

The Influence of Annealing Temperatures on the Ductility and Toughness of Springs.

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ABSTRACT

This study was carried out to investigate the influence of annealing temperatures on the ductility and impact toughness of springs. The springs were made from mild steel rod having a diameter of 6mm. The springs were then subjected to annealing process at temperatures of 650°C, 700°C, and 850 °C. The annealed springs were tested for ductility and impact toughness. The annealed spring became softer with increase in the annealing temperature; its percentage elongation, or ductility, increased from 18.75% to 30% and later 42.5 % with increase in annealing temperature. The impact toughness increased from 40 J to 45J and later to 49 J. The Rockwell hardness values however reduced from 30 RC to 23 RC and later 20 RC as annealing temperature increased.

(Keywords: annealing, temperature, ductility, toughness, springs)

INTRODUCTION

A spring is defined as an elastic body, whose function is to distort when loaded, and to recover to its original shape when the load is removed. The various important applications of springs are as follows:

- 1) To cushion, absorb or control energy due to either shock or vibration, as in car springs, railway buffers, aircraft landing gears, shock absorbers and vibration dampers;
- 2) To apply forces, as in brakes, clutches and spring loaded valves;
- 3) To control motion by maintaining contact between two elements, as in cams and followers.

4) To measure forces, as in spring balances and engine indicators.

5) To store energy, as in watches.

There are various types of springs, these are; coil springs, leaf springs, torsion bars and air springs (Harris, 2009). Coil springs are a mechanical device which is typically used to store energy and subsequently release it to absorb shock, or to maintain a force between contacting surfaces. Leaf springs are suspension springs made up of several thin, curved, hardened-steel or composite-material plates attached at the ends to the vehicle underbody. Torsion bars are long straight steel bars fastened to the chassis at one end and to a suspension part at the other which when twisted provides the spring force. Air springs are mechanical devices using confined air to absorb the shock of motion.

Generally, springs are essential parts used in various machineries and equipments and their failure can and could lead to a failure of such equipment and machinery. It is thus very essential that springs are appropriately manufactured and produced to prevent failure.

Springs are essential parts used in various machineries and equipments and their failure can and could lead to a failure of such equipment and machinery. It is thus very essential that springs are appropriately manufactured and produced to prevent failure (Kadrim, 1992). As the steel is heated above the critical temperature, about 1335°F (724°C), it undergoes a phase change, recrystallizing as austenite. If the austenitic steel is cooled slowly (allowed to cool in the furnace), it will return to the pearlite structure (Htuni et al., 2009).

Many car owners and vehicle operators often change the shock absorbers and suspension

springs of their vehicles due to bad roads as well as badly manufactured springs. It is thus essential that springs are properly produced to withstand all the operational conditions they will be subjected to, and this can be achieved by proper heat treatment process of the spring, thus there is a need to understand the effect of heat treatment on the properties of springs.

The followings are therefore the objectives of this project:

- 1) To design and fabricate coil springs;
- 2) To evaluate the effect of annealing temperature on the ductility and impact toughness of the springs.

MATERIALS AND METHODS

Materials used for this project can be listed as follows;

- 1) Steel rod
- 2) Arbor or Manderel
- 3) Wire cutter
- 4) Pliers
- 5) Electric furnace
- 6) Grinding machine
- 7) Impact tester
- 8) Tensile strength tester
- 9) Hand gloves
- 10) Vernier calipers
- 11) G clamp

Table 1: The Chemical Composition of Steel Rod Used (wt. %).

C	Mn	Si	P	Al	Fe
0.21	0.272	0.016	0.005	0.034	99.3

Fabrication of Springs

The springs were made using mild steel rods having a diameter of 6mm. The following were the steps taken during the making of the springs:

The manderel and one end of the steel rod were clamped together with the use of a g clamp. The steel rod was clamped to the beginning of the manderel. The steel rod was then wound round the manderel at the desired pitch.

When the desired number of turns was reached (i.e. 8 turns), the steel rod was then cut off from the unwound steel rod with the help of a saw.

The mandrel with the spring wound round it was removed from the g-clamp after which the spring was removed from the mandrel. Annealing was carried out by heating the springs each to temperatures of 550, 700, and 850 °C, respectively, after which they were allowed to cool in the furnace by switching off the furnace until the springs cooled down to room temperature.

TESTS FOR MECHANICAL PROPERTIES

Impact Toughness

The impact test is done with an impact tester. This is used to determine toughness of the steel wire used for the spring the impacter was allowed to fall from a certain height in order to crush the steel rod. The height from which the impacter is released can be used to measure the degree of hardness of the steel rod by the amount of energy absorbed by the rod before fracture.

Tensile Test

The tensioning machine was used to determine the strength of the spring. A force is applied axially via weights on the tensioning machine. The amount of force required to produce a certain amount of deflection was then recorded for all the spring samples.

Hardness Test

The surface hardness test was measured by Matsuzawa DXT3 Rockwell test device according to the ISO standards this was done to determine the hardness of the various heat treated springs.

RESULTS AND DISCUSSION

Fabricated Springs

A total of 12 springs were fabricated, three of such springs were not subjected to any heat treatment (as received springs) while three were subjected to annealing, three to normalizing,

three for water quenching and the water quenched springs were also then tempered.

Result of Tension Test in Relation to Annealed Springs

For the annealed sample at 550°C it was observed that every 4 kg of load added produced an extension of 0.5 cm, but when an increment of load from 12 kg to 16 kg occurred, the extension produced was 0.9 cm, which indicated that the yield load was 12 kg as shown in Figure 1 and Table 2. Similarly the yield load for the other annealed spring can be obtained from the Table 3.

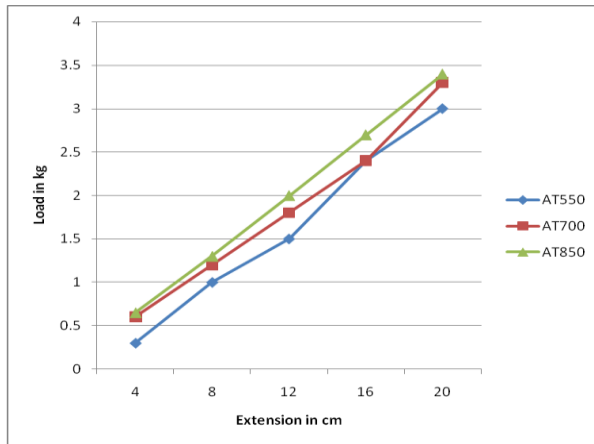


Figure 1: Load in kg against Spring Extension in cm.

Table 2: Tension Test for Annealed and As Produced Springs.

Load (kg)	Extension (cm) Annealed at 550°C	Extension (cm) Annealed at 700°C	Extension (cm) Annealed at 850°C	Extension (cm) As produced sample
4	0.5	0.6	0.65	0.4
8	1.0	1.2	1.3	0.8
12	1.5	1.8	2.0	1.2
16	2.4	2.4	2.7	1.6
20	3.0	3.3	3.4	2.0

Table 3: Impact Toughness and Hardness Test for Annealed Springs.

S/no	Spring Description	YL (kg)	Ys (kg/mm)	Extension (cm)	% Elongation	Toughness (Joules)	Hardness (RC)
1	Annealed at 550	12	0.424	1.5	18.75	40	30
2	Annealed at 700	16	0.565	2.4	30	45	23
3	Annealed at 850	20	0.707	3.4	42.5	49	20

Toughness and Impact Test Result

The result of the impact toughness and the hardness test of the various heat treated samples were tabulated in Table 3.

Percentage Elongation and Yield Stress were Evaluated into the Table

$$\% \text{ elongation} = \frac{\text{increase in length}}{\text{original length}} \times 100,$$

$$\text{stress} = \frac{\text{force}}{\text{area}}$$

Annealed Springs

Fully annealed carbon steel consists, in addition to impurities and other alloyed elements, of a mechanical mixture of iron and iron carbide. The iron takes the crystalline form ferrite, and the iron carbide takes the crystalline form cementite. The overall structure consists of bands of these two components and is known as pearlite. In this state the steel is soft and workable, this accounts for an increase in the softness of the annealed steel spring and as the steel is heated above the critical temperature, about 1335°F (724°C), it undergoes a phase change, recrystallizing as austenite.

Continued heating to the hardening temperature, 1450-1500°F (788-843°C) ensures complete conversion to austenite. At this point the steel is no longer magnetic, and its color is cherry-red, as the annealing temperature is increased at this temperature the structure of steel changes from body centered cubic to face centered cubic.

Cooling of the steel gradually at this temperature results in a very soft steel (i.e. it will return to the pearlite structure) followed only by spheroidized steel as seen in the results above. This thus explains why annealed springs have a greater percentage elongation than the other heat treated springs and are also the softest. This agreed with findings of Qamar, 2009 and Zhen et al., 1997.

CONCLUSION

In summary, the carrying out of heat treatment on springs results in a change/of the mechanical properties of the spring and also results in a change in the microstructure of the steel. The following conclusions were drawn from the result of the study.

The annealed spring became softer with increase in the annealing temperature, its percentage elongation (ductility) increased also with increase in annealing temperature.

Steel springs impact toughness increased with increase in annealing temperatures. However, hardness reduced with increase in annealing temperatures.

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