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Impact of Stress Relieving on Static Load for Helical Compression Springs of Stainless Steel

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Abstract— ***The effect of stress relieving on static load for helical compression springs made of stainless-steel wire is presented in this paper. The most important parameter in spring design is spring rate and static load. In many applications, static load at a specific compressed length is an important design requirement. Tempering is a stress-relieving treatment that is performed at temperatures ranging from 180°C to 330°C. In this study, twelve different helical compression springs with different wire diameters and spring indexes are stress relieved. All spring samples are subjected to a static load test. The variation in static load is observed. This research is useful for spring manufacturers.***

Keyword— ***Helical compression springs, Stress relieving, Static load, Stainless steel wire, Spring index.***

I. INTRODUCTION

Helical springs are used in both automobiles and household appliances. The majority of springs are constructed from stainless steel or spring steel wires. Cold coiling is used for smaller wire diameters. The spring is made by cold coiling by feeding wire from a spool onto a mandrel at room temperature. Residual stresses are generated during the cold coiling of springs; these residual stresses are detrimental to spring function and expected life. These residual stresses are eliminated through stress relieving (tempering) treatment. Stress relief is performed immediately following coiling.

To increase flexibility without melting or deforming the wire, springs are heated to a temperature slightly below the material transition temperature during stress relieving. This temperature is maintained in the springs for 10 to 20 minutes. The springs are naturally cooled after being removed from the furnace. The typical temperature range for stress relief is 180°C to 350°C.

Terms related to springs are wire diameter (d), Coil diameter (D), total number of coils, pitch (P), deflection (δ), free length, Compressed length and Solid or Block length, Basic terms used in springs are shown in figure 1.

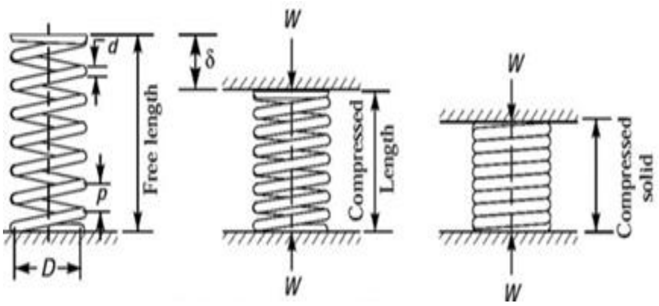

Figure 1. Terms used in helical compression springs

Major steps of spring manufacturing are shown in figure 2.

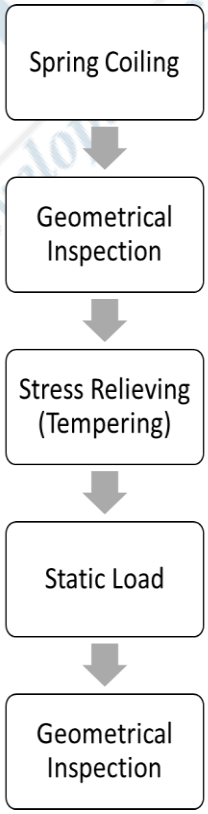

Figure 2. Spring manufacturing process

II. EXPERIMENTAL METHOD

A) Stress Relieving

Experiments are being carried out to relieve the stress of a helical compression spring made of stainless-steel wire. Table 1 shows the specifics of the springs used in the experiments.

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Table 1. Springs used for stress relieving

Spring No.	Wire dia., d (mm)	Spring Index, C	No. of Coils	Total Samples
1	2.3	6.0	5.75	35
2	2.3	8.0	5.75	35
3	2.3	10.0	5.75	35
4	2.3	12.0	5.75	35
5	3.2	6.0	5.75	35
6	3.2	8.0	5.75	35
7	3.2	10.0	5.75	35
8	3.2	12.0	5.75	35
9	3.5	6.0	5.75	35
10	3.5	8.0	5.75	35
11	3.5	10.0	5.75	35
12	3.5	12.0	5.75	35

Experiments for stress relief are carried out at seven different temperatures. Each experiment's tempering time is 10 minutes. Table 2 contains more information. Figure 3 depicts a stress-relieving furnace with a control panel.

Table 2. Details of experimental runs

Expt. No.	Spring No.	Tempering temp., °C	Total spring in furnace
1	1-5	180	60
2	6 - 10	205	60
3	11 - 15	230	60
4	16 - 20	255	60
5	21 - 25	280	60
6	26 - 30	305	60
7	31 - 35	330	60

Figure 3. Stress relieving furnace with control panel

B) Static Load Test

All 420 stainless-steel wire springs are subjected to a static load test. The spring is tested while standing vertically in the normal loading direction. The load testing machine in use has a capacity of 0 to 100 kg. Figure 4 depicts a spring load testing machine. The spring is compressed three times in quick succession to solid length before performing the static test in each case.

Figure 4. Springs Load Testing Machine

Three load readings are taken for each spring by rotating the spring circumferentially. Load tests are carried out at compressed lengths of 19 mm, 24 mm, and 27 mm for springs with wire diameters of 2.3 mm, 3.2 mm, and 3.5 mm, respectively. Figure 5 depicts a static load test.

Figure 5. Helical Spring while static load test

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C) Analysis of data

Tempering temperature versus static load graphs are plotted for springs with wire diameters of 2.3 mm, 3.2 mm, and 3.5 mm. The difference between the highest and lowest static loads is computed. The percentage variation in static load for each spring is calculated to compare the results on common ground.

III. RESULT AND DISCUSSION

Each spring's static load is recorded and saved in Microsoft Excel. The average of all three readings is calculated. The averaging is done for all five-springs static load which has given same stress relieving treatment.

Figure 6. shows the effect stress relieving (tempering) temperature for various springs made of stainless-steel wire, wire diameter d = 2.3 mm and spring index (C = 6, C = 8, C = 10 and C = 12).

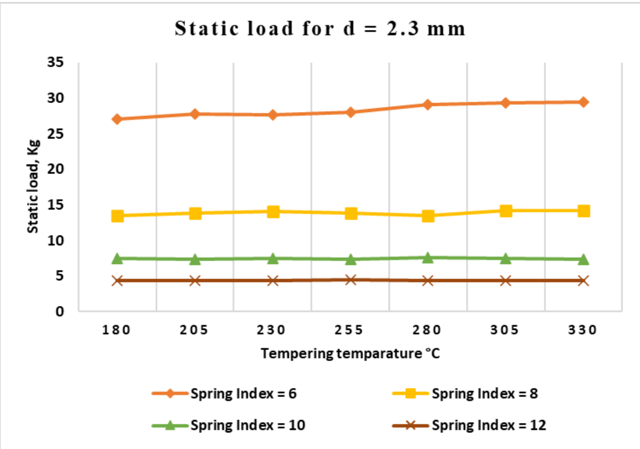

Figure 6. Static load for STSTW2.3 w.r.t tempering temp.

Figure 7. shows the effect stress relieving (tempering) temperature for various springs made of stainless-steel wire, wire diameter d = 3.2 mm and spring index (C = 6, C = 8, C = 10 and C = 12).

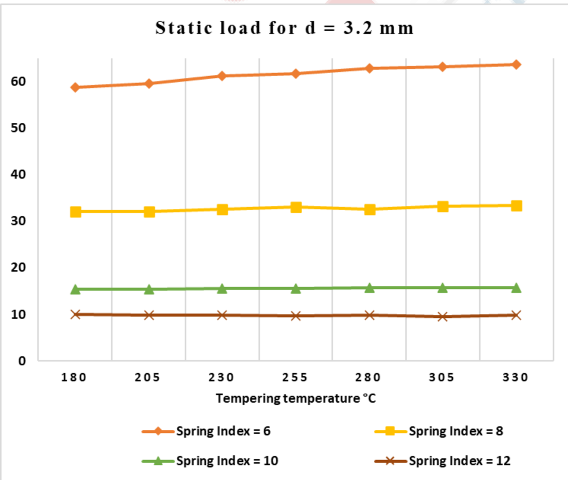

Figure 7. Static load for STSTW3.2 w.r.t. tempering temp.

Figure 8. shows the effect stress relieving (tempering) temperature for various springs made of stainless- steel wire, wire diameter d = 3.5 mm and spring index (C = 6, C = 8, C = 10 and C = 12).

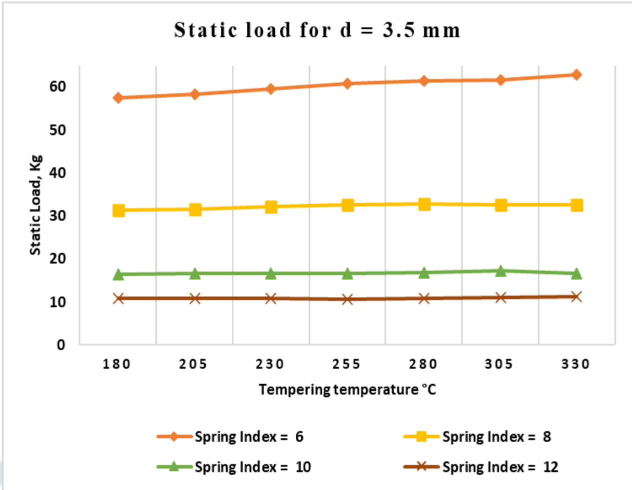

Figure 8. Static load for STSTW3.5 w.r.t. tempering temp.

Following tables show the variation in static load w.r.t. stress relieving temperature for various spring index.

Table 3. Effect on Static load for springs of wire diameter d = 2.3 mm

For d = 2.3 mm	Spring Index (C)			
	6	8	10	12
Variation in static load, Kg	2.34	0.78	0.24	0.11
% Variation in Static load	7.95	5.48	3.18	2.46

Table 4. Effect on Static load for springs of wire diameter d = 3.2 mm

For d = 3.2 mm	Spring Index (C)			
	6	8	10	12
Variation in static load, Kg	5.01	1.33	0.32	0.35
% Variation in Static load	7.86	3.97	2.03	3.52

Table 5. Effect on Static load for springs of wire diameter d = 3.5 mm

For d = 3.5 mm	Spring Index (C)			
	6	8	10	12
Variation in static load, Kg	5.28	1.46	0.86	0.67
% Variation in Static load	8.41	4.43	4.97	5.92

IV. CONCLUSION

The experimental finding demonstrates that the static load is minimal at lower stress relief temperatures (tempering temperatures). With an increase in stress-relieving temperature, static load rises. Additionally, it was noted that as the spring index rises, the percentage variation in static load reduces.

V. ACKNOWLEDGEMENTS

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