THE SPRING RESEARCH AND MANUFACTURERS' ASSOCIATION

DIMENSIONAL CHANGES OF SPRINGS MADE FROM HARD DRAWN CARBON STEEL WIRE DURING LOW TEMPERATURE HEAT TREATMENT AND PRESTRESSING

by

M.S. Bayliss B.Eng.

Report No. 332

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SUMMARY

Ranges of springs were coiled and measured to determine the changes in diameter, free length and end coil position during LTHT and scragging.

By analysing the results and neglecting the insignificant variables a series of graphs and, where possible, simple formulae have been produced to enable the spring designer and machine setter to predict and allow for these movements at the design stage.

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1. INTRODUCTION

In the spring industry the setting of a coiling machine relies almost entirely on the experiences of the setter. To within a reasonably close approximation he usually knows to what size a spring must be coiled in order that the required dimensions will be obtained after LTHT and prestressing. Despite this, one or two springs will have to be processed to check that these allowances are correct. This means that the coiling machine is idle for about 30 minutes, which for a small run could effectively double the time the machine is being used. This, of course, increases further if the setter's initial allowances prove incorrect.

It was decided to carry out dimensional test before and after LTHT and prestressing on a range of springs and wire sizes so that the results obtained would allow the movement of the spring to be compensated at the design stage rather than by the setter.

2. SPRING DESIGNS

Three wire sizes were used: 0.7 mm, 1.6 mm and 2.8 mm all to BS 5216 ND2.

Springs were coiled to a range of 4 indices; 4, 6, 10, 15, and six solid stresses expressed as a percentage of the wire strength; 40, 50, 65, 80, 100, 120%. The number of turns in each index was chosen so that the wire lengths in each spring of the same wire size were similar. The actual designs were as follows:

Some of the designs had very large pitches and helix angles and could not be coiled satisfactorily on the auto coiling machine. This is the reason for the gaps in the table.

Wire Diameter = 0.7 mm

Spring Index	4	6	10	15
Number of Turns	17	12	7	4
Outside Diameter	3.5	4.9	7.7	11.2
Solid Stress	FREE LENGTH			
40%	16.88	16.58	17.99	18.05
50%	17.95	18.44	21.09	21.69
65%	19.56	21.25	25.74	27.15
80%	21.16	24.05	30.39	
100%	23.30	27.79	36.58	
120%	25.44	31.53		

Wire Diameter = 1.63 mm

Spring Index	4	6	10	15
Number of Turns	17	12	7	4
Outside Diam.	8.15	11.41	17.93	26.08
Solid Stress	FREE LENGTH			
40%	37.58	35.59	36.91	36.18
50%	39.64	39.19	42.87	43.18
65%	42.73	44.58	51.82	53.69
80%	45.83	49.98	60.77	
100%	49.95	57.18	72.70	
120%	54.07	64.38		

Wire Diameter = 2.8 mm

Spring Index	4	6	10	15
Number of Turns	17	12	7	4
Outside Diam.	14	19.6	30.8	44.8
Solid Stress	FREE LENGTH			
40%	63.18	58.72	59.40	57.45
50%	66.38	64.30	68.65	68.32
65%	71.17	72.67	82.53	84.61
80%	75.96	81.04	96.40	
100%	82.35	92.20	114.90	
120%	88.74	103.36		

3. EQUIPMENT USED

The springs of 2.8 and 1.6 mm wire were coiled on a Torin 115A single point machine whilst the 0.7 mm was coiled on a Wafios UFM8.

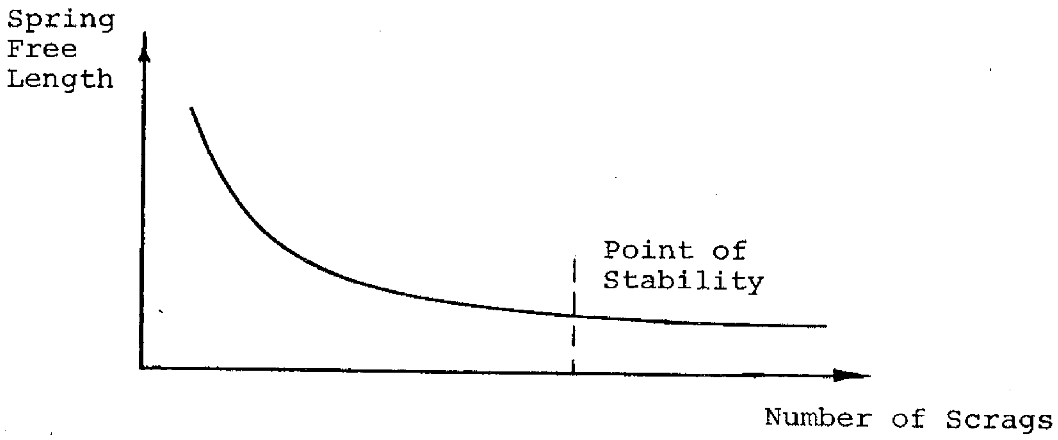
Measurements were made using a Nikon Profile projector fitted with several jigs (Fig. 1) so that consistant datum points were achieved. This meant that as far as possible the measurements would not be subject to setting up errors.

4. EXPERIMENTAL PROCEDURE

The coiling machine was set to produce the required design as closely as possible and five springs collected for measuring. Measurement of free length, diameter and end coil position was made immediately after coiling, when the spring had cooled to ambient temperature, so that any relaxing of the spring due to self-induced stress relieving was not taken into account. Work carried out previously indicated that springs which were not heat treated moved small amounts when left stored for long periods. This would obviously induce variations into the measurements required for this work.

Low temperature heat treatment was carried out at the standard 275^{o}C for 1/2 hour. Re-measurement was then made of the spring dimensions and the changes noted.

Prestressing was carried out using a hand press with mandrels and fixings which were required to minimise distortion of the springs. After each scrag the free length was measured to find the change in length and the number of scrags necessary to arrive at the point of stability. For this work the criteria for stability was the point on the set down curve where the line becomes almost a straight line and parallel to the axis.



After prestressing, the free length, diameter and end coil position were re-measured.

5. RESULTS

The average of each of the batches of five springs was used to find the changes in free length, diameter and end coil position during LTHT and prestressing.

From these results it was possible to detect which were the important variables to consider. This then enabled the effect of these variables to be plotted in graphical form with, where possible, a relatively simple equation that could also be used to predict the results. The measured results have also been extended by interpolating the position of other wire sizes so that the data covers a wider range of wires.

6. DISCUSSION OF RESULTS

The results for the wind-up (change in end coil position) after LTHT and scragging are shown in Fig. (2). It can be seen that after LTHT, wind-up is only dependant on spring index, whilst after scragging the solid stress becomes important in such a way as to lower wind-up with an increase in solid stress.

Changes in outside diameter due to LTHT are shown in Fig.3. The measured results showed a linear trend radiating from the index two point on the x axis; index and wire diameter were the two major variables. The results were such that a simple formula can be used to extend the graph down to 0.2 mm and up to 4.0 mm. The extrapolated points are shown by the dotted lines.

After prestressing, the change in diameter becomes dependant also on solid stress and has to be plotted on a graph shown in Fig.4. The graph allows a factor Δ to be found which is dependant only on spring index and solid stress. The change in outside diameter is then expressed as the product of Δ and d, where d is the wire diameter.

The number of scrags required to stabilise a spring (Fig.5) is dependant on solid stress and spring index and can be read directly off the graph. A formulae has been given which will give an accuracy in the order of 10%. The dotted lines on the graph are drawn through interpolated results.

The results for the change in solid stress after scragging are shown in Fig 6 and are dependant only on index, the higher index springs sitting down sooner than the lower indices.

In all cases the results can only be expected to give a reasonably close approximation to the actual movement because of the uncontrollable effect that different coiling machines, wire batches, heat treatment ovens and scragging machines will have on the way the spring moves.

7. CONCLUSIONS

1. Wind up after LTHT is dependant on spring index, whilst after scragging solid stress also becomes important.

2. Change in diameter after LTHT is dependant on spring index and wire diameter, whilst after scragging solid stress also becomes important.

3. The number of scrags required to stabilise a spring is dependant on the solid stress and spring index.

4. The change in solid stress after LTHT can be neglected but after scragging, it is dependant on spring index and solid stress.

8. EXAMPLE IN THE USE OF THE GRAPHS

The required final dimensions of a compression spring are shown below. The spring is to be subject to LTHT and scragging.

What dimensions should the spring be coiled to and how many scrags are required to make it stable?

Wire Diameter	=	3 mm
Outside Diameter	=	21.49 mm
Free Length	=	70 mm
Total Turns	=	11.52
Solid Stress	=	1015 N/mm^2
Grade 2, U.T.S.	=	1450 N/mm^2

Spring Index: $\frac{D}{d} = \frac{21.49 - 3}{3} = 6.16$

The percentage solid stress of finished spring $= \frac{S.S.}{U.T.S.} \times 100$

$= \frac{1015}{1450} \times 100 = 70\%$

To calculate Solid Stress Before Scragging

Using graph 6, draw a horizontal line from the 70% mark on the y axis so that it intersects the interpolated 6.16 index line. A vertical line is then drawn from the intersect to the x axis. The value indicated by the x axis is the solid stress before scragging.

For the example, the solid stress before scragging equals 97% of the U.T.S.

To Find the Change in O.D. during LTHT and Scragging

Using graph 4 to find the intersect of a vertical line from the 6.16 index point and the 97% solid stress curve it is then possible to find the value Δ

For the example $\Delta = 0.033$

The actual reduction in diameter during LTHT and scragging is Δ.d
$= 0.033 \times 3 \approx 0.1$ mm

Thus the outside diameter to coil the spring to
$= 21.49 + 0.1 = 21.59$ mm

To Find the No. of Scrags Required to Stabilise the Spring

Using graph 5 and projecting back from the intersect of solid stress and spring index an answer of 6.35 is obtained which is rounded up to the nearest whole number of scrags to make the spring completely stable.

To allow for Wind up after LTHT and Scragging

Using graph 2 and projecting back from the intersect of the spring index and solid stress we obtain a wind up value of 2.1°/turn.

There are a total of 11.52 turns which gives a wind up of :-

wind up = 11.52 x 2.1 = 24.2^{o} or 0.067 turns

Thus the number of turns to coil to = 11.52 - 0.067 = 11.45 turns.

<u>To calculate the Free Length to Coil to</u>

The deflection of the finished spring = $L_o - L_s$

= 70 - (11.52 x 3) = 35.44

Hence a deflection of 35.44 mm gives a solid stress of 70%

$\therefore$ a deflection of $\frac{97}{70}$ x 35.44 mm gives a solid stress of 97%

= 49.11 mm

Thus the free length = 49.11 + (11.52 x 3) = 83.67 mm

This is for a ground spring thus for an unground spring the length to coil to = 83.67 + 3 = 86.67 mm

Thus the spring dimensions given to the coiler are:-

O.D.	= 21.59 mm
Free length	= 86.67 mm unground (83.67 mm ground)
Total number of turns	= 11.45
Scrag 7 times	

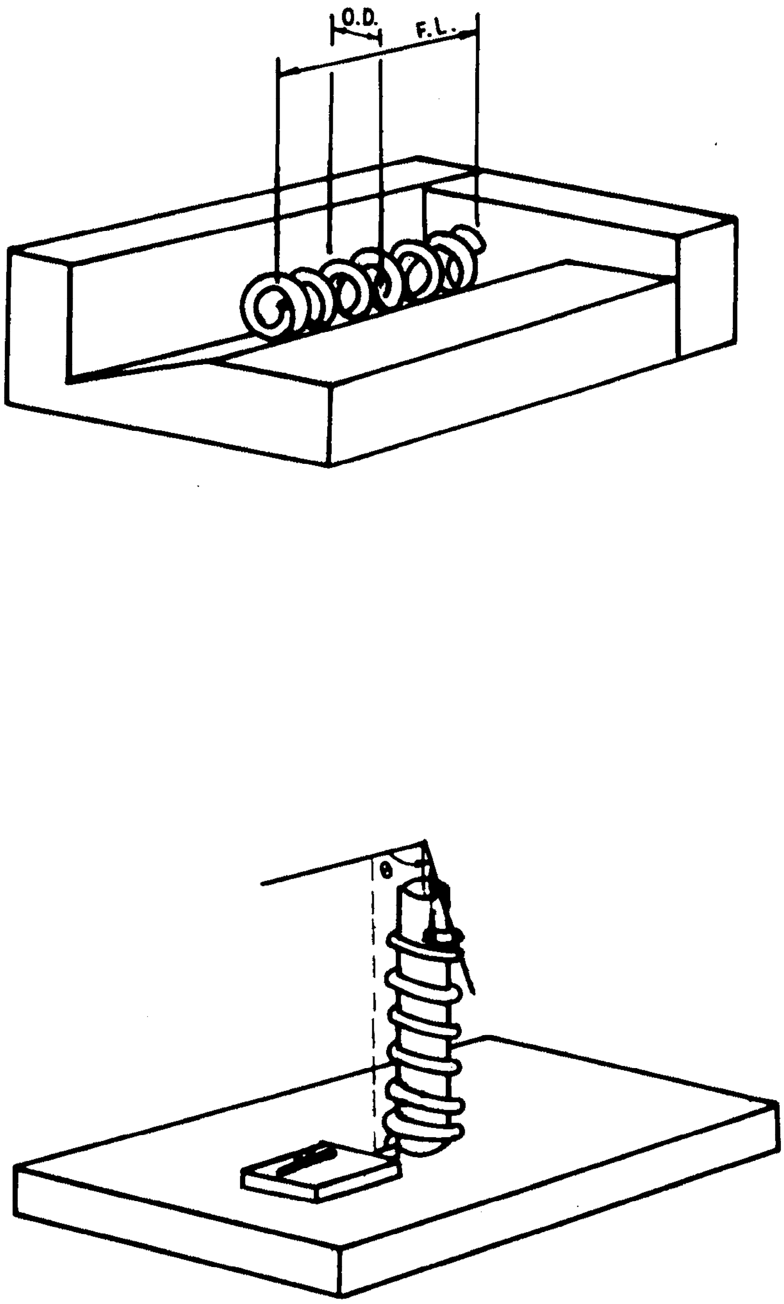


FIG. I MEASURING JIGS USED

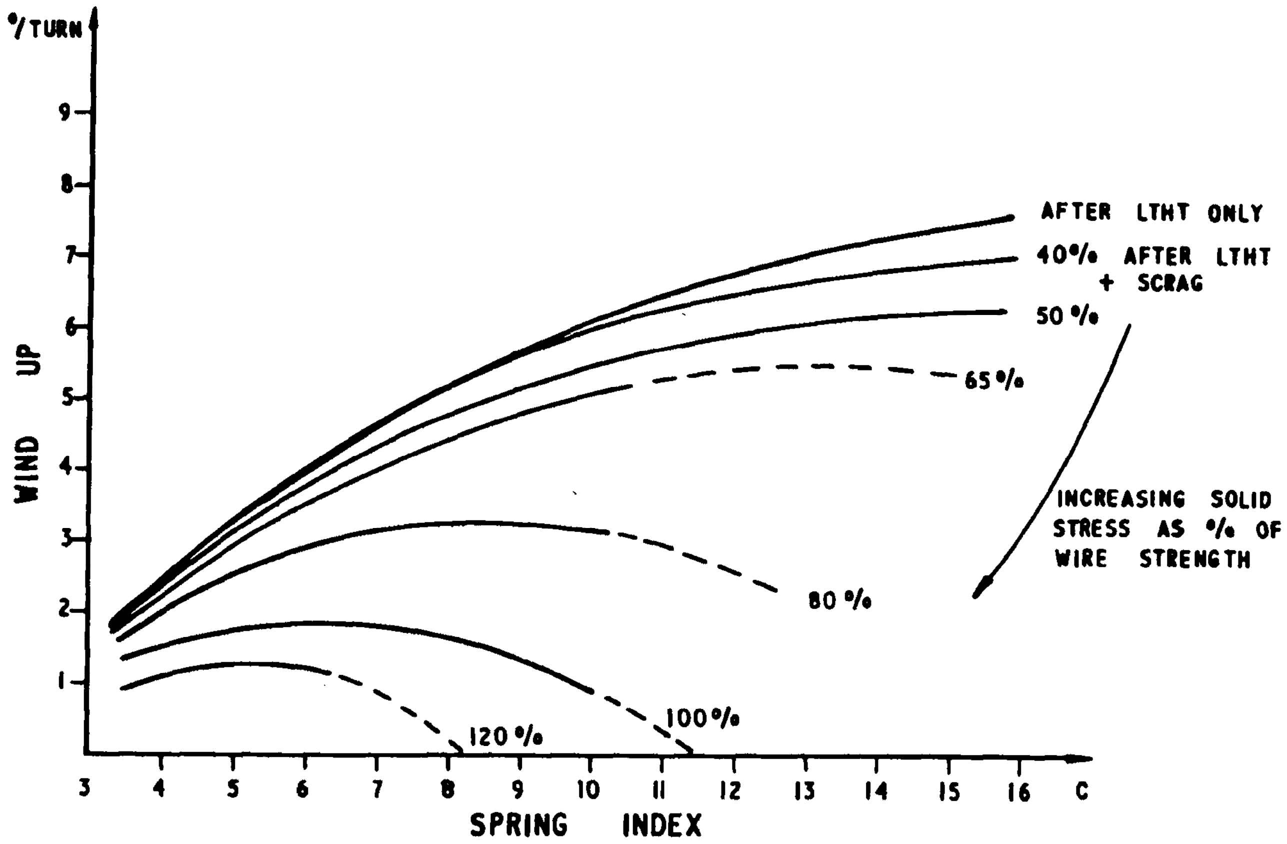
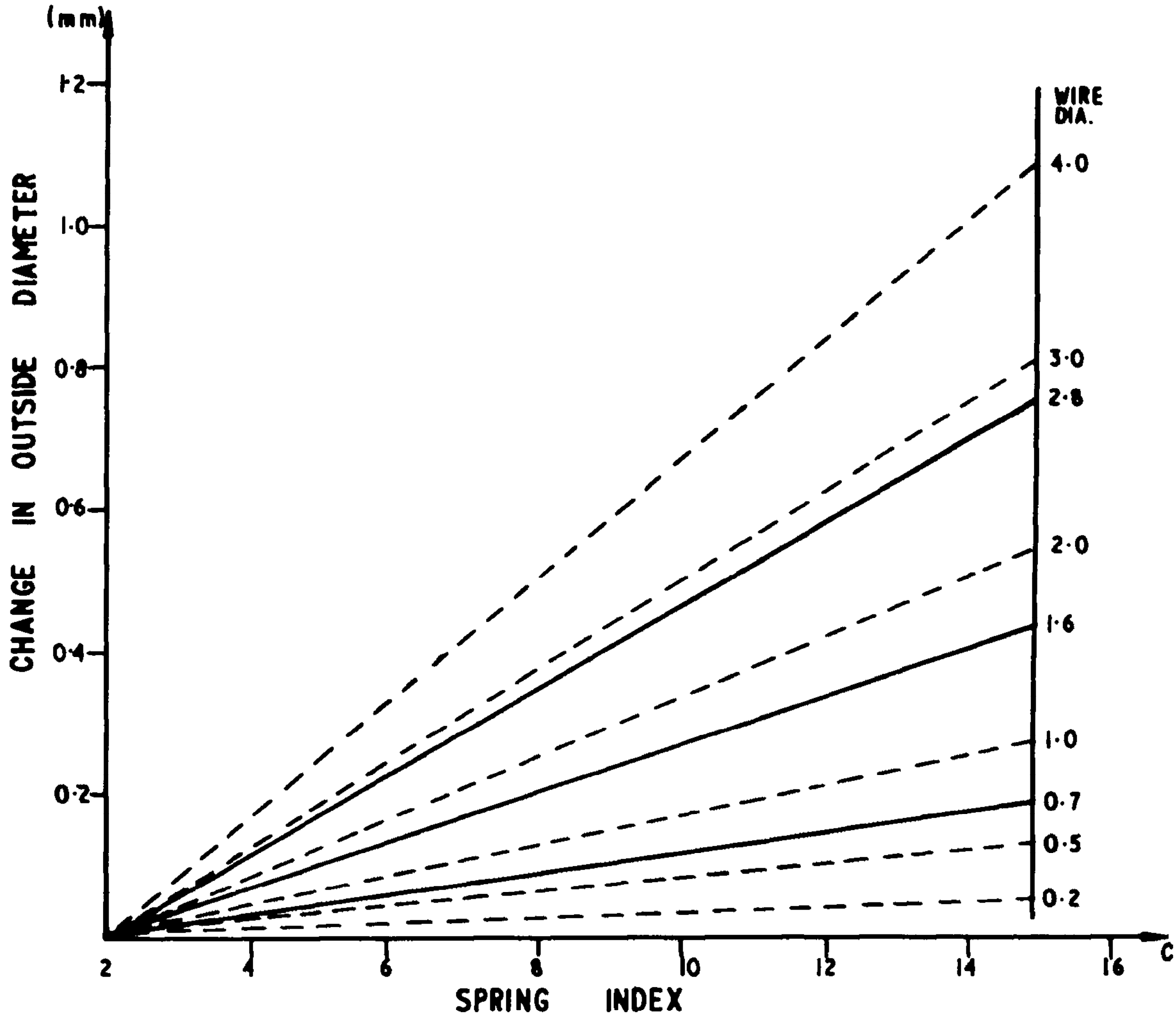
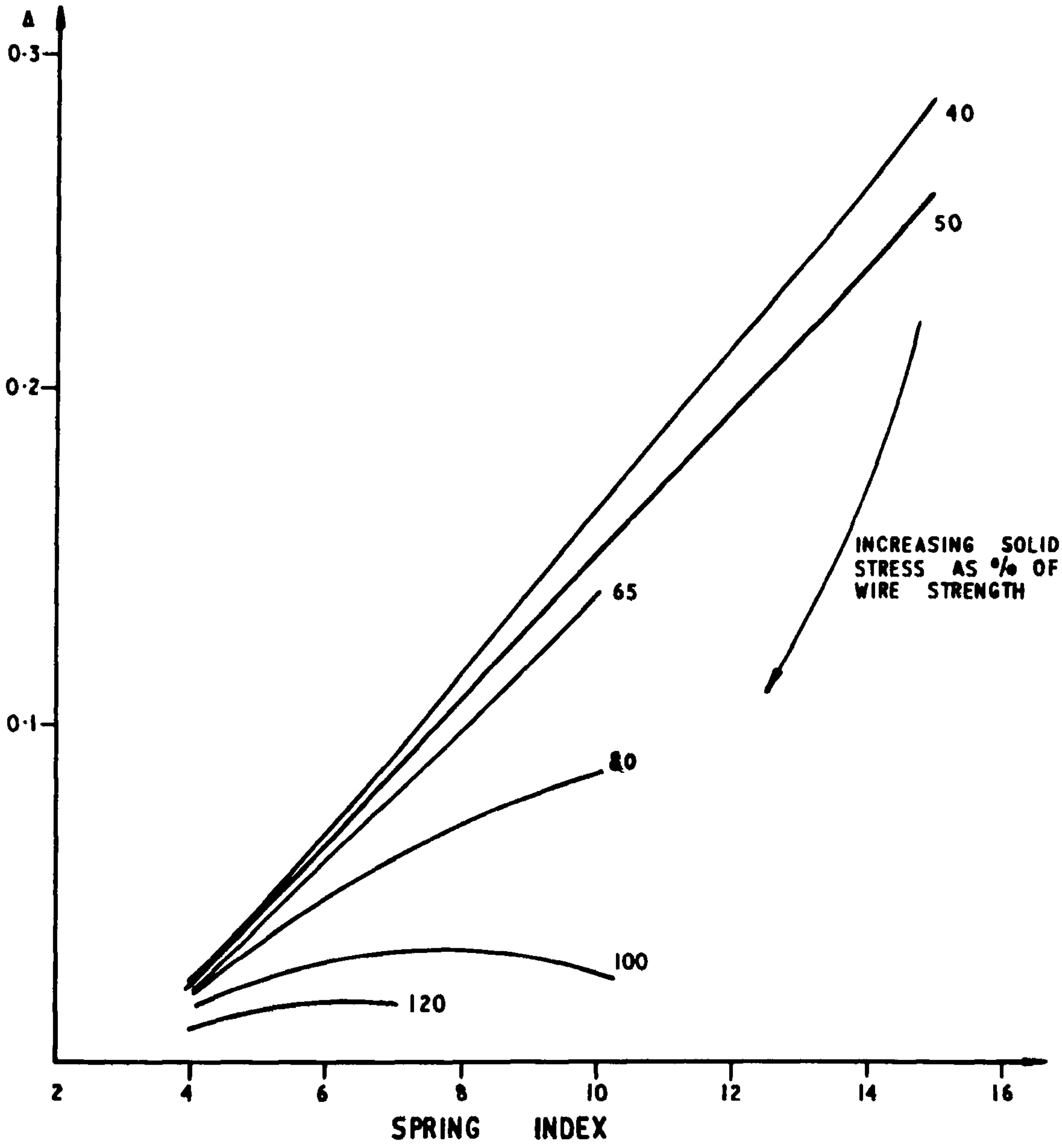


FIG. 2 WIND UP AFTER LTHT AND SCRAGGING.



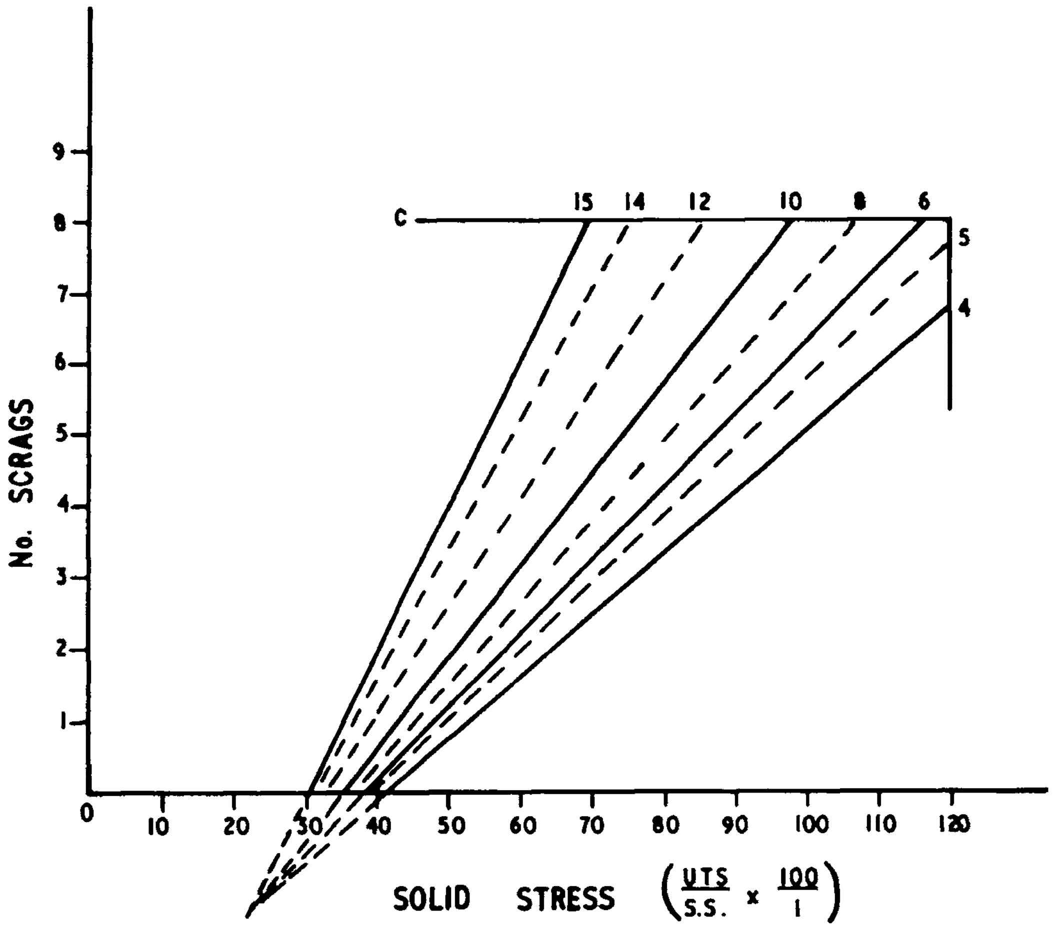
CHANGE IN OUTSIDE DIAMETER $\Delta d = D_0 \times 0{\cdot}021 - 0{\cdot}063\,d$

FIG. 3. CHANGE IN OUTSIDE DIAMETER WITH LTHT.



REDUCTION IN OUTSIDE DIAMETER = Δ× WIRE DIAMETER (mm)
AFTER LTHT + SCRAGGING.

FIG. 4 REDUCTION IN OUTSIDE DIAMETER AFTER LTHT AND SCRAGGING.



$$\text{No. SCRAGS} = 0{\cdot}86 \times \left[\frac{S.S.}{U.T.S.} - 0{\cdot}2\right]\left[C + 6 - 1{\cdot}7\right]$$

FIG. 5 No. SCRAGS v SOLID STRESS.

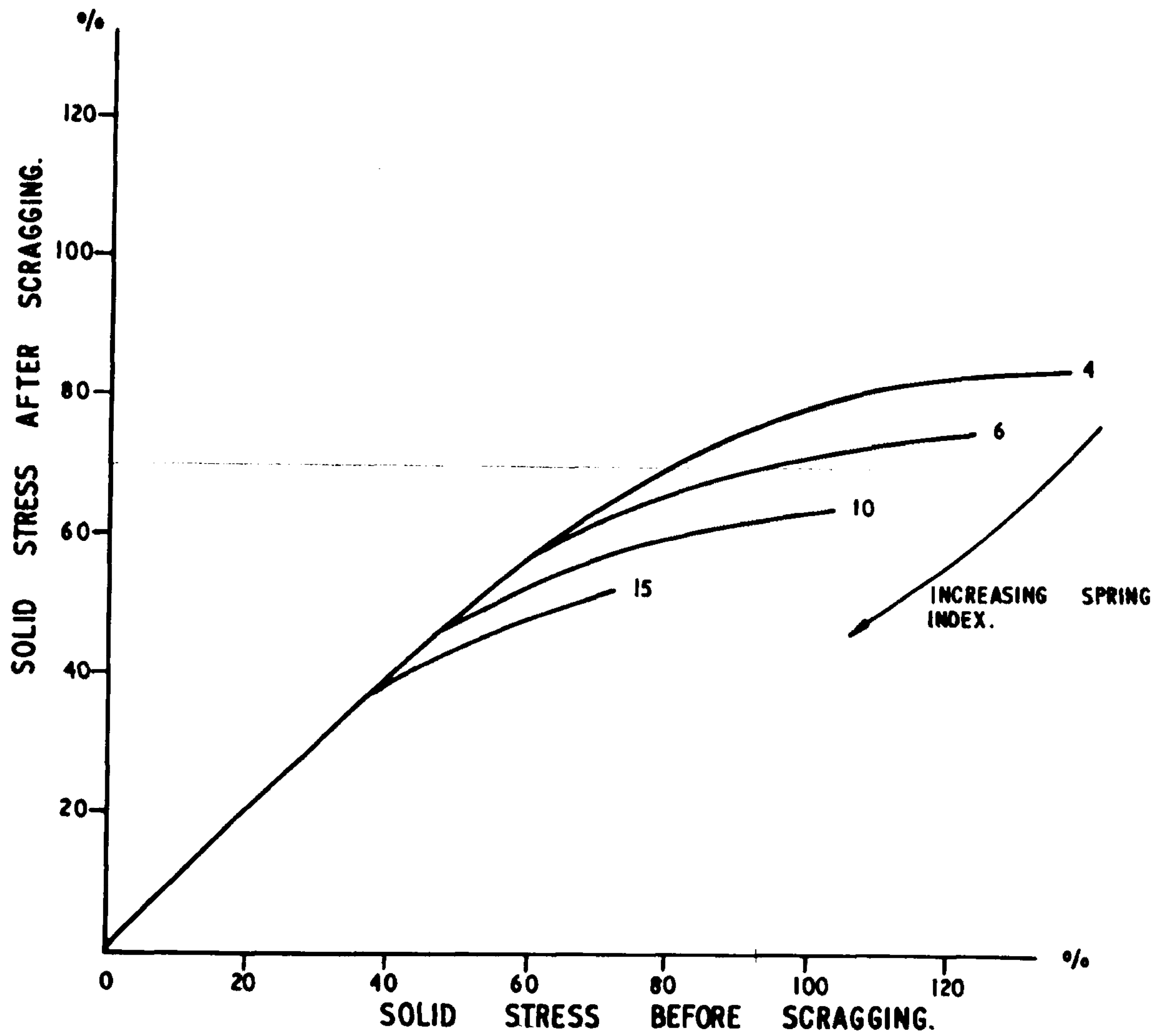


FIG. 6 CHANGE IN SOLID STRESS AFTER SCRAGGING.