Stress Peening of Minibloc-Springs, the most Sophisticated Coil Springs

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ABSTRACT

In this lecture will be presented, that also the most complicated coil spring the Minibloc-spring can be stressed peened.
As a consequence for every suspension coil spring stress peening is suitable way to increase the durability. It is shown the dependence of the residual stress profile in relation to the preload to find the optimum load for peening, which is around 50 % of the maximum load. The roughness of the surface in several directions is shown. The increase of the dynamic life time due to stress peening is determined at high dynamic loads. At least a factor of two or higher can be achieved.

KEY WORDS

Minibloc Spring, stress peening, residual stress profile, durability

INTRODUCTION

Today the reduction of weight or material is a current subject in wide areas of automotive and mechanical engineering. Several possibilities are available, as for instance a better use of the material by higher hardness or optimizing the construction by finite elements. Another possibility is the induction of compressive residual stresses in the surface layers, especially used at tensile pulsating load to enlarge the dynamic life time or respectively reducing the weight. One possibility is stress (shot) peening, intended for coil springs at the suspensions of cars.

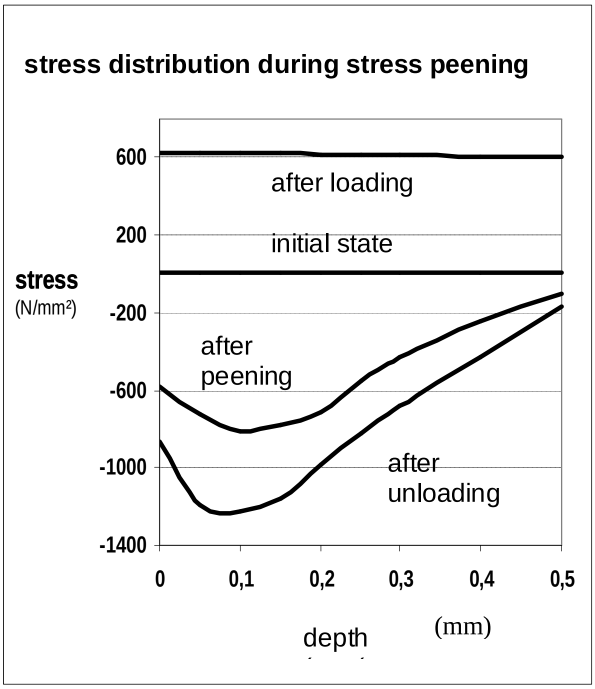

Fig. 1. Example of the residual stress distribution after the different steps

STRESS PEENING

Shot peening is a technology, which is a standard procedure. Peening (in the technical understanding) is the interaction between a particle (with the necessary hardness) with the surface of a working piece. If the particles have a round shape, you call it shot peening (Müller 1994). In the surface layer (up to

0.5 mm depth) compressive residual stresses are induced. At a lower hardness of the working piece an additional hardening is achieved. In order to obtain better results by the peening process, the so-called stress peening is used. Here the working piece or component is stressed in the direction of the later loading. After this step, the original peening procedure is done and afterwards the unloading. The compressive residual stress profile, which is now obtained, is significantly higher than that gained by normal peening (see fig. 1). The result depends on the (torsional-) preload (τ_{ks}) σ_{ks} during peening (e.g.: Müller 1993, Müller 1994, Müller 1996, Müller 97, Müller 2006a, Müller 2006b, Schulze 2005, Zeller 1993).

BASICS MINIBLOC-SPRINGS

The minibloc-spring is a special type of coil spring at the rear axis of many cars. Typical for a minibloc-spring are its small eyes, which are coiled with a wire of a small diameter. The wire diameter and the coil diameter increase continuously. In the middle of the spring there are one respectively two coils, which have a constant wire and coil diameter as shown on the right picture.

When the spring is compressed, the coils do not touch each other, but most of the coils dive into the next one. Due to this fact, the spring works without any noise. Another advantage is that the spring has only a height of two or three wire diameters at the solid length. As a result of this small space of the component, the loading capacity of the car can be significantly enlarged.

The barrel shape is ideal to realize a strong progressive rate. (Sometimes linear rates, which are also possible, are used). That means the higher the load of the vehicle, the harder (higher rate) the spring will be. Such a spring ensures an optimal comfort in riding. At bad road conditions a use of the rubber bumps (jounce) is extremely rare.

EXPERIMENTAL CONDITIONS

The main objective is to achieve the best conditions for stress peening. Two contrary items have to be taken into consideration. The higher the load during peening, the better is the compressive residual stress file. But the higher the load, the more important is the shadowing of the coils, since the inner side of the spring is not covered enough by the shots. In particular, the end coils dive in each other and nearly result in a flat spiral. Therefore the springs were peened under the following conditions:

peening time	preload	notation
(sec)	(% of max. load possible)	
10	0	70/10
20	0	70/20
20	10	10 %
20	20	20 %
20	30	30 %
20	40	40 %
20	50	50 %
20	60	60 %

Tab. 1. Overview of the different peening conditions

After the stress peening, the residual stress profile was determined at the inner and outer side of the wire in the middle of the spring and at 1.7 coils away from the end (see fig. 2). These measurements were executed by x-ray diffraction. The residual stress values were obtained by using the sin²ψ-2θ-method (e.g.: Noyan 1987). The direction of the measurements were 45° to the wire axis. Due to the torsional load in this direction, the maximum load stress was expected. Because of stress peening in this direction, the compressive residual stresses will have the biggest amount.

To obtain the residual stresses under the surface, the material was removed electrolytically. By this way you can be sure that no additional residual stresses are induced. Every 60 µm depth the measurement was done to a depth of 540 µm.

Fig. 2 The two points where the measurements were done

RESULTS

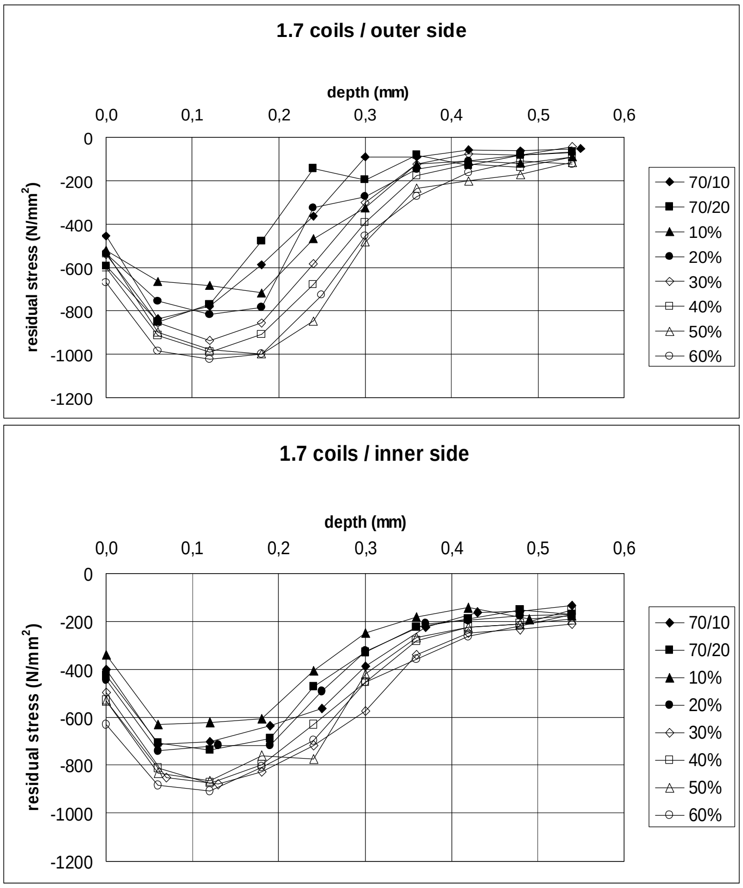

Fig. 3: Residual stress distribution at 1.7 coils

Residual Stresses

The two sections at the spring where the measurements were done are the critical ones. The middle part is loaded up to the solid length. In around 1.7 coils there is a section where the spring has a weak point concerning durability. If you load the spring, you get a shadowing of the coils over the whole spring. This fact causes that at the inner sides of the coil the intensity of stress peening is lower than at the outer side.

You see the typical compressive residual stress profile which can be achieved by the Hertz pressure (see fig. 3, 4). The maximum of the compressive residual stress is at a depth of around 0.15 mm. At a depth of 0.35 mm, there is a nearly constant level of the residual stress. This is due to the fact that the spring was set (plastified) before peening. This compressive residual stress level is higher at the inner side of the coils than at the outer side caused by the forming of the wire to a coil (Fischer 1987).

By increasing the load during peening, the compressive residual stresses will also increase up to a loading stress of 50% of the maximum possible load. A load up to 60 % does not result in a significant increase. At the inner side of coil 1.7, a decrease of 10 % of the load of the residual stresses can be observed due to the fact that this coil dives into another one and is extremely shadow-ed by other coils.

In figure 4, the equivalent situation in the middle of the spring is shown. The compressive residual stress level is slightly higher. In particular, the residual stress at the inner side of the coil is about 100 N/mm² higher in comparison to the inner side of 1.7 coils.

At the outer side, also a higher stress level is obtained. The nearly constant stress level in the region 0.4 mm to 0.6 mm is caused by the presetting of the spring. This level continues to depth of more than 1 mm. (The higher compressive residual stress level at a depth of 0.5 mm is due to the fact that the presetting of the spring always results in higher levels at the inner side of the coil (Fischer 1987).)

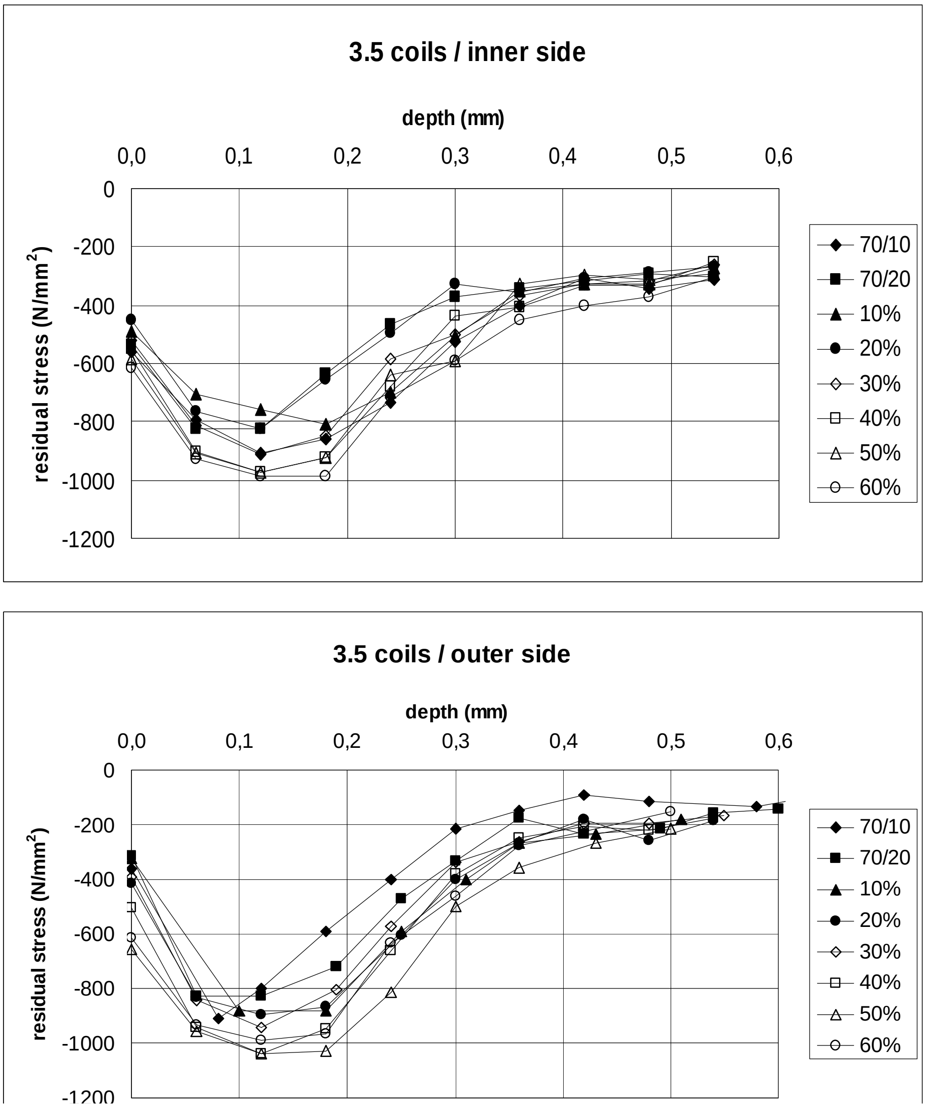

Fig. 4: Residual stress distribution at 3.5 coils

Roughness

The roughness R_t of the stress peened spring was measured by an optical system in direction of the stress direction under load and perpendicular to it (see figure 5). It is a smaller roughness in compressive residual stress direction, which depends on the peeling process of the bars. The difference between these two directions seemed to get slightly bigger with the increased load during peening.

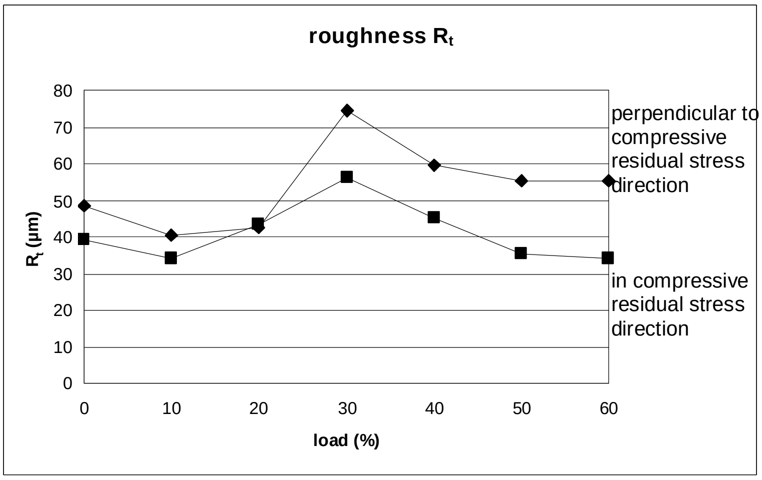

Fig. 5: The roughness in dependence of the pre-load

Durability

Due to the better compressive residual stress distribution, a higher durability is expected. The springs with 30 % of the maximum possible load were tested in the area of the endurance limit. The analysis was done with the help of the Weibull distribution, as shown in figure 6.

The durability increased by a factor of about 4 related to 10% failure probability (from 125,000 lifetime cycles to 408,000 lifetime cycles) .

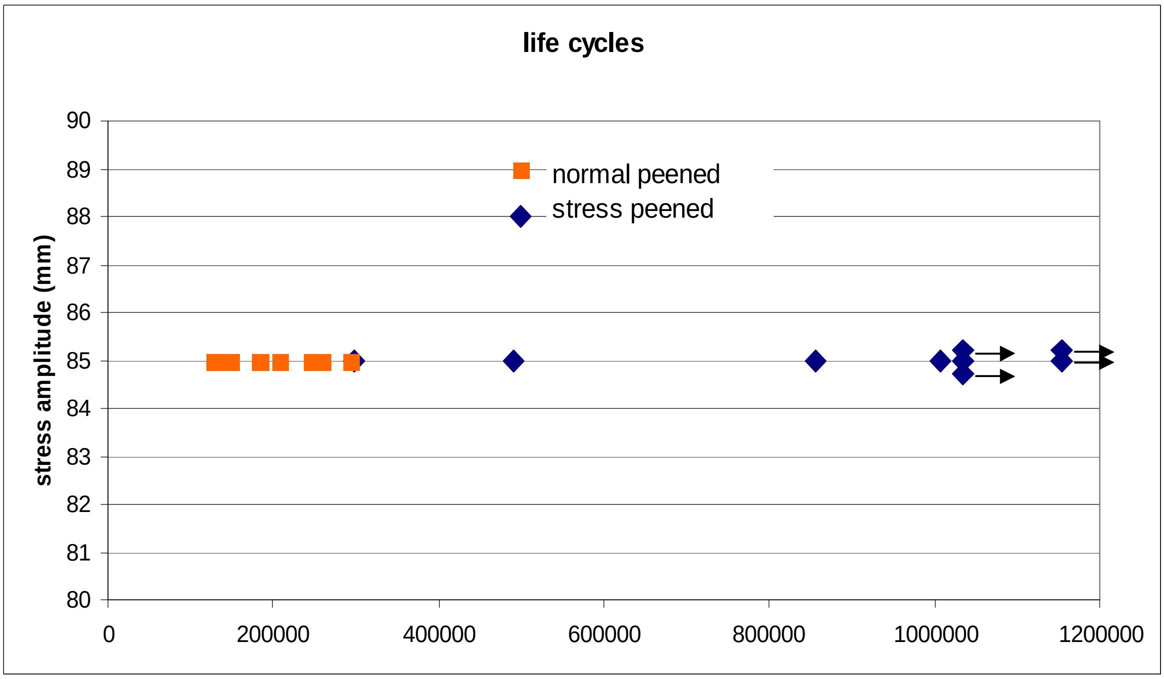

Fig. 6: The different life cycles of normal and stress peened springs according the the test conditions of the automotive industry

CONCLUSION

Stress peening is also possible for springs with a sophisticated geometry. All coils were peened over the whole surface (inner and outer side) with a sufficient intensity. At 50 % preload of the maximum load a saturation of the increase of the compressive residual stress is reached. At higher preloads a shadowing of the coils will not give a sufficient intensity at the inner sides of the coils. Also under economical reasons a 50 % preload is the best load for stress peening. The roughness may give a slight difference between the two directions of loading. The increase in the durability is significant.

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REFERENCES

Fischer 1987 — Fischer F. u. Vondracek H.: Warmgeformte Federn, Hoesch Hohenlimburg AG, Hagen 1987

Müller 1993 — Müller E.: Some aspects of stress peening of coil springs for vehicle suspensions, Proceedings of the 5th Int. Conf. on Shot Peening, pp. 341, Coventry University (UK), 1993

Müller 1994 — Müller, E: Stress Peening of Compressive Coil Springs; WIRE 44 (1994) 6, pp. 368 - 372

Müller 1996 — Müller E.: Die Ausbildung von Eigenspannungen an Torsionsproben beim Spannungsstrahlen, Mat.-wiss. u. Werkstofftech. 27, (1996), p. 354.

Müller 1997 — Müller E.: Eigenspannungsabbau an spannungsgestrahlten Torsionsproben unter dynamischer Belastung, Mat.-wiss. u. Werkstofftech. 28, (1997), p.549.

Müller 2006a — Müller E.: Optimization of shot peening for fatigue critical applications. In Baiker St. (edit.): Shot Peening, pp. 120, mfn publishing house, Wetzikon, 2006

Müller 2006b — Müller E. et al.: Die Ausprägung von Druckeigenspannungen durch Spannungsstrahlen an Minibloc-Federn, VDI-Berichte Nr. 1972, pp. 285, Düsseldorf 2006

Noyan 1987 — Noyan I. C. u. J. B. Cohen: Residual Stress, Springer Verlag, New York, 1987

Schulze 2005 — Schulze V.: Modern Mechanical Surface Treatment, Wiley-VCH, Weinheim 2005

Zeller 93 — Zeller R.: Influence of stress peening on residual stresses and fatigue limit, in Residual Stresses, pp 907, DGM-Verlag, Oberursel, 1993