THE SPRING RESEARCH AND MANUFACTURERS' ASSOCIATION

THE EFFECT OF THE RATE OF PRESTRESSING ON THE FATIGUE PROPERTIES OF SPRINGS

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P.F. Heyes, B.Met., M.Met.

Report No. 259

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SUMMARY

With the aid of a specially developed prestressing machine, the effect has been investigated of varying the rate of prestressing on the fatigue performance of unpeened helical compression springs made from 2.4 mm diameter, prehardened and tempered carbon steel wire. Results indicate that there is a significant gradual improvement in the limited life fatigue performance as the rate of prestressing is increased progressively from 30 to 180 compressions per minute. The fatigue limit, however, does not appear to be affected by changes in the rate of prestressing.

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CONTENTS

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1. INTRODUCTION

The prestressing of springs raises the torsional elastic limit of the material to the solid stress of the spring and introduces beneficial residual shear stresses, thus improving the fatigue performance. In general, whether the prestressing operation is manual or automatic, little attention is paid to the rate at which the spring is compressed to solid. This investigation was undertaken to examine the effect of the rate of prestressing on the fatigue performance of unpeened springs made from pre-hardened and tempered carbon steel wire. The first stage of the work was concerned with the development of a machine capable of prestressing compression springs to solid at various measurable rates without the attendant risk of "hammering" the spring when solid. The later stage involved fatigue testing of springs which had been prestressed at different rates.

2. MATERIAL

2.1 Composition

Pre-hardened and tempered carbon steel wire having a diameter of 2.37 mm and conforming to BS 2803 Grade II was employed. The actual composition is shown in Table I, together with the specified composition. The wire surface was free from defects and a metallographic examination showed that no decarburisation was present.

2.2 Spring Design and Manufacture

All springs were manufactured according to the design details given in Table II. Approximately one hundred springs were produced on an automatic spring coiling machine, and, following end grinding, were stress relieved at 350°C for half an hour. In each case prestressing was the last operation to be carried out.

3. PRESTRESSING EQUIPMENT

A machine capable of prestressing engine valve springs to solid at a variable rate was developed, as is shown in Fig. 1. The device consists basically of a pneumatic cylinder each cycle of which produces one prestressing operation on a test spring. A pneumatic valve at each end of the stroke enables the cycle to repeat automatically when compressed air is supplied. The stroke of the cylinder is adjustable in order to accommodate springs with different solid lengths and the compression rate is varied by means of two flow regulators, one in each of the air supply lines to the cylinder. The operator measures the rate by counting the number of compressions over a period of time.

In practice, the free height of the test springs in any batch always varies and, since this device is designed to prestress through a constant deflection, there is a tendency for "hammering" of some of the springs to occur. In order to prevent this, the machine is equipped with an overload device. The lower platen of the machine, on which the spring stands, is supported by a compression spring. The length of the support spring can be varied, so that, knowing the rate of the spring, the maximum load which the support spring can withstand without deflection can also be varied. If this load is made equal to the solid load of the test springs, then the lower platen will be depressed when a load exceeding the solid load is applied. Hence the possibility of "hammering" is eliminated.

4. EXPERIMENTAL PROCEDURE

4.1 Static Mechanical Testing

Static tensile and torsional tests were carried out on samples of wire in both the as-received and the low-temperature-heat-treated conditions. The results shown in Tables III and IV, were obtained by taking the average of three sets of test results.

4.2 Prestressing

The stroke of the prestressing machine was set so that the distance between the platens at the bottom of the compression was equal to the solid length of the test springs. The length of the support spring was adjusted so that the support load was equal to the solid load of the test springs. The prestressing rate for manual prestressing of engine valve springs was estimated to be approximately 60 compressions per minute. The rates chosen for this investigation were 30, 60, 120, 180 compressions per minute. For each rate a batch of 10 to 20 unpeened springs was prestressed six times to solid. It had been established previously that, at all prestressing rates, the springs were fully set down after six scrags. The free height of each spring was measured before and after prestressing and the average percentage set down was calculated for each prestressing rate. These data are summarised in Fig. 2 which shows the relationship of mean percentage set down on prestressing to the rate of prestressing. The line on the graph represents the best fit through the experimental points as determined by the method of least squares.

4.3 Fatigue Testing

Each batch of springs was fatigue tested in the usual manner using a multi-stage forced motion fatigue testing machine. The initial stress was maintained at 100 N/mm^2 throughout the fatigue testing programme and the maximum shear stress was varied between 710 and 1120 N/mm^2. The results obtained for the various prestressing rates are presented in the form of S/N curves as Figs. 3 to 6. Fig. 7 shows how the maximum working stress varies with the rate of prestressing for various endurance levels.

5. RESULTS

It is apparent from the fatigue data that, over the range of prestressing rates considered, the limited life fatigue performance improved as the rate of prestressing was increased. The fatigue limit, however, was not affected significantly. It can also be observed that the knee of the S/N curves moves to the right as the speed of prestressing is increased. Fig. 2 shows that, as the rate of prestressing was increased, there was a small increase in the plastic set down of the test springs. These percentage set down data were analysed statistically and the differences, although small, were shown to be significant.

6. CONCLUSIONS

1. A machine capable of prestressing engine valve springs at various measurable rates has been developed.

2. For unpeened helical compression springs made from pre-hardened and tempered carbon steel wire, the percentage set down increases as the speed of prestressing increases.

3. The limited life fatigue performance is improved by increasing the rate of prestressing from 30 to 180 compressions per minute.

4. The fatigue limit does not appear to be affected significantly as the prestressing rate is varied over this range.

TABLE I CHEMICAL COMPOSITION

	%C	%Si	%Mn	%S	%P
ACTUAL	0.69	0.17	0.69	0.019	0.017
SPECIFIED	0.55 - 0.75	0.30 max	0.60 - 0.90	0.040 max	0.040 max

TABLE II SPRING DESIGN

Wire Diameter (mm)	2.36
Mean Coil Diameter (mm)	20.80
No. of Active Coils	3.5
Total No. of Coils	5.5
Theoretical Solid Stress After Prestressing (N/mm^2)	1095 - 1121
Free Height After Prestressing (mm)	37.0 - 37.7

TABLE III TENSILE PROPERTIES

Condition	Tensile Strength	0.1% P.S.	0.2% P.S.
	N/mm^2	N/mm^2	N/mm^2
As Received	1660	1485	1520
L.T.H.T.	1650	1490	1515

TABLE IV TORSIONAL PROPERTIES

Condition	Max. Shear Stress	0.1% P.S.	0.2% P.S.	Twists to Failure
	N/mm^2	N/mm^2	N/mm^2	
As Received	1530	1075	1130	33.3
L.T.H.T.	1435	1060	1110	21.4

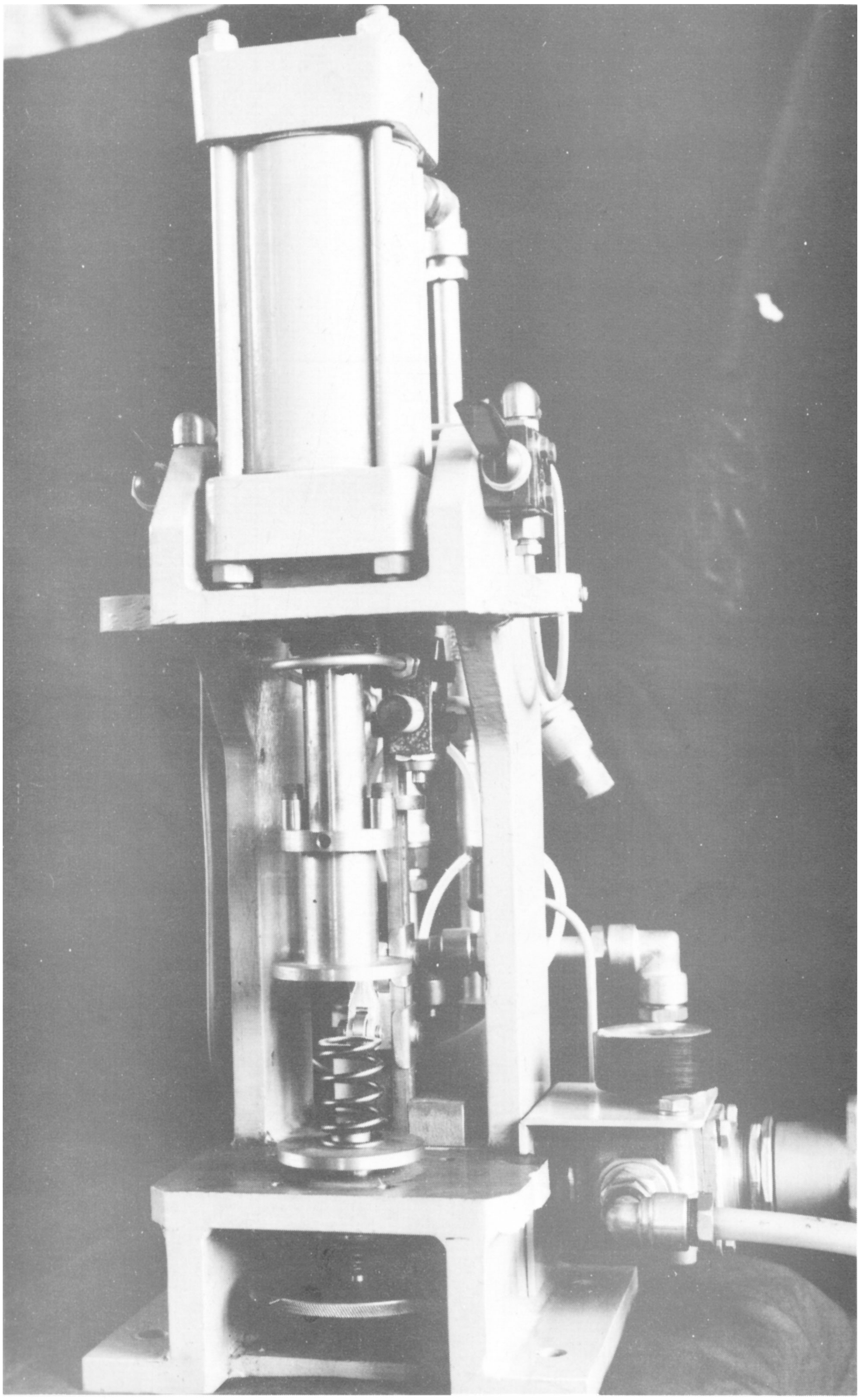

FIG. I VARIABLE RATE PRESTRESSING MACHINE

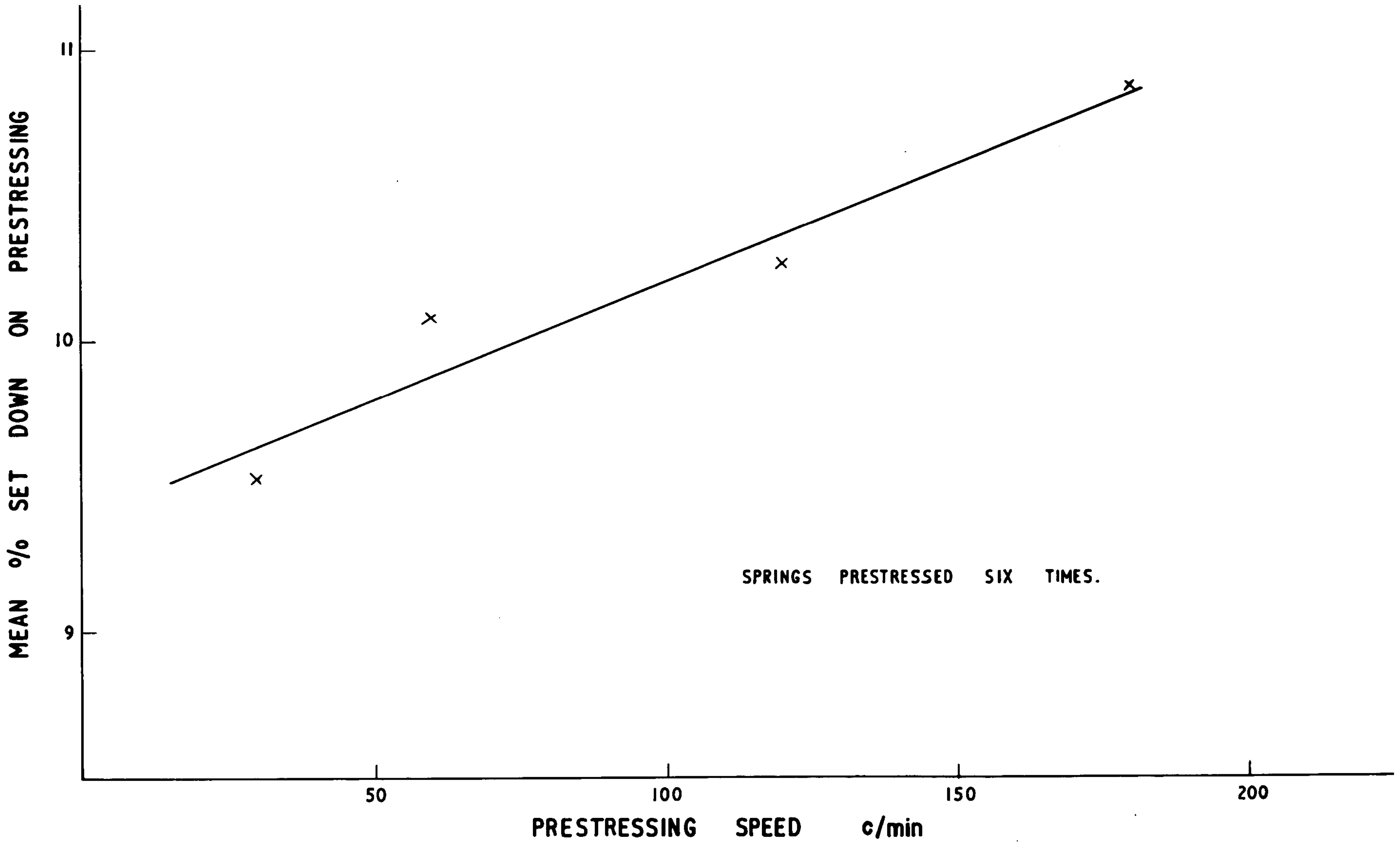

FIG. 2 GRAPH OF MEAN °/o SET DOWN AGAINST PRESTRESSING SPEED.

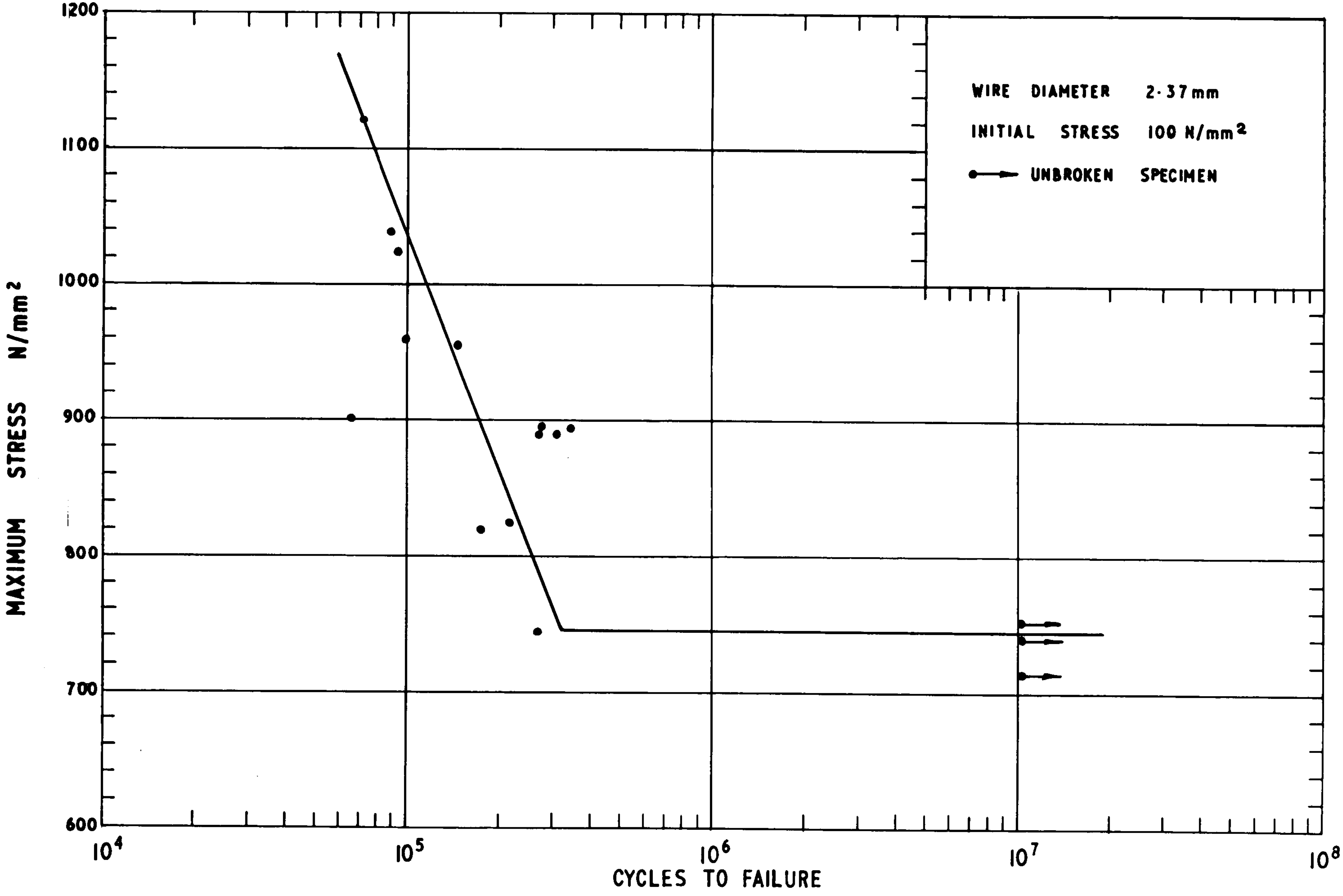

FIG. 3 S/N CURVE FOR UNPEENED SPRINGS PRESTRESSED AT 30 c/min.

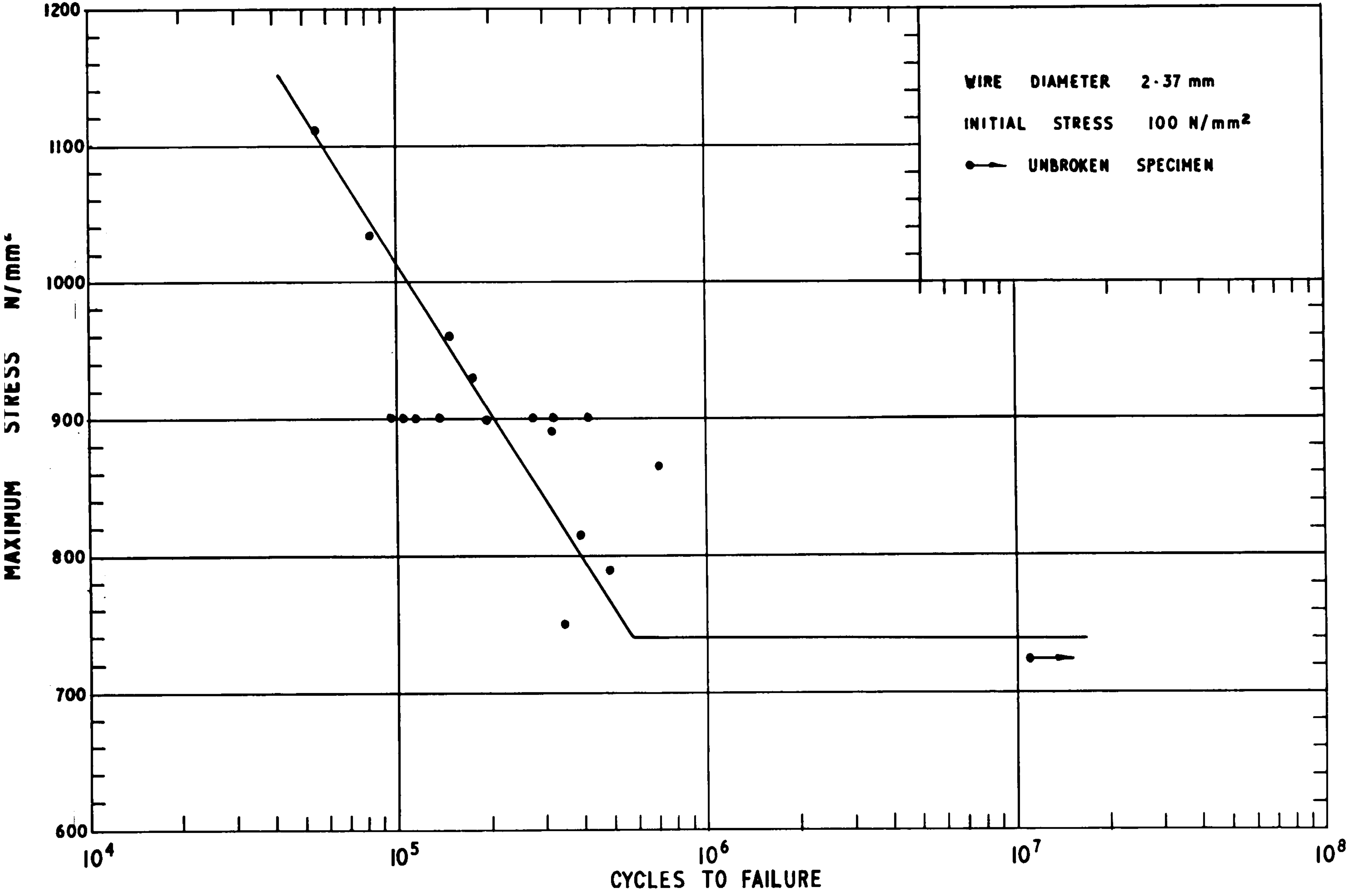

FIG. 4 S/N CURVE FOR UNPEENED SPRINGS PRESTRESSED AT 60 c/min.

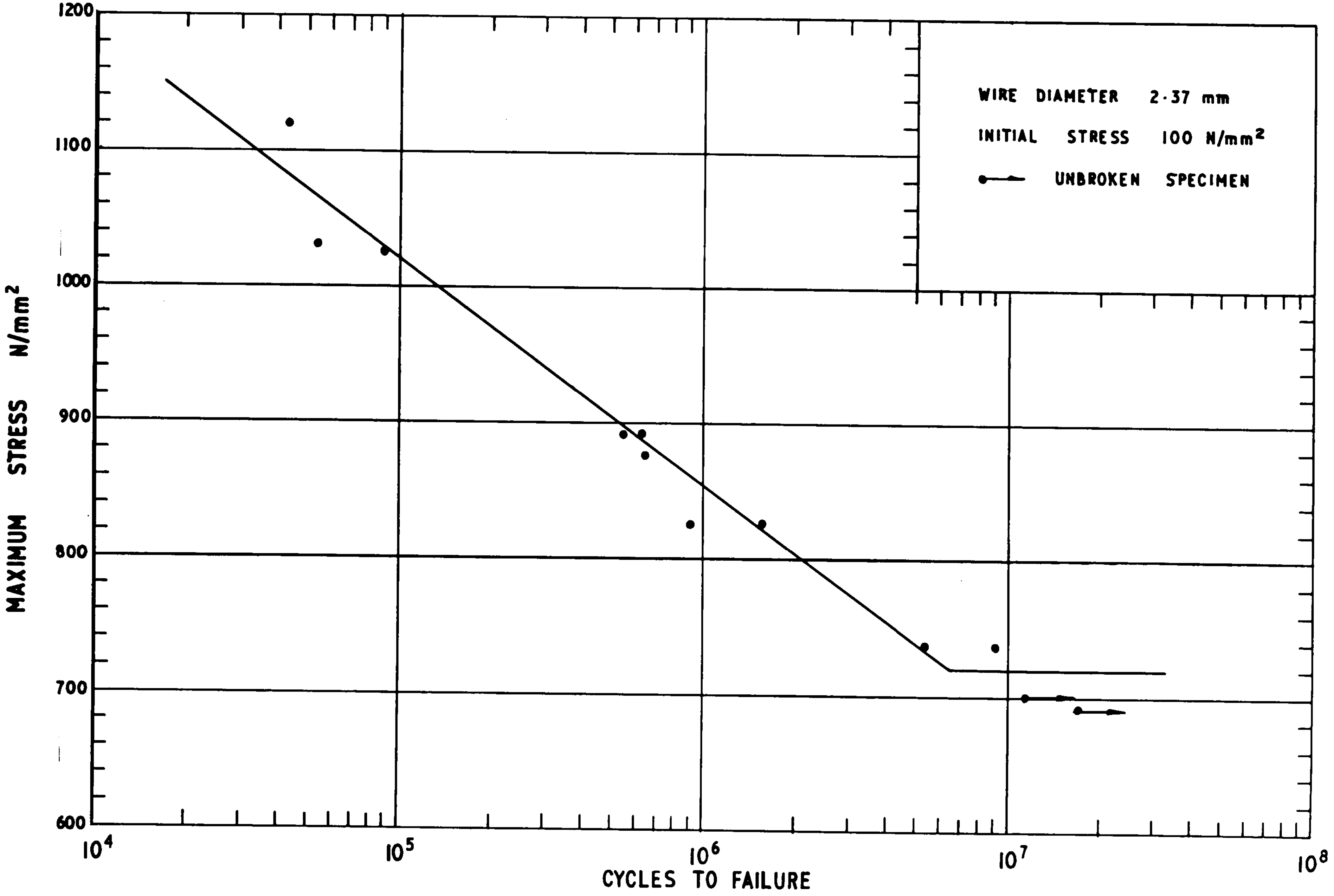

FIG. 5 S/N CURVE FOR UNPEENED SPRINGS PRESTRESSED AT 120 c/min.

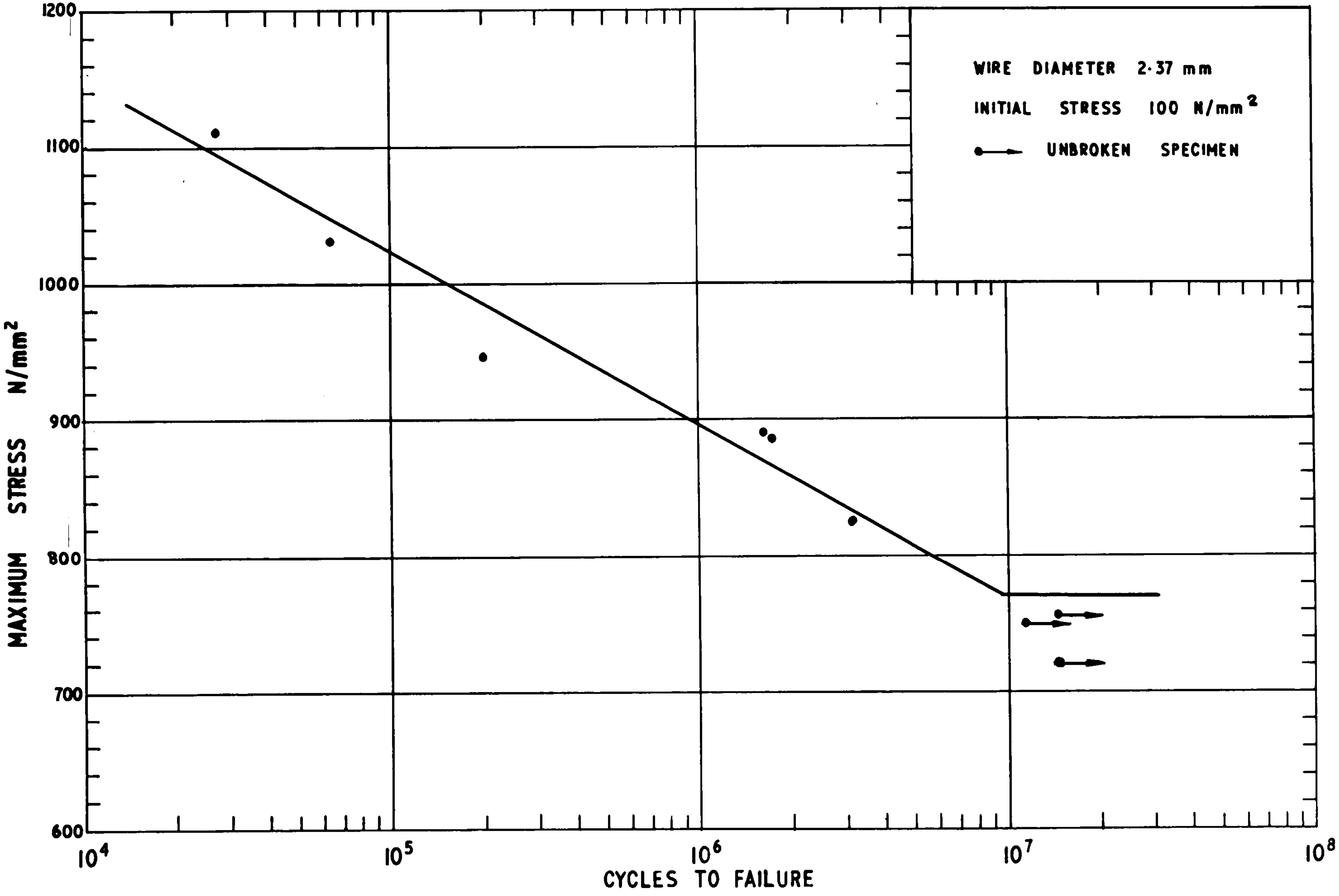

FIG. 6 S/N CURVE FOR UNPEENED SPRINGS PRESTRESSED AT 180 c/min.

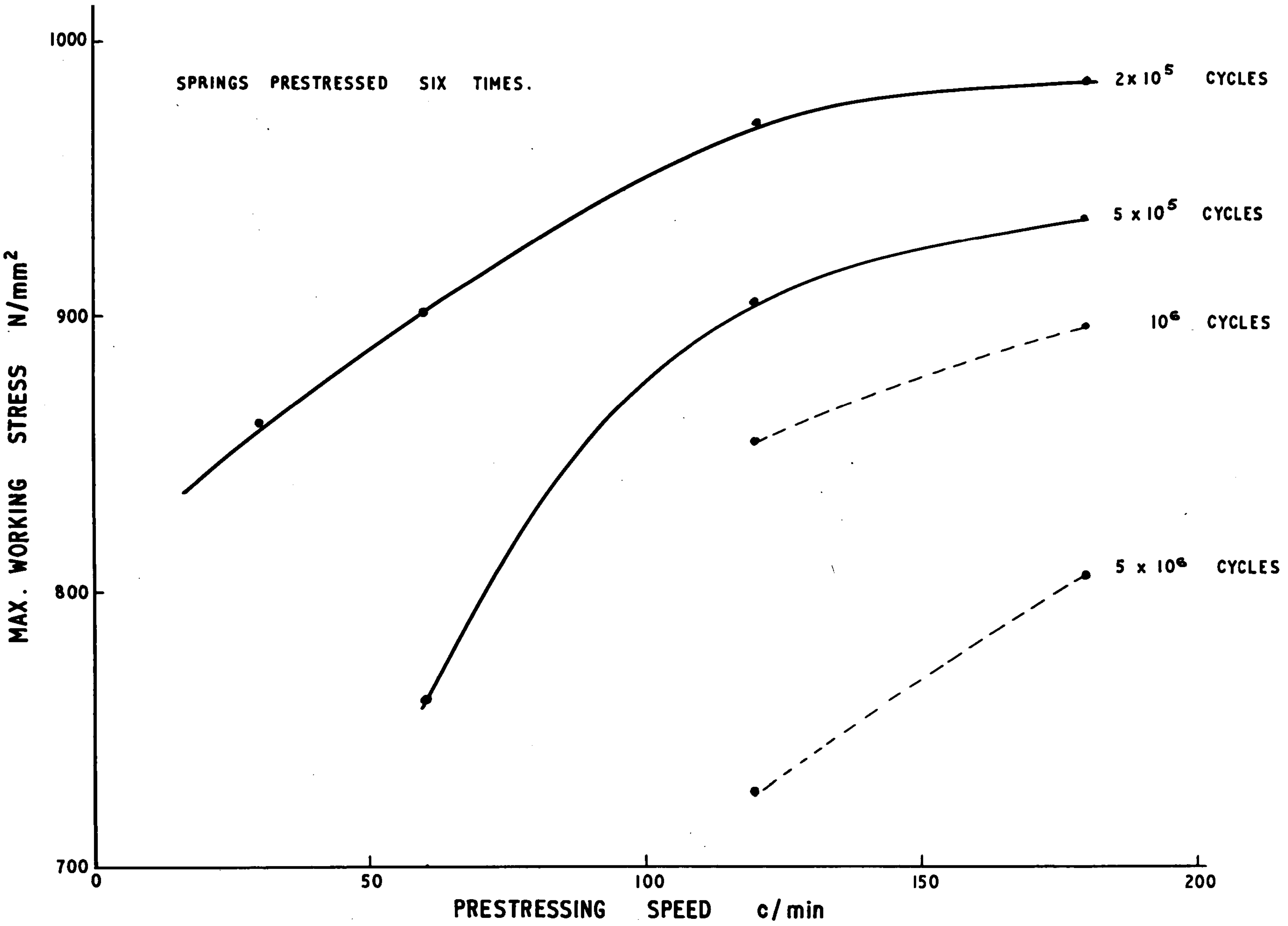

FIG. 7 RELATIONSHIP BETWEEN LIMITED LIFE FATIGUE DATA AND SPEED OF PRESTRESSING.