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DIMENSIONAL ANALYSIS OF HELICAL COMPRESSION SPRING MADE OF STAINLESS-STEEL WIRE DURING STRESS RELIEVING

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Abstract: One of the many types of mechanical springs that are widely used in automotive and mechanical systems are helical springs. Residual stresses are produced in springs during the process of cold coiling. To relieve these undesirable stresses, stress relieving is done. This study was carried out to investigate the effect of stress relieving process of helical compression springs made of stainless-steel wire. Experimentation is carried out on sixteen different springs. Stress relieving (tempering) is carried out at different temperature ranging from 180°C to 330°C. Change in outer diameter and no. of turn are noted and analyzed. The result shows slight change in outer diameter and no. of turn. This study is useful for spring manufacturers.
***Index Terms* – Stress relieving, Helical Compression spring, Stainless-steel, Spring index.**

I. INTRODUCTION

Helical springs can be divided into three groups: compression springs, tension springs, and torsion springs. Generally, springs are made using metal materials. Spring steel or stainless steels are used in the majority of applications. Helical compression springs can be made by coiling wire either at normal temperature (cold coil) or at high heat (hot coil).

Hot coiling is the process of feeding heated, cut-up steel wire segments directly onto a mandrel, which quickly coils the wire into a coil. The manufactured coil is quenched and then tempered after being cooled to a temperature well below the austenitizing temperature. The springs are set with torsional residual stress by being shot peened and compressed to solid height (bulldozing). The main downsides of the hot coiling procedure are the potential for decarburization and wire surface scaling. Scaling lowers the spring's resistance to wear.

In cold coiling, the coil is made by feeding wire from a spool onto a mandrel while it is still at room temperature. Large stresses and plastic strains are created during the cold coiling process used to make helical compression springs. These persistent strains produce residual stresses after the procedure is over, which lower spring performance and fatigue life. Tensile residual stresses are recognized to be bad because they encourage crack initiation and subsequent propagation. The inner coil surface experiences tensile residual stresses throughout the spring forming process, whereas the outer coil surface experiences compressive residual stresses.

One of the most important steps in the production of springs is stress relieving. Spring molecular architectures can be physically altered to alleviate stress, resulting in stronger, more dependable, and longer-lasting springs. Heat treatment is frequently used to relieve stress, but it is actually a far broader group of operations that are applied to the majority of metal products for a variety of reasons. Specifically designed to lessen molecular stress in the product, stress relieving is a sort of heat treatment. Stress relief techniques typically involve the use of heat. Freshly wrapped springs are heated to a temperature that is slightly below the material transition temperature in order to increase their flexibility without melting or deforming the wire. Then, once the springs are at room temperature, they are gently chilled. Overly rapid heat reduction might result in extra faults like cracking and distortion. The typical range for stress-relieving temperatures is 180° C to 350° C.

Dimensional shift takes place during the stress reliving treatment of springs. The wire diameter, coil diameter, number of turns, and modulus of rigidity of spring wire all play significant roles in spring design. In general spring manufacturers compensate for these changes by finding the right settings through a combination of experience, calculations and trial and error method. The undertaken study is carried out to reduce the effort and save the time of spring manufacturer.

II. EXPERIMENTAL METHOD

A) Description of experiment

Experimentation for stress reliving of helical compression springs made of stainless-steel wire is carried out. Spring index ranges from 6 to 12 is selected. As per availability of spring wire, wire diameter (d) selected are 1.2 mm, 2.3 mm, 3.2 mm, 3.5 mm. Total 560 spring are manufactured from stainless steel wire.

Figure 1. Sample spring made of Stainless-steel wire (1 to 16)

Details of Stainless-steel springs are as follows;

Table 1. Details of Stainless steel springs

Spring No.	Spring Designation	Wire Diameter (mm)	Spring Index	Outer Diameter (mm)	No. of Coils
1	STSTW1.2C6	1.20	6.00	8.40	5.75
2	STSTW1.2C8	1.20	8.00	10.80	5.75
3	STSTW1.2C10	1.20	10.00	13.20	5.75
4	STSTW1.2C12	1.20	12.00	15.60	5.75
5	STSTW2.3C6	2.30	6.00	16.10	5.75
6	STSTW2.3C8	2.30	8.00	20.70	5.75
7	STSTW2.3C10	2.30	10.00	25.30	5.75
8	STSTW2.3C12	2.30	12.00	29.90	5.75
9	STSTW3.2C6	3.20	6.00	22.40	5.75
10	STSTW3.2C8	3.20	8.00	28.80	5.75
11	STSTW3.2C10	3.20	10.00	35.20	5.75
12	STSTW3.2C12	3.20	12.00	41.60	5.75
13	STSTW3.5C6	3.50	6.00	24.50	5.75
14	STSTW3.5C8	3.50	8.00	31.50	5.75
15	STSTW3.5C10	3.50	10.00	38.50	5.75
16	STSTW3.5C12	3.50	12.00	45.50	5.75

B) Procedure for experimentation

A spring coiling machine is used to coil 35 samples of each spring number (1–16). Each spring is assigned a number between 1 and 35 using soft metal wire and metal tags. Seven groups of five springs each are formed from the total 35 springs. Before stress reliving, dimensions of the entire spring are measured and recorded in tabular form.

Figure 2. Stainless steel springs ready for stress relieving

Seven distinct temperatures, ranging from 180°C to 330°C, are used for stress reliving, with a 10-minute tempering period for each temperature. There are a total of 7 experimental variations for stress relieving. The information is as follows;

Table 2. Details of experimental runs

Experiment No.	Spring Nos.	Tempering Temperature, °C	Tempering Time, minutes	Total Spring in furnace
1	1 to 5	180	10	80
2	6 to 10	205		80
3	11 to 15	230		80
4	16 to 20	255		80
5	21 to 25	280		80
6	26 to 30	305		80
7	31 to 35	330		80

Spring is kept in a metal tray for each experiment. A metal tray is placed inside the furnace, in the centre. The temperature is set using the temperature control knob. The furnace fan is kept running to ensure even heating.

Figure 3. Spring placed in furnace

Figure 4. Control Panel of furnace

After attending to the specific temperature, the time is set using the time setting knob. The furnace is turned off after heating for the specified amount of time. The spring tray is removed from the furnace and left outside to cool slowly. A cloth is used to clean the springs. After stress relieving, the dimensions of each spring are measured and tabulated.

C) Measurements and Calculations

Each spring's measured dimensions (outer diameter of coil & number of turns/coils) are saved in Microsoft Excel. The difference in the outer diameter of the coil and the number of turns is calculated. For each experimental result, the average difference is computed for each sample spring (1–35).

Graphs are plotted for:

- Tempering temperature and time versus Average change in coil diameter.
- Tempering temperature and time versus Average change in no of coil (turns).

III. RESULT AND DISCUSSION

The purpose of this study is to determine the effect of stress relieving treatment on the outer diameter and number of turns of helical compression springs made of stainless-steel wire. To improve the reliability of the results, five samples are treated and measured to determine average values. The outer diameter of springs is measured at both ends. The number of turns is calculated by holding the spring vertically.

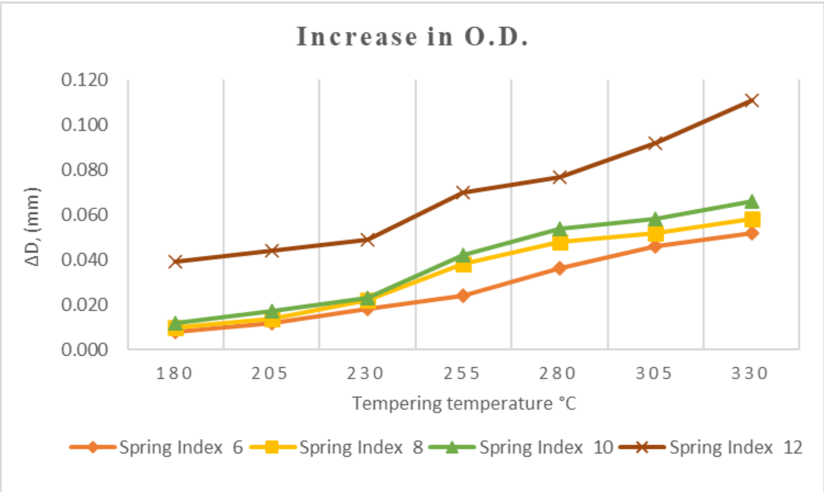

Figure 5. Increase in coil diameter for STSTW1.2 w.r.t spring index

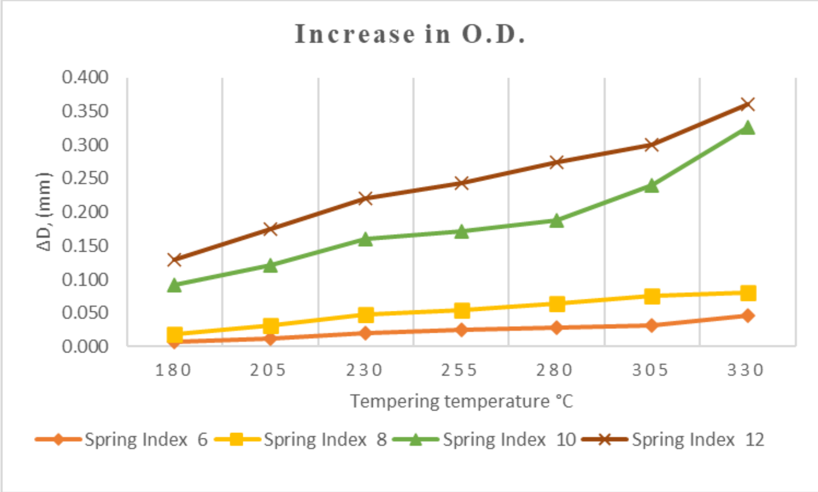

Figure 6. Increase in coil diameter for spring STSTW2.3 w.r.t spring index

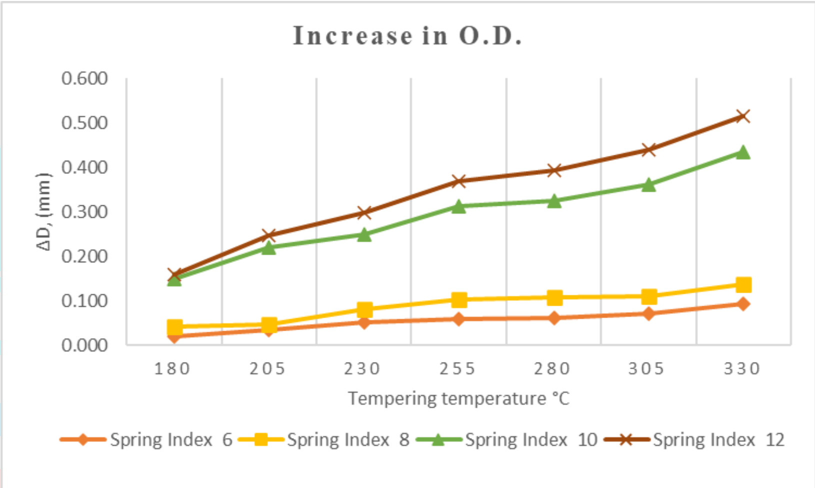

Figure 7. Increase in coil diameter for spring STSTW3.2 w.r.t. spring index

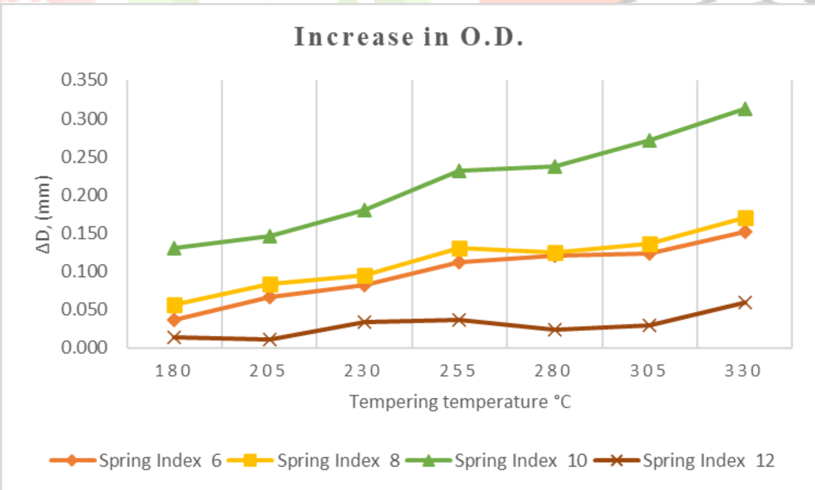

Figure 8. Increase in coil diameter for spring STSTW3.5 w.r.t. spring index

Figures 5 to 8 show the average value of increase in outer diameter ΔD, (mm) for temperatures ranging from 180°C to 330°C for springs with wire diameters d = 1.2 mm, d = 2.3 mm, d = 3.2 mm, and d = 3.5 mm respectively. It was observed that the maximum increase in outer diameter ΔD for wire diameter 1.2 mm is 0.111 mm, the maximum increase in outer diameter ΔD for wire diameter 2.3 mm is 0.360 mm, the maximum increase in outer diameter ΔD for wire diameter 3.2 mm is 0.516 mm, and the maximum increase in outer diameter ΔD for wire diameter 3.5 mm is 0.313 mm.

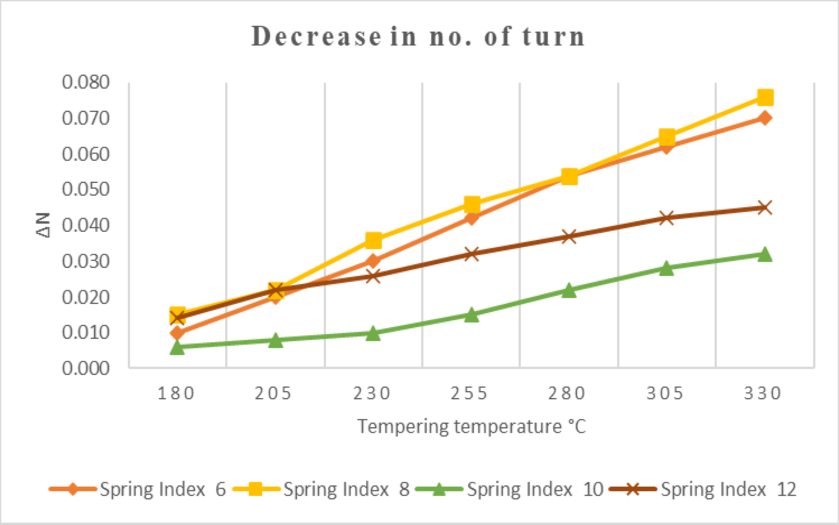

Figure 9. Decrease in no. of turn for spring STSTW1.2 w.r.t. spring index

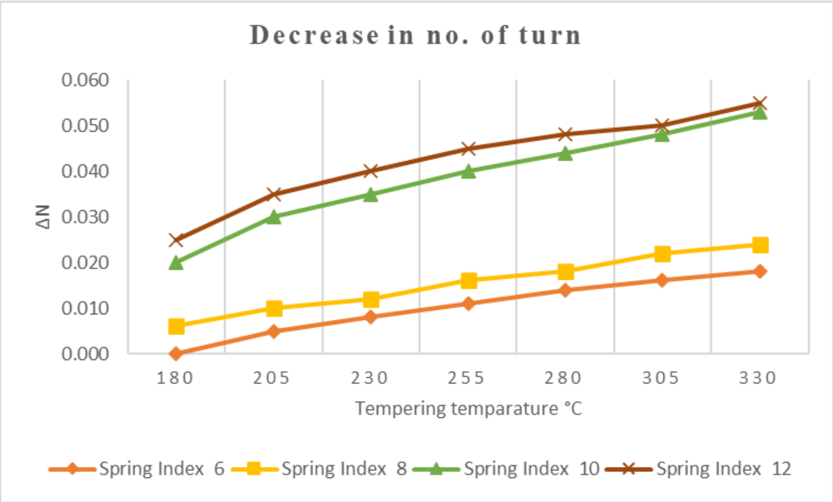

Figure 10. Decrease in no. of turn for spring STSTW2.3 w.r.t. spring index

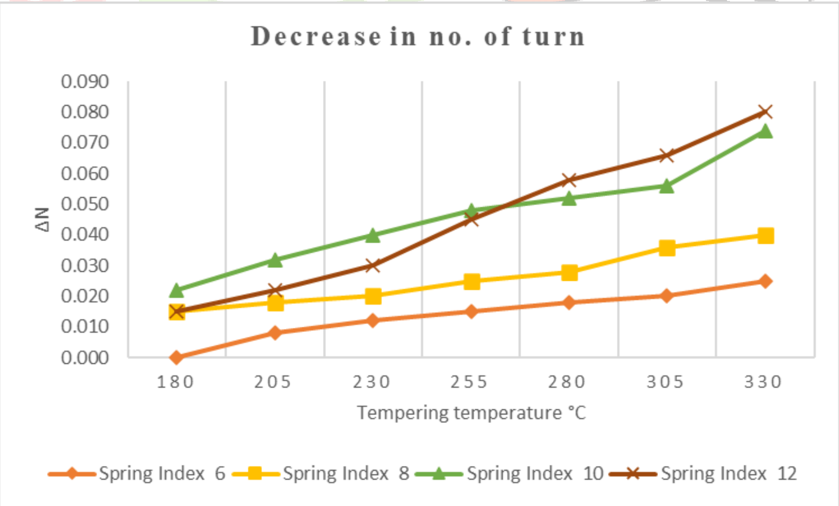

Figure 11. Decrease in no. of turn for spring STSTW3.2 w.r.t. spring index

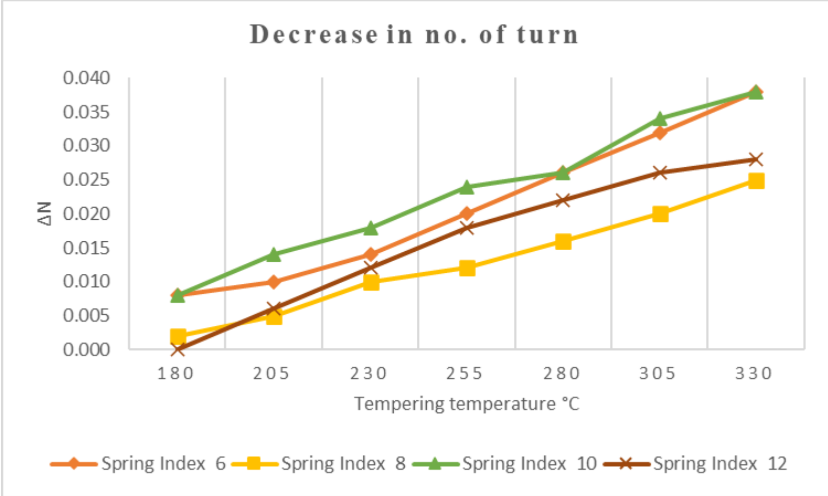

Figure 12. Decrease in no. of turn for spring STSTW3.5 w.r.t. spring index

Figures 9 to 12 show the average value of decrease in number of turns ΔN for temperatures ranging from 180°C to 330°C for springs with wire diameters d = 1.2 mm, d = 2.3 mm, d = 3.2 mm, and d = 3.5 mm respectively. It was observed that the maximum decrease in number of turn ΔN for wire diameter 1.2 mm is 0.076, for wire diameter 2.3 mm is 0.055, for wire diameter 3.2 mm is 0.080, and for wire diameter 3.5 mm is 0.038.

IV. CONCLUSION

When stress relieving of the spring made of stainless-steel wire, the coil diameter (outer diameter) of the spring increases slightly and the number of coils decreases slightly as the stress relieving temperature rises. The stiffness of the spring changes as the coil diameter and number of coils changes. The stiffness of a spring is an important characteristic. As a result, necessary corrections are required for spring coiling setting purposes. The data from the above results can be used by spring manufacturers to set the machine in the least amount of time, minimize waste due to trial and error, and reduce machine idle time.

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