THE SPRING RESEARCH AND MANUFACTURERS' ASSOCIATION

A NOTE ON HEAT TREATMENT EQUIPMENT SUITABLE FOR THE RAPID LOW TEMPERATURE HEAT TREATMENT OF LIGHT SPRINGS

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SUMMARY

Current low temperature heat treatment practice has been briefly reviewed and the effects of process time on the mechanical properties of wire and springs considered by reference to previous work carried out by the Association.

A survey of commercially available purpose built low temperature heat treatment ovens and furnaces has been carried out and the pertinent characteristics of each unit has been listed to enable comparisons to be made with respect to process time and output rate

It has been shown that output rate is largely dependent on the size of the spring being treated and would be the most important factor to consider should spring makers wish to apply on-line continuous heat treatment immediately after spring coiling.

The introduction of on-line continuous heat treatment with the attendant cost savings in materials handling and reduction in spring tangling problems would be an important and attractive factor to the introduction of a fully automated manufacturing schedule for volume springs.

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1. INTRODUCTION

The vast majority of light springs are cold formed from materials which are already at, or near to, their optimum strength. However, resulting from the inevitable plastic deformation of the material during cold forming, residual stress systems are set up within the spring material which can affect adversely the ultimate performance of the spring. It is therfore common practice after cold forming springs to carry out some form of heat treatment, usually referred to as low temperature heat treatment or stress relieving within the temperature range of 150°C to 550°C according to the material being treated and the type of enhancement of properties required.

The purpose of a low temperature heat treatment (L.T.H.T.) is to:-

i relieve residual stresses produced by wire drawing and spring forming;

ii increase the mechanical properties of the wire and therefore the spring;

iii stabilise the properties of springs subjected to elevated temperatures.

2. CURRENT L.T.H.T. PRACTICE

In the United Kingdom the process is normally undertaken in batch-type forced air circulation ovens/furnaces which are either gas or electrically heated. The size of these units can vary greatly from small tool room tempering furnaces of 0.01 m^3 capacity upwards to box type ovens of 8 m^3 capacity or more. In well organised coiling shops the number and size of L.T.H.T. units available will be geared to the size and volume of the expected production run. Using the larger type L.T.H.T. unit it is not uncommon for batches of springs to be stacked in wire baskets or on metal trays until sufficient springs have accumulated to constitute a full furnace charge.

Overall process times can vary greatly depending on such factors as the packing density of the springs, batch size and the amount of cold material which constitutes racking, containers, etc. For effective low temperature heat treatment of springs it is important to recognise that the usual temperature indicator is not necessarily a true measure of the furnace charge. With heavily loaded ovens and furnaces sufficient time must be allowed to enable the centre of the charge to attain the required process temperature.

Heat treating small batches of springs usually presents less of a problem in obtaining a uniform temperature throughout the charge. For small batch production liquid heating baths of molten lead and salt are not uncommon but they suffer from a restricted temperature range in the case of molten lead (melting point 327^{o}C) and the toxicity of lead fumes. Using salt baths there is a danger of corrosion from residual salts if these are not completely removed after heat treatment. By virtue of their high heat transfer properties, treatment in liquid baths has certain attractions in reducing the overall process time but on balance such factors as the safety aspects and other limitations and disadvantages have been instrumental in their limited use for the low temperature heat treatment of springs.

3. EFFECT OF PROCESS TIME

Clearly, the influence of process time of low temperature heat treatment is of great interest to the spring manufacturer as any reduction in this parameter could lead to economies in fuel and capital equipment, increased productivity and hopefully reduced production costs.

Before such alterations to L.T.H.T. schedules are made, however, the spring manufacturer must satisfy himself, and possible his customer too, that a reduction in process times does not adversely affect the properties of the finished spring. Work undertaken in the past by the SRAMA[1] has shown the feasibility of shortening process times without, in general, significantly affecting spring properties. Of necessity, the work was restricted in its scope but nevertheless several conclusions and broad indications of the influence of reduced time can be drawn. These were:-

i Heating in air the elastic properties of patented cold drawn wires can be increased in a matter of minutes to similar values as those obtained by conventional L.T.H.T. at $225^{\circ}C$ for 30 minutes.

ii Increasing the temperature of L.T.H.T. reduced the process time to a matter of seconds to achieve the necessary improvements in mechanical properties. However, precise control of temperature and process duration become more important with respect to the consistency of the improvement in properties.

iii Relief of residual stress, as measured by "wind-up" of the spring, would indicate substantial stress-relief after only a few minutes even when air is used as the heating medium.

iv Fatigue tests carried out on springs at room temperature showed no difference in endurance between springs conventionally treated for 30 minutes and those which had received a short process time. In addition, dynamic relaxation occurring at room temperature after testing for 10×10^3 cycles was the same.

One aspect of spring performance which was not investigated was the influence of short term L.T.H.T. on the elevated temperature relaxation behaviour of springs. Any manufacturer considering seriously the adoption of shortened progress times would be well advised to check out this feature before embarking on changes in current L.T.H.T. practice.

However, for applications where the operating conditions of the springs are moderate and relaxation resistance at temperature is not of prime importance rapid L.T.H.T. as a production process would appear to offer certain attractions.

4. FURNACE REQUIREMENTS

From a study and assessment of the low temperature heat treatment equipment in general use within the spring industry it is clear that the vast majority of units are of the air circulation type primarily designed for batch heat treatment. In view of the remarks made earlier regarding these ovens/ furnaces it is clear that they are not particularly suitable for the application of rapid low temperature heat treatment methods and some other design of oven or furnace is required which will enable fairly rapid heating of the spring coupled with accurate control of process time. Since one of the major problems with existing batch type ovens and furnaces is the difficulty of ensuring a uniform process time through a batch due to the sheer volume of springs placed in the furnace the most expedient method of avoiding such a situation is to feed the springs separately into some form of continuous oven or furnace. The need to heat up extraneous material such as racks and metal trays etc. can be avoided and by careful design of the interior of the oven/furnace tangling of the springs can be minimised or avoided entirely.

5. SURVEY OF PURPOSE BUILT L.T.H.T. UNITS

From a world-wide survey recently undertaken it has been shown that only three companies (all of them foreign) manufacture on a commercial basis continuous type ovens/furnaces specifically for the purpose of low temperature heat treating springs. The manufacturers are:-

i Wafios (G.B.) Ltd., Evesham Walk, Redditch, Worcs. England.
ii Adnik MEC Corporation, 7520 Jefferson Street, Paramount, California 90723, U.S.A.
iii Tokyo Gasden Ro Co. Ltd., 2865 Shin Yoshida-cho, Kohoku-ku, Yokohama, Japan.

5.1 Wafios Ltd.

One low temperature heat treatment unit is available from this company as model No. FTA1. The unit consists of a horizontal tube furnace approximately 1.5 metres in length supported in a moveable steel framework to give an acceptable working height of about 1 metre from the floor. Below the circular tube furnace is placed the electrical switch gear and temperature controls. The furnace is rated at 5kw but no details of the maximum operating temperature is given in the literature. The springs are fed through the tube furnace by means of a conveyor which has an infinitely variable speed control which enables an output rate of up to 70 springs per minute to be achieved. It is claimed the FTA1 unit is suitable for heat treating springs produced from wire 0.2 to 0.8 mm diameter, 2 to 10 mm outside diameter and lengths up to 50 mm. Fig. 1 shows the general layout of the unit.

5.2 Adnik MEC

Although marketed in the U.S.A. by Adnik MEC Corporation these heat treatment units are believed to be of Japanese manufacture.

Early models, designated 1.500 and 2.500. were designed around a vertical cylindrical furnace having an inlet hopper at the top which feeds the springs to a continuous circular track within the furnace which eventually discharges the springs through the side of the furnace.

Situated below the furnace is the electrical and temperature control equipment. The essential features of the two models are given below:-

Features	Model 1.500	Model 2.500
Max. wire diameter (mm)	1.2 mm	1.98 mm
Max. Spring O.D.	19 mm	29.7 mm
Max. free length	76 mm	100 mm
Conveyor length	3960 mm	4870 mm
Process time	3 to 20 mins	3 to 20 mins
Electrical rating	2.5 kw	5.0 kw
Max. operating temp.	450^{o}C	450^{o}C

Both models are fitted with adjustable legs which allow the inlet chute to the furnace to be conveniently placed close to a spring coiler. To ensure uniform heating a forced air circulating fan is provided.

A new range of portable stress relieving ovens (Models VR400, VR500 and VR600) which from their specification would appear to supercede the earlier models is now marketed by Adnik MEC. Three different models provide a choice of oven size to match, it is claimed, wire size, spring size and production speed. The units are box shaped with the electronic temperature control, feed control, process timer and associated switches placed above the oven. According to the literature the ovens are suitable for stress relieving compression, extension and torsion springs as well as small multi-formed parts. Again the springs are loaded individually through an inlet chute positioned towards the top of the oven and progress through the heating zone by means of an electro-magnetic feed system. Claims are made that such an arrangement minimises the tangling of the springs. Finally the springs are discharged, after the appropriate pre-set process time, by means of the outlet placed towards the bottom of the oven.

The units are on castors and portable and can therefore be placed close to spring making machines thus offering the facility of heat treatment immediately after coiling with reduced material handling.

Relevant details of the various models are:-

Features		Model VR400	Model VR500	Model VR600
Overall size -	width	470 mm	550 mm	650 mm
	length	450 mm	550 mm	650 mm
	height	900 mm	900 mm	1000 mm
Inlet size -	width	75 mm	100 mm	125 mm
	height	50 mm	50 mm	50 mm
Process time		1 to 30 mins	1 to 30 mins	1 to 30 mins
Electrical rating		3 kw	4.5 kw	6 kw
Max. operating temp.		500°C	500°C	500°C
Max. wire diameter		1.0 mm	2.0 mm	3.0 mm

5.3 Gasden Ro Co. Ltd.

The T.B.C. series of continuous air circulating furnaces comprise some 10 different models which are electrically heated by Nichrome tube type elements. These ovens/ furnaces are designed for direct feeding from the spring coiler to reduce handling and tangling problems. All models consist of a horizontal furnace through which passes an endless variable speed conveyor belt. The tube type heating elements are positioned in the roof of the heating chamber and uniform heating is obtained by a circulating fan placed behind the heating elements. The control panel for temperature and conveyor speed is placed above the furnace chamber. The six smaller units are portable in the sense that they are fitted with castors which allows movement within the spring shop. The larger units due to their weight are static models. Obviously as the physical size of the units increase so the electrical requirements increase from as low as 4 kw to as high as 65 kw. Likewise the number of temperature control points increases from 1 to 3. In all cases the maximum working temperature is set at 500^{o}C.

Major characteristics of the various models are listed below:-

Feature	Model Number TBC-				
	175	210	310	315	415
Overall Size - width (mm)	625	725	825	825	925
height (mm)	1070 to 1270	1080 to 1280	1150 to 1350	1150 to 1350	1260 to1460
length (mm)	1650	2000	2000	2600	2800
Heated zone - width (mm)	100	200	300	300	400
height (mm)	70	90	90	90	90
length (mm)	750	1000	1000	1500	1500
Process time - (mins)	2 to 40	2 to 40	2 to 40	2 to 40	2 to 40
Electrical rating kw	4	8	11	16	20
Max. wire diameter (mm)	1.6	2.6	3.2	4	5

Feature	Model Number TBC-				
	420	520	530	630	740
Overall size - width (mm)	925	970	1020	1120	1220
height (mm)	1300 to 1500	1700	1700	1700	1700
length (mm)	3300	3400	4800	4900	5800
Heated zone - width (mm)	400	500	500	600	700
height (mm)	90	90	120	120	120
length (mm)	2000	2000	3000	3000	4000
Process time (mins)	2 to 40	10 to 35	10 to 35	10 to 35	10 to 35
Electrical rating kw	26	30	40	48	65
Max. wire diameter (mm)	6	7	8	10	12

With the smaller models, up to TBC 420 there is a facility for adjusting the conveyor height to allow convenient feeding directly from some previous operation. Model TBC210 is illustrated in Fig. 2.

In the western world Gasden Ro furnaces are marketed by K.P. American Corp., 21200 Telegraph Road, Southfield, Michigan 48034, U.S.A.

6. DISCUSSION

The Wafios FTA1 has an output rate of up to 70 springs per minute which for a spring having the maximum recommended free length of 50 mm would mean an overall process time of some 25.7 seconds, perhaps too short a time to adequately stress relieve and develop full mechanical properties. However, with springs produced from wire of 0.8 mm a more typical free length would be of the order of say 25 mm and the process time of 51.4 seconds would be much more acceptable. Likewise with very small springs of about 10 mm in length each spring would receive 2 mins. 8 seconds of processing, a time shown to be perfectly adequate for most springs.

Considering the Adnik range of ovens/furnaces, for Models 1.500 and 2.500 a minimum process time of 3 minutes is given in the technical literature. Thus for the Model 1.500 unit a spring having a typical free length of 30 mm would be heat treated at the rate of 44 per minute reducing to 17 per minute for a spring of 76 mm free length. With the larger model 2.500 the production rate would be 27 springs and 16 springs per minute for free lengths of 60 mm and 100 mm respectively.

Regarding the newer range of Adnik stress relieving ovens (VR 400, 500 and 600) output will again depend on the dimensions of the springs being treated. Unfortunately no dimensions of the conveyor are given or typical spring sizes indicated but figures of 350 to 450 per minute are quoted presumably for small springs with the conveyor set to its highest speed.

Taking the smallest unit produced by Gasden Ro as an example, the TBC-175 is suitable for springs manufactured from wire sizes up to 1.6 mm diameter. Bearing in mind the chamber size and taking a typical spring of say d = 1 mm OD = 9 mm and F.L. = 30 mm efficient packing in one layer across the width of the belt would allow some 250 springs in the furnace at any one time.

With a maximum conveyor speed of 2 minutes an output of 125 springs per minute would be possible. Such figures would match a coiling machine producing springs at a rate of 7500 per hour.

Before any intended purchase of the rapid low temperature heat treatment units described in this paper the spring maker would be well advised to look very carefully at the production rates claimed for these ovens/furnaces as the rate can vary quite considerably depending on the dimensions of the springs being treated. Clearly, to apply these units to on-line heat treatment immediately after coiling the capacity of the unit must match the production rate of the spring coiler if bottle-necks are to be avoided.

The benefits of rapid low temperature heat treatment are the likelihood of more uniform heating and consistency of mechanical properties within a consignment. Due to the continuous nature of the process, labour costs due to materials handling and tangling problems are also likely to be reduced. Since the rapid L.T.H.T. process is essentially a continuous process it would obviously lend itself to one stage of a fully automated production schedule where the springs remain separated and therefore are highly suited to individual loading into the next production stage of end grinding.

7. REFERENCES

1. Graves, G.B. and Heap, J.M.A., Rapid low temperature heat treatment of cold drawn steel wire and springs. The Spring Journal, No. 106, March, 1972, pp 16 - 27.

FIG. 1 WAFIOS SPRING TEMPERING UNIT FTA1

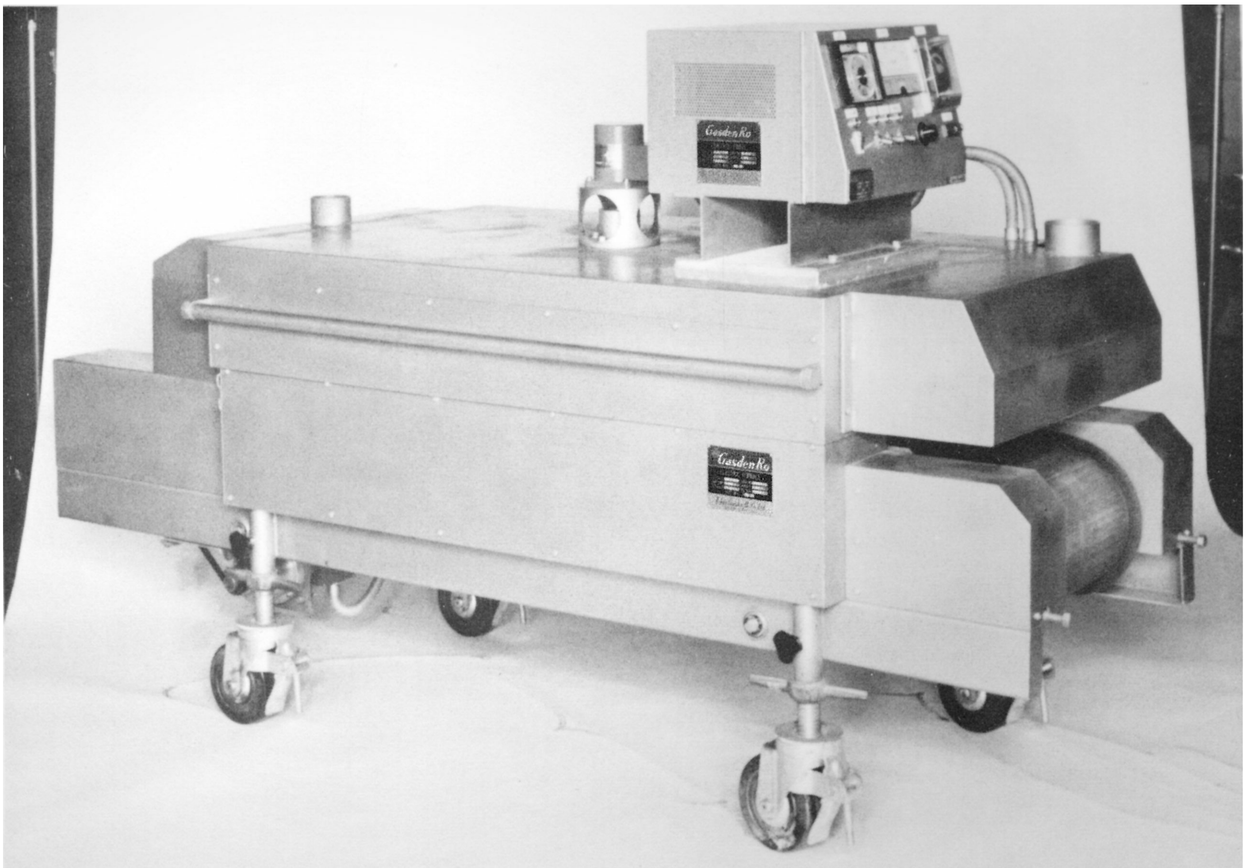

FIG. 2 GASDEN RO MODEL NO. TBC 210