Some Aspects of Stress Peening of Coil Springs for Vehicle Suspensions

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ABSTRACT AND KEYWORDS

Stress peening of coil springs is getting more and more popular, because it causes better durability or weight reduction. In this paper after some fundamentals it is presented special aspects of stress peening or dependency between stress peening and other characteristics of compressive coil springs for vehicle supension. The relation between the amount of load during peening and the durability is shown. The positive dependency on stress corrosion is demonstrated. The accordance between the model of local durability and the distribution of crack starting points is proved. Further the relaxation is not negatively affected by stress peening. At last a developed loading tool is shown.

stress peening, residual stress profile, crack starting points, stress corrosion, relaxation

1. INTRODUCTION

Shot peening has been established very well in industrial processes during this century [1]. In particular it is used in order to increase the durability of materials under dynamic load. Stress (or strain) peening was invented in 1949 [2].

In the course of the years this process was also introduced into the production of spring elements. Because of the low investment, stress peening is a standard procedure in the production of leaf springs. It has made a contribution to reduce the mass of the springs and to increase their durability.

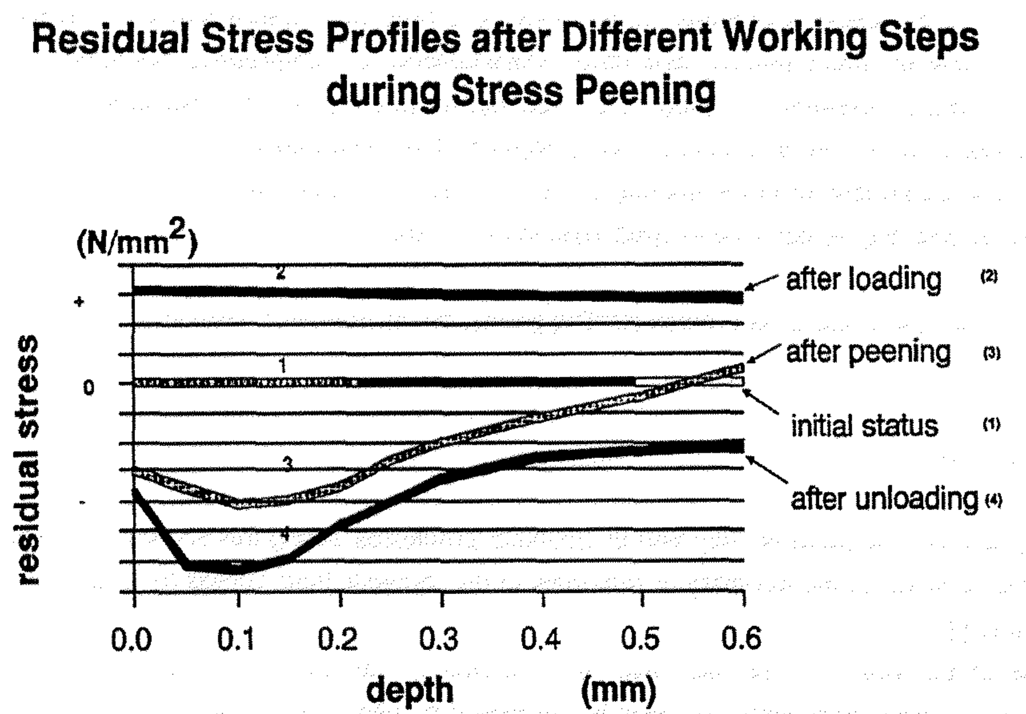
Today first experiences are made in the field of stress peening of coil springs [3, 4]. Some interesting aspects of stress peening of coil springs will be discussed in this paper.

2. DEFINITION AND FUNDAMENTALS

From a contemporary point of view, the term >shot peening a material surface< is the interaction of a sufficiently hard shot in a particular shape and with kinetic energy to the surface layers of a workpiece. The shot is composed of either metal (steel, steel cast, cut wire, etc.) or non-metal particles (glass, ceramics, etc.). If the grains used in the peening process are formed like balls the term "shot peening" is being used [5].

Stress peening of coil springs means that during the peening process the spring is under load, actually in the same direction as during its later use. Therefore at an angle of 45° to the wire-axis you will find the highest compressive residual stresses, whereas under work load the highest tensile loading stresses will appear [4].

Figure 1 shows the behavior of the residual stress profile in the 45°-direction during the whole process of stress peening. For reasons of simplification it is assumed that you can find no residual stress in the initial status. After loading the normal tensile stress appears. After peening you get a stress distribution, which is also reached under normal shot peening conditions. After unloading an increase of the compressive residual stress is to be found at and under the surface.



	Schematic Evaluation of the Residual Stress Profile	Figure 1

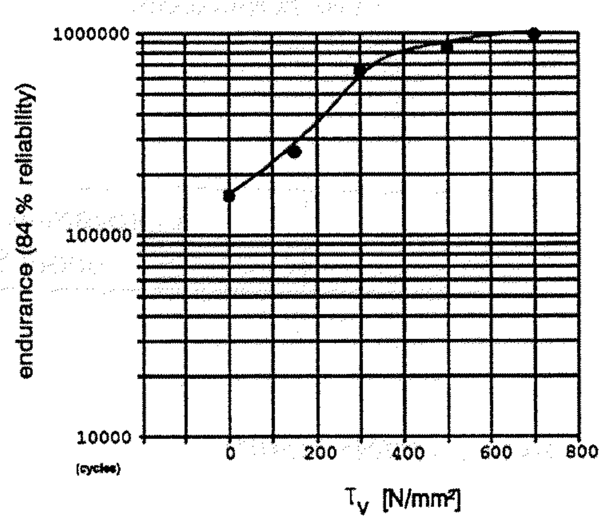
3. ENDURANCE AND PRELOAD

An interesting aspect is the dependency of the endurance life on the amount of load τ_V during stress peening. It is also strongly dependent on the shape of the spring. A good example is shown in figure 2. The examined object was a linear rate coil spring for spring brake applications with a tensile strength of R_m = 1930 N/mm². The endurance test was done under straight compression with a load of $\tau_m \pm \tau_a$ = (547 ± 490) N/mm². The springs were prepeened (see chap. 8) without load and then stress peened with different loads up to τ_V = 700 N/mm². In the low-load-range the increase of the endurance life is high whereas the curve gets flatter towards higher loads τ_V. Under high pressure the coils of spring are near together, that there is a shadowing against each other for the shots. Also the increase of the residual stress is getting lower in the higher load region [6].

But nevertheless an increase of the endurance life was reached, which was six times as much as without preloading.

Endurance and Preload

spring type:	linear rate coil spring for spring brake application
tensile strength:	R_m = 1934 N/mm²
preload:	τ_V = 0 / 150 / 300 / 500 / 700 N/mm²
endurance test conditions:	straight compression
	$\tau_m \pm \tau_a$ = 547 ± 490 N/mm²



An Example of the Dependency between Preload and Endurance Life — Figure 2

4. ENDURANCE AND STRESS CORROSION

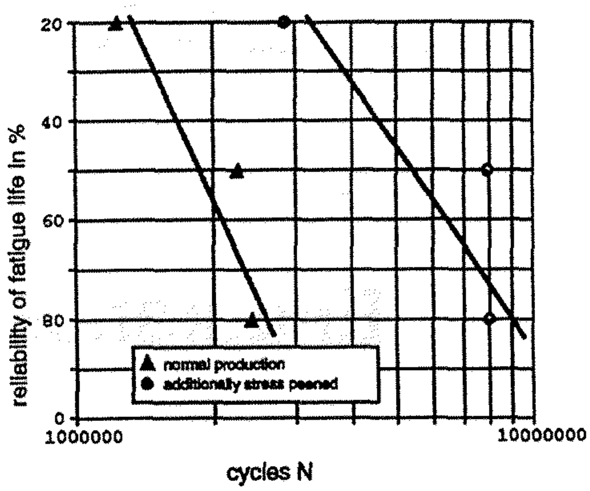
A very important question is how do the stress peened coil springs behave under dynamic load and corrosion. A linear rate coil spring was prepeened and stress peened at a load τ_V = 545 N/mm². The springs were dynamically tested under straight compression with a load $\tau_m \pm \tau_a$ = (581 ± 235) N/mm². Periodically after 10 min. of drying a 3% NaCl-water-solution was sprinkled on the spring for 90 seconds. Figure 3 shows the results of the endurance tests. Also the endurance life of stress peened coil springs under corrosion increases rapidly.

Endurance and Stress Corrosion

spring type: linear rate pigtail spring

preload: $\tau_V = 545$ N/mm²

endurance test conditons : straight compression under corrosion
$\tau_m \pm \tau_a = 581 \pm 235$ N/mm²
periodically 10 min drying
1.5 min 3%-NaCl-sparkling



Improvement of the Endurance Life under Stress Corrosion

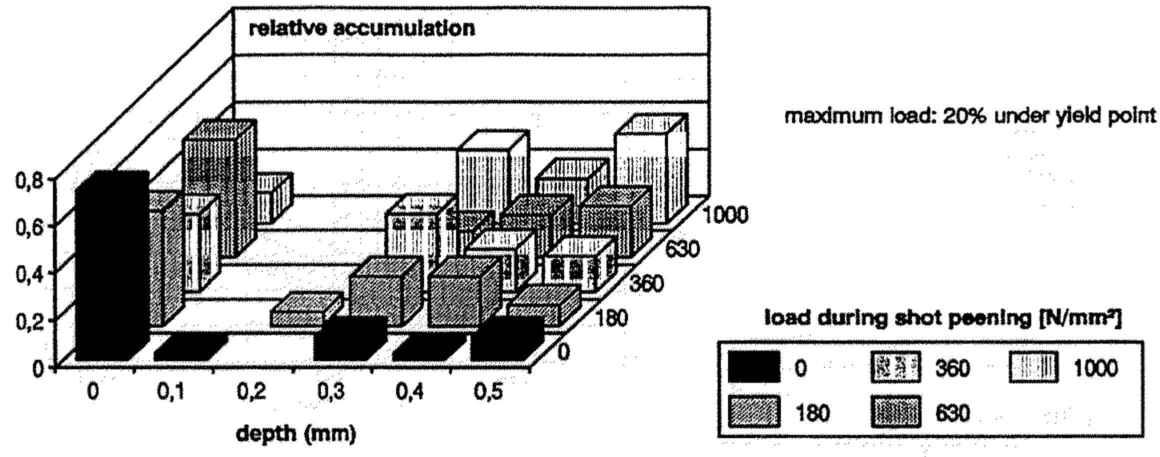
Figure 3

5. CRACK STARTING POINTS

Concerning the model of local durability [7] the crack starting points have to be more and more under the surface when the load stress τ_V had been higher during stress peening. The local durability due to the higher compressive residual stress in the surface layers (0.0 mm - 0.3 mm depth) is better than under these layers. The results as shown in figure 4 were achieved from torsion bar specimens peened under load τ_V in 5 steps between $\tau_V = 0$ N/mm² and $\tau_V = 1000$ N/mm². The relative accumulations normalized on each loading step τ_V are given in dependency of the depth. The columns on the right hand side are an accumulation of all crack startingpoints found at the depth of 0.5 mm or deeper.
You will notice that the number of crack starting points at the surface decreases with higher loads τ_V during peening. (The high column at $\tau_V = 630$ N/mm² contains a enormous statistical error and is by no means indicative.) At a depth of 0.5 mm a permanent increase of the numbers of crack starting points could be proved with higher loads τ_V. In the region of 0.1 mm to 0.2 mm nearly no cracks start, as in accordance with the model of local durability no crack starting points were expected. In this depth the material seemed to have an infinite durability.

Crack Starting Points

A higher load during stress peening induces more crack starting points under the surface



	Distribution of the Crack Starting Points	Figure 4

6. STRESS PEENING AND RELAXATION

One big demand of the car manufacturers is a low relaxation of the springs. In this context relaxation means the loss of load in a certain time during a constant deformation. This fact was examined at a linear rate coil spring for spring brake application with a tensile strength of R_m = 1900 N/mm². The coil spring was warm presetted. The test was done at room temperature with an initial shear stress of τ_n = 1050 N/mm². The device contained three sets of two springs each: The first was peened without load, the second with τ_v = 350 N/mm² load and the third with τ_v = 700 N/mm² load. The relaxation was measured beginning one day later and lasting up to one month.

Figure 5 shows the results. Each line stands for one spring. Within the statistical and measuring errors you can see no difference between stress peened springs and springs peened the normal way after nearly 1000 hours.

7. STRESS-CYCLE-DIAGRAM

From our experiments a stress-cycle-diagram could be obtained, which shows tendencies of the increase in durability. Figure 6 presents the first results. With stress peened coil springs an increase in durability of a factor of 2 or more can be obtained, depending on many factors , like the shape of the spring, the amount of load τ_v during peening, the conditions in the shot peener (e. g. shot diameter, intensity. etc.). The shaded area in the diagram shows the expected fatigue lives of stress peened coil springs.

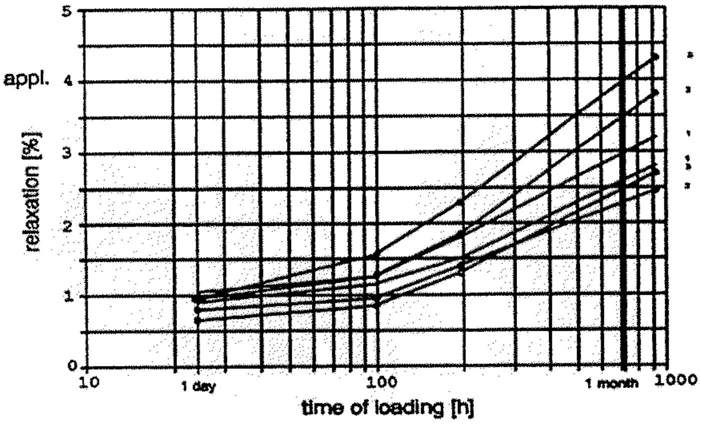
Stress Peening and Relaxation

Stress peening does not affect the relaxation of springs.

spring data:
linear rate coil spring for spring brakes appl.
50CrV4
R_m-1900 N/mm²
P = warm
T = RT
τ_N= 1050 N/mm²

test serie		treatment
1	——	peened
2	•—•	τ_v = 350 N/mm²
3	•—•	τ_v = 700 N/mm²

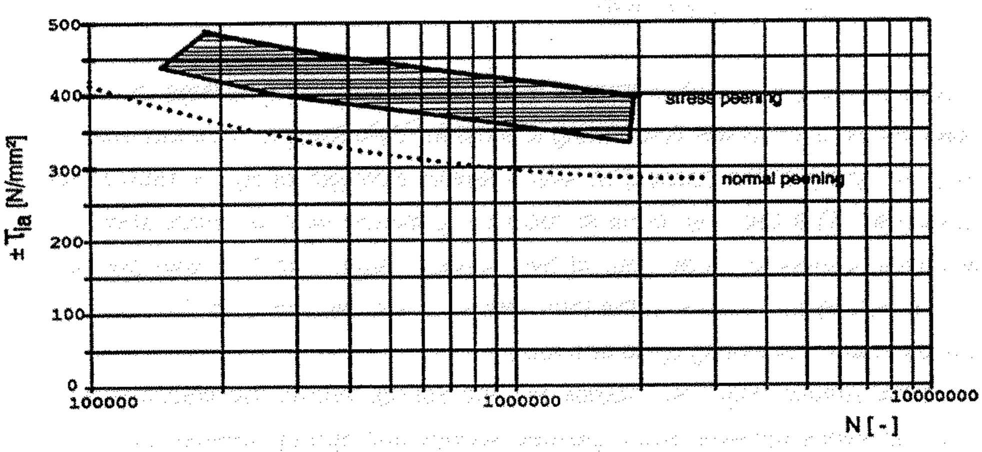
2 springs for each series



Relaxation of Normally and Stress Peened Coil Springs

Figure 5

Stress-Cycle-Diagram (first results)

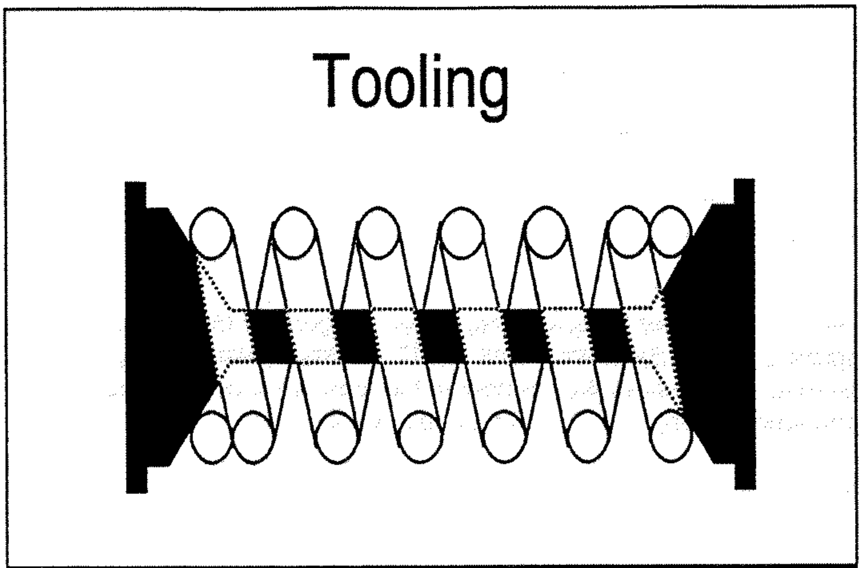


The Obtained Durability Expressed in a Stress-Cycle-Diagram

Figure 6

8. TOOLING

One way of compressing a coil spring is demonstrated in figure 7. The spring is loaded between two cones. This means that the end coils of the spring have to be peened before loading to get a coverage from the grains there. Therefore most of the springs must be peened twice, in a prepeening and later in a stress peening cycle.



Tool for Stress Peening Coil Springs — Figure 7

One cone is movable on the rod. A special breech holds this cone with the help of the spring force in position and can be removed with a special device after the peening process.

9. CONCLUSIONS

The main results are:

1. A higher durability is received with stress peening.
2. Or a mass reduction at the same durability is possible.
3. The higher the load during stress peening the better is the durability of the spring, provided the mutual shadowing of the coils is avoided.
4. Under stress corrosion an increase of the durability is obtained.
5. Most crack starting points are deeper under the surface after higher loading during stress peening.
6. The relaxation is not negatively affected by stress peening.
7. A prepeening operation of the end coils is necessary in most of the cases.

10. REMARKS

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