THE SPRING RESEARCH ASSOCIATION

AN INVESTIGATION INTO THE EFFECTS OF WARM COILING USING ELECTRICAL RESISTANCE HEATING

by

M. R. Southward, B.Sc.

Report No. 239

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SUMMARY

An investigation has been carried out to develop a method of heating wire electrically during the coiling of helical compression springs and to determine the effects of warm coiling on the characteristics of the springs produced.

A Wafios two-point coiling machine was modified, enabling a current to be passed through the wire as it moved between the coiling points. Trials were conducted with cold coiling, and with warm coiling at temperatures of 150°C and 180°C. The machine was adjusted between trials to obtain the same spring design at all temperatures; it proved impossible to coil springs at 210°C.

The results show that warm coiling reduces the free length variation of prestressed springs and improves the elastic properties of the material so that subsequent stress relieving treatment may not be necessary.

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CONTENTS

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1. INTRODUCTION

The object of this investigation was to develop a method of heating wire electrically during coiling and to determine whether warm coiling can improve the free length variability of springs or eliminate the need for subsequent stress relieving treatment. In a previous method for the warm coiling of helical compression springs, the wire was heated by means of a lead bath placed immediately before the drive rolls; the disadvantage of such a method is that much heat is lost as the wire passes through the drive rolls.

In order to examine the effects of heating the wire during the formation of the spring, a modified double-point coiling machine (Wafios UFM 8) was used, the means of heating being a current passed through the wire as it moved between the two coiling points.

The current was adjusted so that the springs were coiled at several different temperatures. The free lengths of the springs were measured and the variation compared with that of identical springs coiled without heating. In addition, the amount of set after prestressing was measured for warm and cold coiled springs, both in the as-coiled condition and after a low-temperature heat treatment.

2. MATERIAL AND SPRING DESIGN

A commonly used spring material was chosen for this investigation: a patented, cold-drawn spring steel wire to BS 1408B Range 3.

Details of the spring design are given below:

Wire diameter	0.66 mm
Mean coil diameter	4.47 mm
Total No. of coils	9.25
Active coils	7.25
Spring Index	6.77
Free length	13.9 mm
Solid stress	960 N/mm^2
Free length tolerance (to BS 1726)	$\pm$ 0.382 mm
Ends closed but not ground	

3. EXPERIMENTAL PROCEDURE

3.1 Equipment

The coiling trials were carried out using a Wafios UFM 8 coiling machine. The wire was heated during coiling by passing a current through it between the two coiling points (see Fig. 1). Special coiling points were made which were insulated from the machine using Tufnol. A micro-switch, actuated by the drive roll cams, was connected into the circuit in order that the current would pass through the wire only when it was in motion, the current used being sufficiently high to melt the wire when stationary.

3.2 Coiling

In the initial setting of the coiling machine, a close coiled spring was first produced to obtain the correct coil diameter. Warm coiling was found to reduce the initial tension in the spring, which caused difficulty in obtaining a spring with closed ends, and also to increase the dimensions of the spring. Consequently, the machine had to be adjusted for each coiling temperature to produce the desired spring.

For the cold coiling trials, the machine was set and springs were coiled at approximately 40 per minute. An initial batch of 200 springs was produced, to enable the tooling to settle; 1000 springs were then produced, the last 10 of each 100 being taken as samples. Their free lengths were measured and recorded. The first half of each batch of 10 was scragged three times; the remaining 5 were given a low temperature heat treatment at 250°C for half-an-hour and were then scragged three times. On completion of each operation, the free lengths of the springs were measured using a Nikon profile projector.

For the warm coiling trials, the current was adjusted to give the desired temperatures of 150°C and 180°C. (It had been hoped to coil springs at 210°C but it proved impossible to set the machine to produce springs at this temperature.) Springs were produced at each temperature in batches of 1000, the last 10 from each 100 being collected for measurement. In addition, two batches of springs were collected to determine the temperature of the springs after coiling by the calorimetric method.

The same procedure of free length measurement was carried out on springs coiled at both temperatures.

4. RESULTS

From the free length measurements, the values of standard deviation (σ) and solid stress were calculated for each batch of springs; these are shown in Tables I and II respectively.

In order to compare the measured variation in free length with that required to meet industrial specifications, the free length tolerance, as specified in BS 1726, was calculated as follows:

Free length tolerance

$$T = \pm (1\tfrac{1}{4}\% \text{ of free length} + 0.127)(1 + \frac{C}{25}) \text{ mm}$$

where C = Spring Index (D/d)

For the spring design used:

Free length = 13.9 mm
Spring index = 6.77

Free length tolerance = $\pm$ 0.382 mm

5. DISCUSSION

The results presented in Table I show that the free length variation after coiling, in terms of the standard deviation for the whole sample, increases as the coiling temperature is increased.

Prestressing appears to improve the tolerances on warm coiled springs but has a detrimental effect on the cold coiled springs. This occurs with both Samples I and II, either with or without a low temperature heat treatment. The low temperature heat treatment per se does not appear to have any significant effect on the free length variation.

The solid stress of the springs, as shown in Table II, was calculated from the mean free length of the springs after the various processes. It can be seen that the as-coiled solid stress is approximately the same for all three batches. The effect of warm coiling can be seen from the solid stress values for the springs prestressed after coiling: springs coiled at the highest temperature exhibited the least amount of set. The stress relieving treatment had only a slight effect on the solid stress, but with springs prestressed after heat treatment, those coiled at the highest temperature again exhibited the least amount of set. There was, however, less difference in set-down between the two warm coiled batches.

From the results obtained to date, it seems that warm coiling raises the elastic properties of the material, so that a subsequent heat treatment may not be necessary, and improves the free length variability of springs which have been prestressed.

It is intended to carry out additional work on this subject, in order to verify the results obtained using a different coiling machine and wire size, and to investigate the feasibility of using such a device for manufacturing purposes.

6. CONCLUSIONS

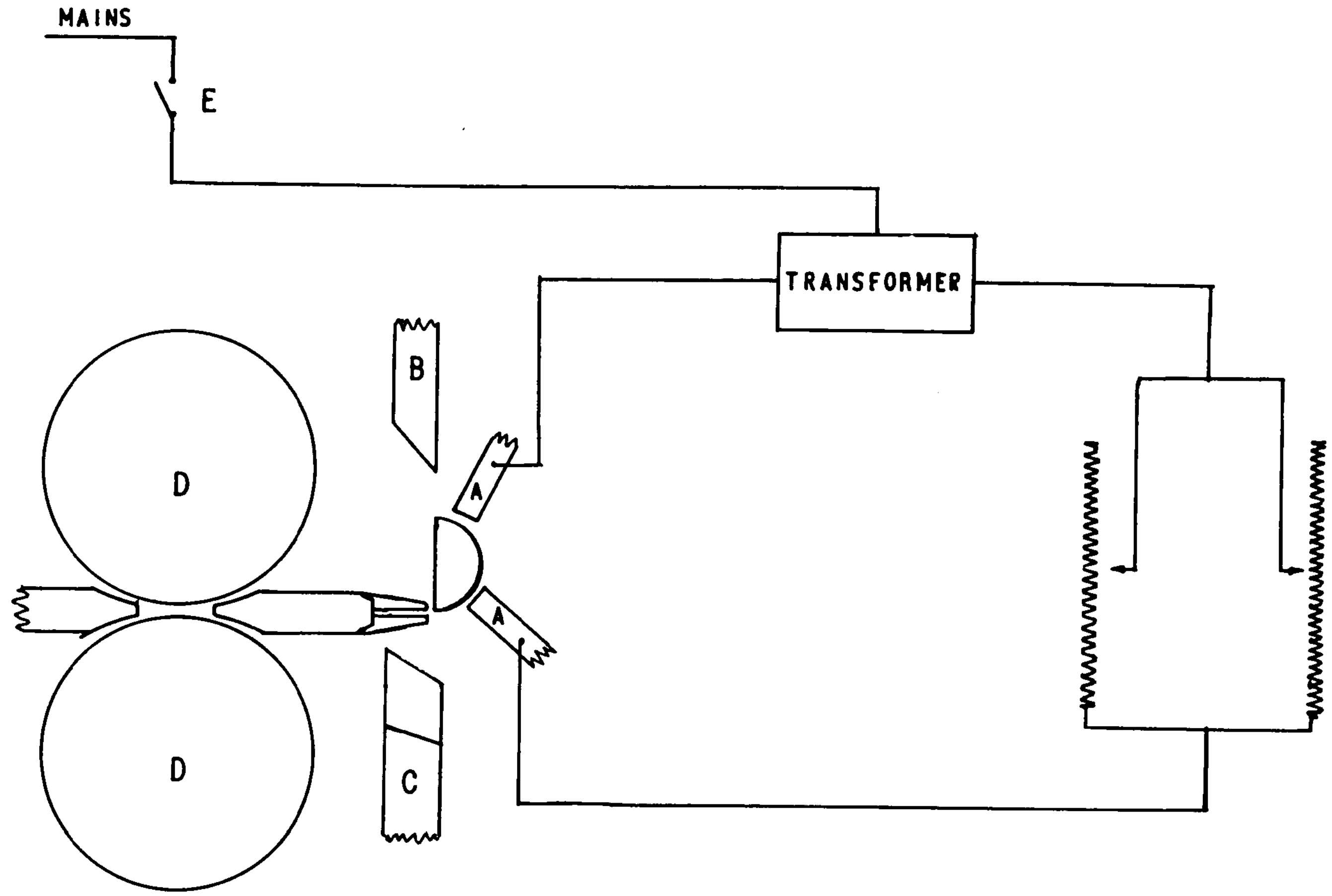
1. Warm coiling reduces the free length variation of prestressed springs.
2. The operation of warm coiling improves the elastic properties of the material so that a subsequent stress relieving treatment may not be necessary.

TABLE I EFFECT OF WARM COILING ON FREE LENGTH VARIATION

	Standard Deviation (mm)		
	Cold Coiled	Coiled at 150°C	Coiled at 180°C
Total Sample			
As-coiled	0.077	0.107	0.174
Sample I			
As-coiled	0.083	0.108	0.206
After prestressing	0.151	0.099	0.109
Sample II			
As-coiled	0.081	0.106	0.141
After L.T.H.T.	0.076	0.095	0.143
After prestressing	0.145	0.059	0.064

TABLE II EFFECT OF WARM COILING ON SOLID STRESS

Solid Stress Calculated from Free Length (N/mm^2)			
	Cold Coiled	Coiled at 150°C	Coiled at 180°C
As-coiled	1004	1006	1020
After prestressing	708	769	821
After L.T.H.T.	1008	981	995
Prestressed after L.T.H.T.	839	894	898



A COILING POINT
B CUT OFF TOOL
C PITCH TOOL
D DRIVE ROLL
E MICRO SWITCH ACTUATED BY DRIVE ROLL CAM

FIG. I SCHEMATIC CIRCUIT DIAGRAM