THE SPRING RESEARCH ASSOCIATION

A Study of some Factors which might Affect the Free Length Variability of Springs Produced on a Torrington 115A Coiling Machine

Report No. 174

by

J.M. Bowles

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SUMMARY

This investigation was carried out to determine the effect of four factors on the free length variability of springs. The four factors; production rate; weight of wire bundle on the swift; type of lubricant, and type of swift (conventional or motorised), were chosen because it was felt they might have a significant influence on variability.

Each factor was investigated at two levels, as below:-

Production rate	40 springs per minute and 70 springs per minute
Weight of wire bundle on swift	112 lbf and 330 lbf
Lubricant	Duckham's 'Adformal EP8/10' and Delapena 'J50'
Swift	Conventional and motorised

A statistical level of significance was not obtained except in the case of the swift where the use of a motorised swift reduced the short term variability.

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1. INTRODUCTION

This investigation was carried out on a Torrington 115A coiling machine to determine the influence of various factors on the variability of the free length dimension of the springs produced.

The four factors chosen were:

- A: Production Rate
- B: Weight of Wire on Swift
- C: Type of Lubricant
- D: Type of Swift

Each factor was tested at two levels as listed below:

- A: 40 springs per minute and 70 springs per minute
- B: 112 lbf and 330 lbf
- C: Duckham's "Adformal EP8/10" and Delapena "J50"
- D: Conventional and motorised

2. SPRING DESIGN

Nominal free length	=	1.2 in
Outside diameter	=	0.3 in
Wire diameter	=	0.048 in
Total number of coils		16

One coil at each end closed

Coiled left handed

Material to B.S. 2803 Grade III

3. EQUIPMENT AND TOOLING

A Torrington 115A coiling machine was used with 'standard' high speed steel tooling as supplied by the machine maker.

The drive rolls, which were also standard, had grooves of 0.048 in, 0.080 in and 0.116 in. The load was applied through a belleville washer and piezo-electric load cell in series. The latter gave a direct reading of the load which in this experiment was 0.1 tonf. A coiling point was chosen after inspection on a Universal projector to ensure that the groove diameter gave the appropriate clearance for a wire diameter of 0.048 in.

4. EXPERIMENTAL PROCEDURE

Each of the four factors was tested at two levels, one designated 'low' the other 'high'. The experimental order as listed below was only partially randomised because of the practical difficulties in changing from one type of swift to another. Every change would have necessitated cutting the wire and resetting the machine.

negative = low level positive = high level

Experimental Order	Factor Level	Factor A	Factor B	Factor C	Factor D
1	(1)	-	-	-	-
2	a	+	-	-	-
3	b	-	+	-	-
4	ab	+	+	-	-
9	c	-	-	+	-
10	ac	+	-	+	-
11	bc	-	+	+	-
12	abc	+	+	+	-
5	d	-	-	-	+
6	ad	+	-	-	+
7	bd	-	+	-	+
13	abd	+	+	-	+
8	cd	-	+	-	+
14	acd	+	-	+	+
15	bcd	-	+	+	+
16	abcd	+	+	+	+

Factor		Low	High
A:	Production Rate	40 springs/min	70 springs/min
B:	Weight of Wire on Swift	112 lbf	330 lbf
C:	Type of Lubricant	'Adformal EP 8/10'	'J 50'
D:	Type of Swift	Conventional	Motorised

The machine was set up to produce the required spring at a drive roll load of 0. 1 tonf under the conditions of the first experimental order viz. 40 springs per minute, 112 lbf of wire, which had been degreased in trichloroethylene, 'Adformal 8/10' lubricant and the conventional swift.

Several hundred springs were coiled at this setting to allow the machine and tools to settle and attain a working temperature. Five hundred springs were then produced with the machine running continuously; no adjustments whatsoever were made to the machine during this period. Sub-samples consisting of the last ten in each batch of fifty were collected in sequential order and placed on peg boards for subsequent low temperature heat treatment and measurement.

After stress relieving the springs were measured on a universal projector.

The data were punched onto cards in order to calculate the means, standard deviations and variances on the IBM 1130 computer. The variances were then analysed using a statistical technique (see Appendix for details).

5. RESULTS

The mean free length, long term variance, short term variance and the calculated free length ranges are given in Table I.

6. DISCUSSION OF RESULTS

It was felt beforehand that the four factors chosen for this investigation might have a statistically significant influence on the free length variability of the springs but this proved not to be the case with the number of observations taken.

A statistical analysis was carried out, on both the overall variances of the sub-samples and the mean variances of the batches, which gave a measure of the long and short term variabilities i.e. for 500 springs and for batches of 10 springs. It was interesting to note that in the majority of cases in this experiment the long term variability was approximately double that of the short term. This gave an indication of the scatter that had taken place within the 500 sample. Almost without exception the difference was due to random scatter rather than a progressive drift in either direction. However, experiment number 16 was repeated because a severe drift was observed during the first run and it was later ascertained that the lubricant had gelled in the lubricator and this prevented the lubricant from flowing onto the wire. The lubricator was situated between the last pair of feed rolls and the block wire guide thus forming part of the final wire guide. It consisted of a drip feed bottle piped to a block containing felt pads which were lightly clamped round the wire.

The only factor which proved statistically significant was the swift in that the short term variability was reduced when using a motorised swift.

7. CONCLUSIONS

This investigation showed that more information is required to establish statistical levels of significance when using different combinations of the four factors:-

Production Rate	40 and 70 springs per minute
Weight of wire bundle on swift	112 lbf and 330 lbf
Lubricant	Duckham's 'Adformal EP 8/10' and Delapenas 'J50'
Swift	Conventional and Motorised

Although trends may have been shown up in the data the degree of scatter is relatively large for the number of experiments made. As a result most of the factors have not been having a statistically significant effect on the variance of the mean free length. However, if the programme were to be repeated twice more the increased amount of information would allow a much better measure of the effect of the various factors to be made.

8. ACKNOWLEDGEMENT

The Association wishes to thank Mr. A. A. Greenfield of BISRA for his assistance with the statistical analysis and computer programming used in this investigation.

TABLE I

COMPARISON OF RESULTS

Experiment	Mean Free Length (in)	'Short Term' variance σ^2 x 10^{-4}	'Long Term' variance σ^2 x 10^{-4}	Free Length Range 95.4% ($\pm$ 2σ)	99.7% ($\pm$ 3σ)
1	1.0827	.2771	.6058	±.016	±.023
2	1.1452	.4395	.6659	±.016	±.024
3	1.0896	.4707	1.3460	±.023	±.034
4	1.1277	.2550	.5261	±.015	±.022
5	1.1281	.1797	.2950	±.011	±.016
6	1.1723	.2093	.5536	±.015	±.022
7	1.1238	.3176	1.1790	±.022	±.032
8	1.1472	.2442	.5545	±.015	±.022
9	1.1570	.2430	..4692	±.014	±.021
10	1.2023	.2878	.4117	±.013	±.019
11	1.1149	.1851	.7392	±.017	±.026
12	1.1703	.2900	.3874	±.012	±.019
13	1.1805	.1355	.2879	±.011	±.016
14	1.1722	.1286	.2400	±.010	±.015
15	1.1172	.1899	.3770	±.012	±.018
16	1.2244	.3592	.8743	±.018	±.028

APPENDIX

Details of Statistical Analysis Employed in this Investigation

The calculated variances were statistically analysed using a computer programme previously written and tested by BISRA. This gave a quantitative measure of the effects of each variable and compared them with the overall variance in free length of all the springs in the form:-

$$y = m + (\pm A) + (\pm B) + (\pm C) + (\pm D)$$

where

y	=	Total free length variance
m	=	Mean variance of all obervations
A	=	Effect of Production Rate
B	=	Effect of Weight of wire bundle on swift
C	=	Effect of Lubricant
D	=	Effect of Swift
r	=	Residual

There were two relationships produced for this investigation; one using the long term variances and the other the short term variances.

Note:- All numbers in equations (1) and (2) below are x 10^{-4}.

Equation (1) gives the contribution to the long term variance of the factors A, B, C & D.

$$1) \quad E(y) = 0.4525 + \overset{A}{\begin{matrix}(+0.0408)\\(-0.0408)\end{matrix}} + \overset{B}{\begin{matrix}(+0.0219)\\(-0.0219)\end{matrix}} + \overset{C}{\begin{matrix}(-0.0541)\\(+0.0541)\end{matrix}} + \overset{D}{\begin{matrix}(+0.0399)\\(-0.0399)\end{matrix}} \quad \begin{matrix}\text{'low'}\\\text{'high'}\end{matrix}$$

The negative sign indicates the smallest variance that has occurred and is, therefore, the appropriate value of the factor to aim for. Its statistical significance can be tested with the 'F ratio test'. In this case the 'F' ratio values are as follows:-

	A:r	B:r	C:r	D:r
F ratio values:	0.9206	0.7638	1.4081	0.6621

Similarly Equation (2) shows how the short term variance is built up from the variances due to the factors A, B, C & D

$$2) \quad E(y)=0.2572 \quad + \quad \begin{matrix}(-0.0058)\\(+0.0058)\end{matrix} + \begin{matrix}(-0.0060)\\(+0.0060)\end{matrix} + \begin{matrix}(+0.0162)\\(-0.0162)\end{matrix} + \begin{matrix}(+0.0482)\\(-0.0482)\end{matrix} \quad \begin{matrix}\text{'low'}\\\text{'high'}\end{matrix}$$

Here the F ratios are:-

	A:r	B:r	C:r	D:r
F ratio values:	0.1383	0.0261	0.2290	5.2055

In this analysis the F ratio values are only significant at the 95% level if the value is greater than 4.84. Hence in the equations (1) and (2) above only the last value in equation (2) is significant i.e. 5.2055 for factor 'D' which is 'type of swift'.