THE SPRING RESEARCH AND MANUFACTURERS' ASSOCIATION

THE EFFECT OF ROLLER AND SPINNER STRAIGHTENING ON THE FREE LENGTH VARIABILITY OF SPRINGS MADE ON AN AUTOCOILING MACHINE

by

M.R. Southward, B.Sc.

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SUMMARY

Previous work by the Association has indicated that improvements can be made in the free length variability of compression springs if the wire is passed through a roller straightening device prior to coiling. Another method of straightening wire used in the spring industry, but not applied to automatic coiling machines, is spinner straightening. Devices for carrying out both these straightening methods were obtained and attached to an automatic coiling machine. Springs were produced using each device, both singly and in combination, enabling a comparison to be made of the free length variability of springs produced from wire to BS 1408C Range 3.

Both types of straightening device depressed the elastic properties of the wire during the coiling operation but these were completely restored by the subsequent low temperature heat treatment given to the springs.

The results of the coiling tests indicate that straightening the wire improved the free length variability of the springs, the improvement being shown in both the 'long term' and 'short term' coiling tolerances. Coiling a batch of wire to BS 2803, where the wire is straight from the coil, gave a similar free length variation to that of the unstraightened BS 1408 material, indicating that it is probably the reduction in the elastic properties of the wire rather than the actual straightness which gives rise to the improvement in coiling performance.

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1. INTRODUCTION

Two methods are used in the spring industry for straightening wire. One method employs a roller device, consisting of a series of rollers horizontally and vertically opposed, which is often attached to a coiling machine. The effect of this straightening method on the free length variability of springs made on an autocoiling machine has previously been investigated by the Association[1]. The second method of wire straightening is spinner straightening, which is used to produce straight lengths of wire for wire forms or for torsion springs where straight legs are required. As far as is known a spinner straightening attachment has not been used in conjunction with an autocoiling maching for the production of compression springs. The aim of this investigation, therefore, is to investigate any improvements which might be obtained by using roller straightening and spinner straightening, both separately and in combination, in the free length tolerances of autocoiled compression springs.

In addition, the effect of the straightening processes on the tensile properties of wire will be determined, together with the effect of the subsequent low temperature heat treatment.

2. MATERIALS USED AND THE SPRING DESIGN

The main experimental work was carried out on patented cold drawn spring steel wire to BS 1408C Range 3. A few coiling tests were also undertaken on oil hardened and tempered spring steel wire to BS 2803, in order to obtain a comparison between the coiling tolerances obtainable with straightened wire and wire manufactured in the "fly-straight" condition. With both materials the springs were coiled to the following spring design:

Wire diameter	1.22 mm
Mean coil diameter	6.4 mm
Total no. of coils	12
No. of active coils	10
Spring index	5.25
Nominal free length	27.0 mm
Ends closed but not ground	

The full tensile properties of wire to both specifications were measured in the "as received" condition and after a low temperature heat treatment of 225^{o}C for a period of 30 minutes. In addition, samples of the patented cold drawn wire were obtained after they had been subjected to the straightening processes and the full tensile properties measured both in the "as received" condition and after the low temperature heat treatment. The diameter of the wire was carefully measured and changes in diameter resulting from the straightening processes were recorded. In order to obtain a measure of the wire straightening efficiency, samples of the wire were laid on a flat surface and the natural coil diameter measured. The results obtained for the mechanical properties of the wire are presented in Table I, the figures given being averages of duplicate tests based on the actual wire diameter, and those for the wire and coil diameter measurements in Table II.

3. EXPERIMENTAL PROCEDURE

The springs were coiled on a Torrington 115A autocoiling machine equipped with a silver steel coiling point. The roller straightening device employed, which was supplied with the coiling machine, consists of seven rollers in each plane (see Fig. 1) which can be individually adjusted by grub screws.

The spinner straightening device is illustrated in Fig. 2. It consists of seven dies, each of which can be individually set. The frame containing the die was rotated at a speed of

3000 rpm during the straightening process.

The power supply for the spinner straightening device was connected through micro switches actuated by the drive roll cam shaft of the coiling machine, thus operating the device only during coiling of a spring. This was necessary because it was found that if the wire was stationary while the spinner was rotating, as occurs during the dwell time of the coiling machine, then it soon fractured in a torsional mode.

When both forms of straightening were operated together, the roller straightening device was located next to the coiling machine, so that the wire passed from the swift via the spinner straightening and then the roller straightening device to the drive rolls of the coiling machine. In both types of straightening device, the rolls or dies were adjusted so that the maximum deflection of the wire occurred on the entry side and decreased as the wire passed through the device.

The coiling machine was adjusted to coil the spring to the required design using the cold drawn wire. The coiling point was retracted so that the wire could be removed from the coiling machine without distortion. The roller straightening device was attached to the coiling machine and the wire fed through the drive rolls. The coiling machine was switched on and the roller straighteners adjusted to produce the straightest possible wire without distortion. This procedure was then repeated with the spinner straightening device alone. Finally both straightening devices were attached to the coiling machine and, since the wire produced had an extremely large coil diameter, neither device was further adjusted.

The straightening devices were removed and once again the coiling machine was adjusted to produce springs to the required design using the cold drawn wire. Springs were produced at a rate of approximately 40 per minute, the first hundred being discarded to allow the tooling to settle and the machine to reach an even working temperature. The last five consecutive springs from each successive 50 were collected and identified in sequential order until 1,000 springs had been produced. On completion of this run, the procedure was repeated for the following coiling trials:

1. roller straighteners attached to coiling machine;
2. spinner straighteners positioned between the drive rolls and the wire swift;
3. roller straighteners attached between coiling machine together with spinner straightening device;
4. all straightening devices removed (repeat of first run); and
5. wire changed from cold drawn to oil-hardened and tempered spring steel wire (BS 2803) with no straightening devices attached to the machine.

Before each coiling trial, the coiling point was retracted and the coiling machine actuated, thus enabling a sample of wire to be collected after being straightened and fed through the drive rolls. These samples of wire were then subjected to the tests described in Section 2.

The free lengths of the collected springs were measured using a Nikon profile projector. In order to eliminate end coil discrepancies in the results, the free lengths of the springs were measured in the manner shown in Fig. 3.

4. RESULTS

From the free length data, as measured for each coiling trial, the variance and the standard deviation were calculated for both the short term and long term effects. The short term variance was calculated by taking the mean of the variances of the subsamples and the long term variance was calculated from all the free length measurements for that particular coiling trial.

To enable a comparison to be made between the measured variation in free length with that required to meet the industrial specification, the free length tolerance as specified in BS 1726 was calculated to be $\pm$ 0.52 mm for the spring design used.

Tables III and IV show the value of the variance and the standard deviation. It should be noted that a tolerance band of 2σ

(where σ = standard deviation of free length) encompasses 95% of the free length variation and that a tolerance band of 3σ includes 99%.

5. DISCUSSION

The spinner straightening operation deformed the wire so that it was no longer circular in section. This ovalness varied along the length of the wire, the maximum measured at any one section being 0.018 mm (0.0007 in). The values given in Table II show the largest and smallest diameters produced by spinner straightening, though these did not occur at the same cross-section. The roller straighteners did not distort the wire and when they were applied after the spinner straightening, the amount of distortion was reduced.

The tensile property data given in Table I for the BS 1408 wire from the coil were obtained without any straightening of the wire, as even hand straightening was found to reduce the measured elastic properties. The spinner and roller straightening devices reduced the elastic properties of the wire but had no effect on the tensile strength. Roller straightening produced the largest reduction in proof stress values, although the stresses in the spinner straightened wire were difficult to calculate because of the variation and ovalness in the wire. It can also be seen that the subsequent low temperature heat treatment restored the proof stress values to those of the unstraightened wire.

The coiling properties of the wire after various straightening methods can best be compared by considering the results for the short term tolerance (Table III). These results represent the potential coiling properties of the straightened wire and place the various methods in the following order of merit:

1. roller and spinner straightening
2. spinner straightening
3. roller straightening

If the long term tolerance results (Table IV), which indicate the actual coiling properties of the wire in this investigation, are considered, the straightening methods are in the same order of merit as above. Moreover, for each wire condition, the 3σ limit is well within the British Standard tolerance. If the coil diameter of each wire (Table II) is compared, it can be seen that, neglecting the oil hardened and tempered wire, the table formed for the coiling properties corresponds to that for the degree of wire straightness prior to coiling. However, if the 'short' and 'long' term tolerances of BS 2803 wire, which lies straight from the coil, are compared with those of the other wires they are found to be similar to those of the unstraightened BS 1408 wire. As Table I shows, the ratio of 0.1% proof stress to tensile strength was similar for both these materials and lower for wire that had been straightened. This indicates that the improvement in coiling properties is due to the method of straightening and the structure of the wire and not only the degree of straightness in the wire. The table below indicates the actual (long term) and potential (short term) percentage improvement in coiling properties effected by each method of straightening wire.

	Short term	Long term
Roller straightening	30%	9%
Spinner straightening	45%	41%
Roller and spinner straightening	54%	50%

The long term results obtained with the latter two methods in this investigation almost equalled the potential coiling properties, indicating that very little drift occurred during these coiling trials. Drift did occur during the coiling of the roller straightened wire, as the actual improvement in coiling properties fell short of the potential.

6. CONCLUSIONS

1. Wire straightening improves the coiling properties of cold drawn wire.

2. The straightening methods can be placed in the following order or merit:

1. Roller and spinner straightening
2. Spinner straightening
3. Roller straightening

3. Any reduction in the tensile properties of the wire caused by the straightening processes is restored by the low temperature heat treatment after coiling.

7. REFERENCE

1. ELLIOTT I.B.R. "The Effect of Roller Straightening on the Free Length Variability of Springs Made on an Autocoiling Machine". SRA Report No. 207.

8. ACKNOWLEDGEMENTS

The author would like to thank Torin Ltd and Salter Precision Presswork Ltd for the loan of the straightening devices used in this investigation.

TABLE I MECHANICAL PROPERTIES OF WIRE

Material and Condition	Wire Diameter (mm)	Tensile Strength (N/mm^2)	0.2% Proof Stress (N/mm^2)	0.1% Proof Stress (N/mm^2)	0.05% Proof Stress (N/mm^2)	Elastic Limit (N/mm^2)	Ratio [illegible] / R_m
As received BS 1408 C (from coil)	1.220	2170	2020	1850	1690	1420	0.85
BS 1408 C (roller straightened)	1.220	2160	1641	1430	1240	920	0.66
BS 1408 C (spinner straightened)	1.200	2150	1880	1660	1470	1010	0.77
BS 1408 C (roller and spinner straightened)	1.220	2130	1770	1560	1350	920	0.73
BS 2803	1.240	1770	1580	1550	1510	1270	0.87
After LTHT 225°C/½hr BS 1408 C (from coil)	1.220	2240	-	2210	2070	1640	0.99
BS 1408 C (roller straightened)	1.220	2210	-	-	2100	1810	-
BS 1408 C (spinner straightened)	1.200	2190	-	-	2070	1820	-
BS 1408 C (roller and spinner straightened)	1.220	2200	-	2150	2100	1690	0.98
BS 2803	1.240	1740	1600	1570	1550	1310	0.90

TABLE II PHYSICAL PROPERTIES OF WIRE

Wire type and Condition	Natural coil diameter (m)	Wire diameter in two planes at right angles (mm)	
BS 1408, from coil	0.5	1.219	1.219
BS 1408, roller straightened	3.1	1.219	1.219
BS 1408, spinner straightened	4.0	1.237 max	1.210 min
BS 1408, roller and spinner straightened	5.4	1.224	1.222
BS 2803, from coil	[illegible]	1.238	1.238

TABLE III 'SHORT TERM' FREE LENGTH TOLERANCES

Type of wire	Variance σ^2 (mm^2)	Std. deviation $\pm\sigma$ (mm)	$\pm 2\sigma$ (mm)	$\pm 3\sigma$ (mm)
BS 1408 unstraightened	0.0031	0.06	0.11	0.17
Roller straight	0.0015	0.04	0.08	0.12
Spinner straight	0.0010	0.03	0.06	0.09
Roller & spinner	0.0007	0.03	0.05	0.08
BS 1408 unstraightened	0.0043	0.07	0.13	0.20
BS 2803	0.0030	0.05	0.11	0.17

TABLE IV 'LONG TERM' FREE LENGTH TOLERANCES

Type of wire	Variance σ^2 (mm^2)	Std. deviation $\pm\sigma$ (mm)	$\pm 2\sigma$ (mm)	$\pm 3\sigma$ (mm)
BS 1408 unstraightened	0.0138	0.12	0.23	0.35
Roller straight	0.0115	0.11	0.21	0.32
Spinner straight	0.0047	0.07	0.14	0.21
Roller & spinner	0.0035	0.06	0.12	0.18
BS 1408 unstraightened	0.0144	0.12	0.24	0.36
BS 2803	0.0189	0.14	0.27	0.41

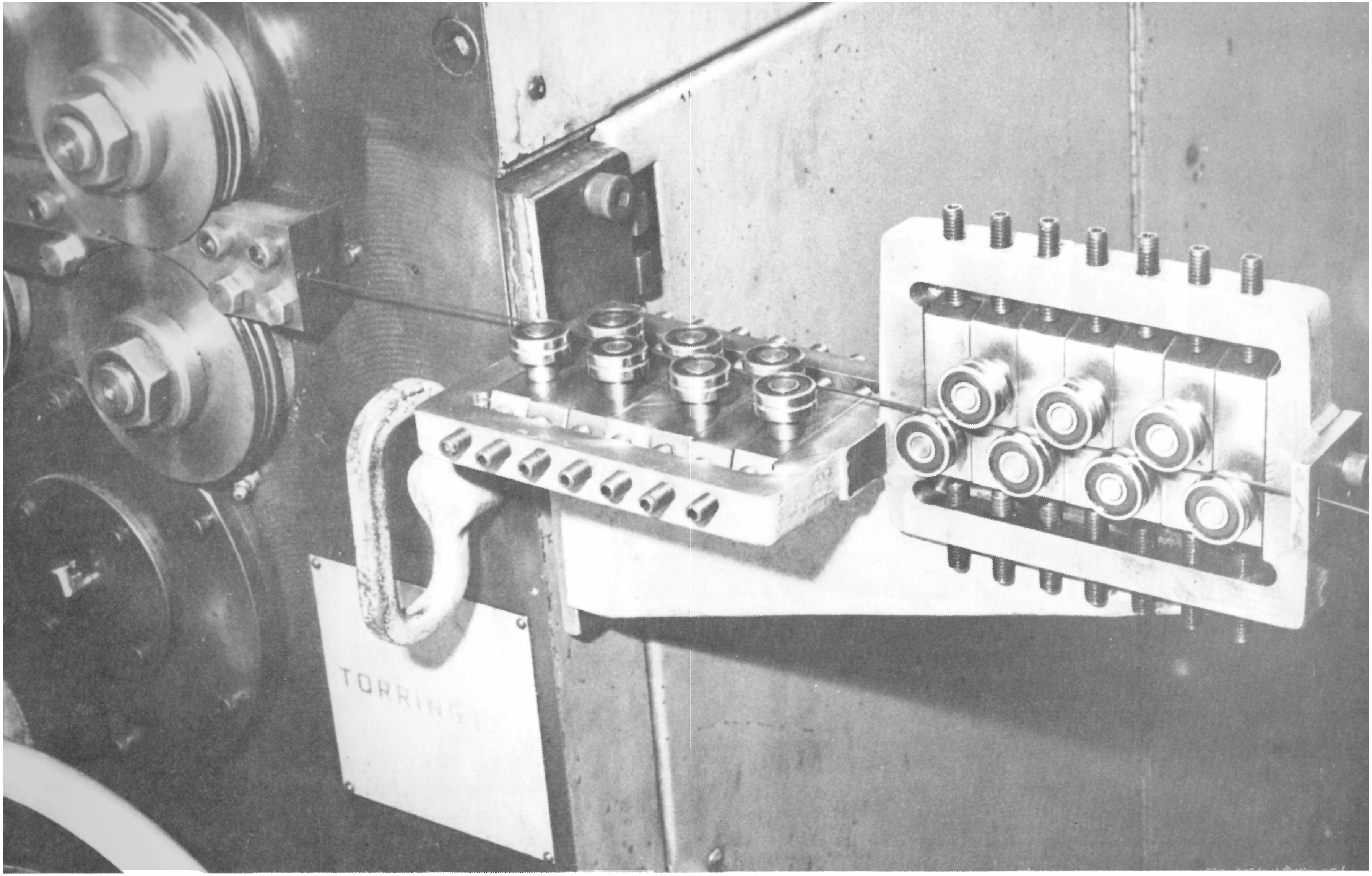

FIG. I ROLLER STRAIGHTENING ATTACHMENT

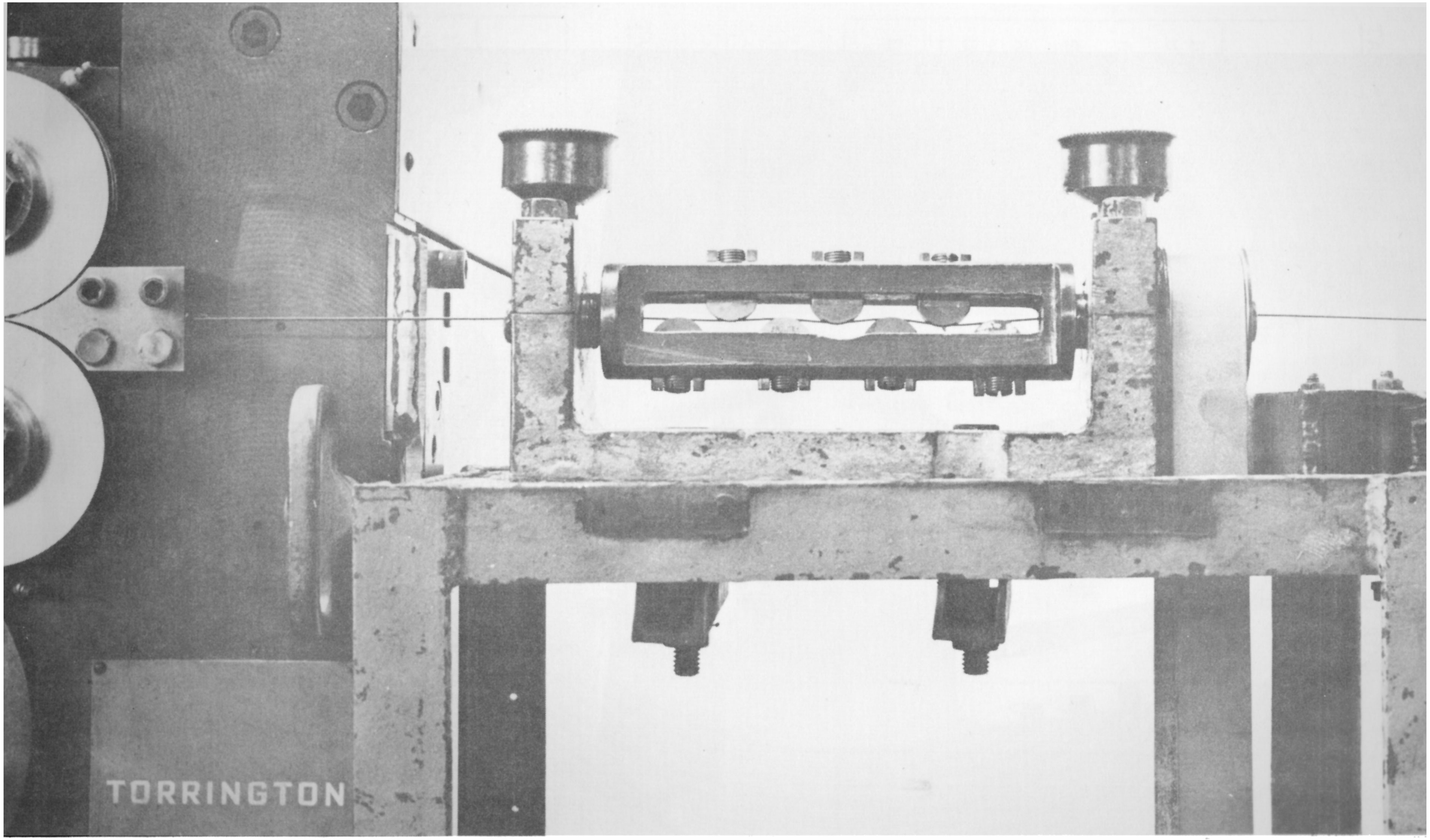

FIG. 2 SPINNER STRAIGHTENING DEVICE

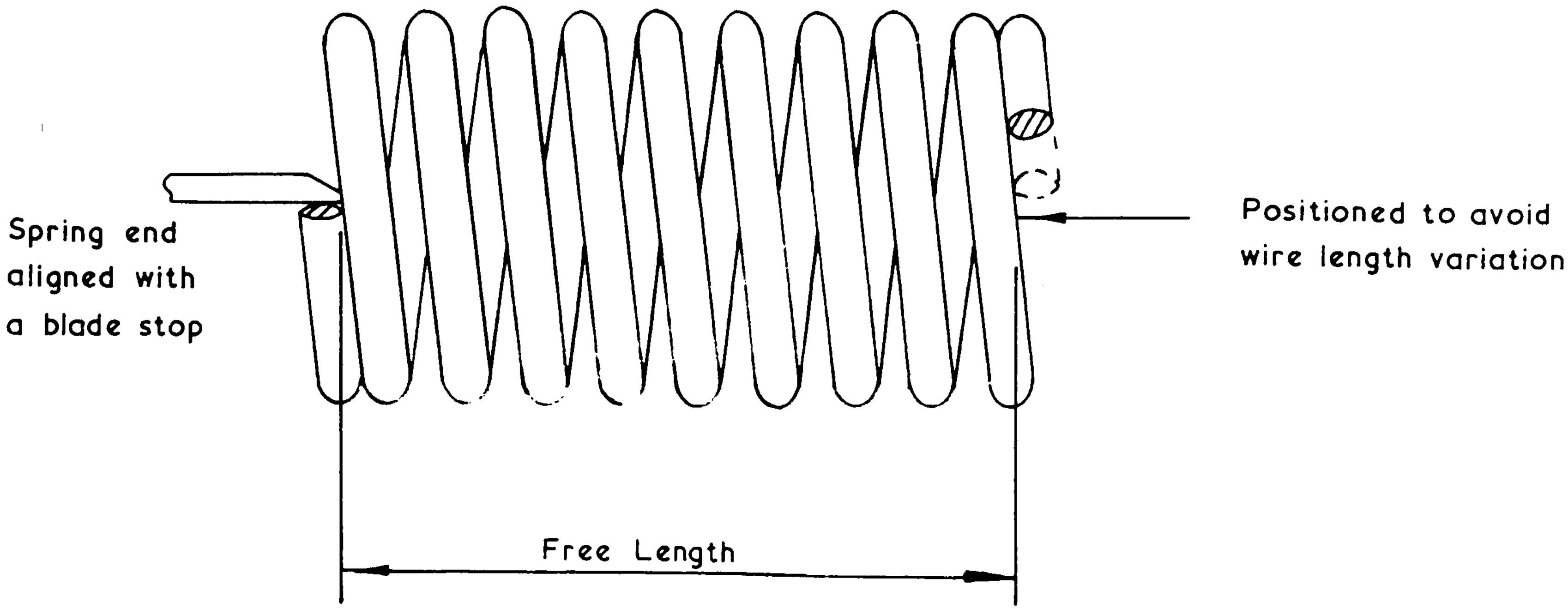

FIG. 3 METHOD OF LOCATING SPRINGS FOR MEASURING