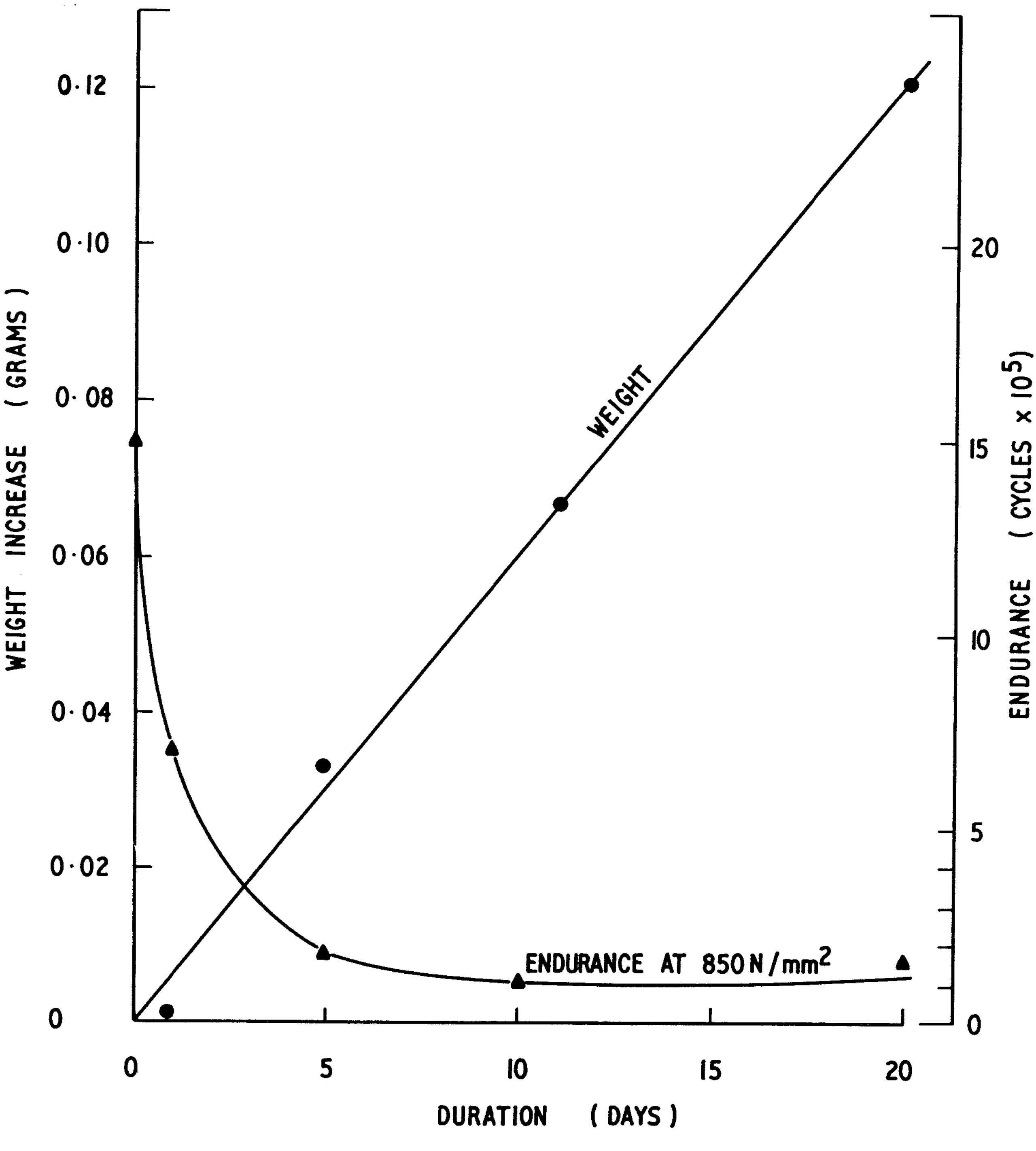

FIG.6. EFFECT OF CORROSION DURATION ON WEIGHT OF SPRINGS AND ENDURANCE AT 850 N/mm^2 (55 $tonf/in^2$)