Stress Peening

A Practical Application: Minibloc Springs

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Stress (shot) peening can be used in the manufacture of auto suspension coil springs to provide a better utilization of the material via higher hardness resulting in reduced material used and reduced weight.

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A list of references used in this work is available from the author, Eckehard.Mueller@fh-bochum.de.

Today the reduction of weight or material is a current subject in wide areas of automotive and mechanical engineering. Several possibilities are available, such as better utilization 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 reduce the weight. One possibility is stress (shot) peening used in the manufacture of coil springs for the suspensions of cars.

Stress Peening Basics

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 workpiece. If the particles have a round shape, you call it shot peening. In the surface layer (up to 0.5 mm depth), compressive residual stresses are induced. At a lower hardness of the workpiece, an additional hardening is achieved.

In order to obtain better results by the peening process, stress peening is used. Here the workpiece 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 (**Figure 1**). The result depends on the (torsional) preload (τ_{ks}) σ_{ks} during peening.

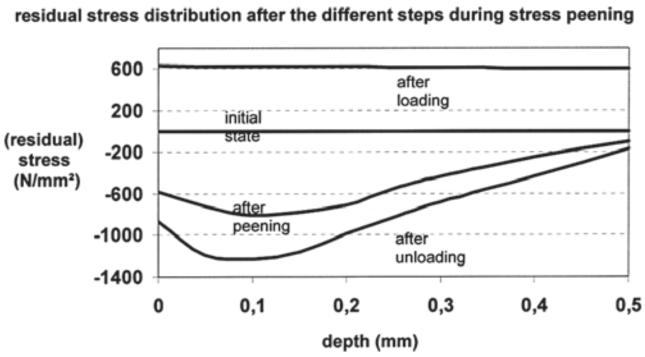

Fig. 1 — The residual stress distribution (schematically) after the different steps.

Minibloc Spring Basics

The minibloc spring is a special type of coil spring that is used at the rear axis of many cars. A typical characteristic for a minibloc spring is its small eyes that 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 two coils that have a constant wire and coil diameter as shown in **Figure 2**.

Fig. 2 — A minibloc spring unloaded (top) and loaded (bottom).

When the spring is compressed, the coils do not touch each other, but most of the coils dive into the next one. Because of this, the spring works with no 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 provides optimal ride comfort.

Application

Two methods for obtaining a higher performance of the spring include changing the material to achieve a higher hardness and increasing the amount of the compressive residual stresses in the surface layer.

One possibility concerning the second method is stress peening. In this case, I will report about the performance increase by stress peening. Since there is a complicated geometry at minibloc springs, the experiment has to show the optimal parameters. Therefore, a typical minibloc spring was peened under different preloads as seen in **Table 1**.

After 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 **Figure 3**). These measurements were executed by x-ray diffraction. The residual stress values were obtained by using the $\sin^2\psi$-2θ method. 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. This method ensures that no additional residual stresses are induced. At every 60 µm depth, a measurement was taken to a depth of 540 µm.

Results

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

You can see the typical compressive residual stress profile, which can be achieved by the Hertzschen pressure, in **Figure 4** (on this page) and **Figure 5** (on the next page of this article). 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 of the coils, caused by the forming of the wire into a coil.

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 of 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 shadowed by other coils.

In **Figure 5** (next page), 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 with the inner side of 1.7 coils.

A higher stress level is also obtained at the outer side. The higher 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.

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Table 1. Different Preloads Under Which the Minibloc Spring Was Peened.

peening time (sec)	preload (% of max. load possible)	notation
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 %

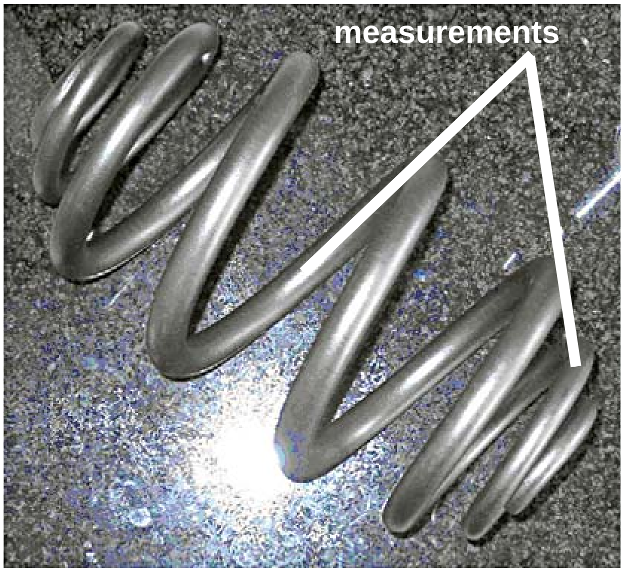

Fig. 3 — The two points where the measurements were taken.

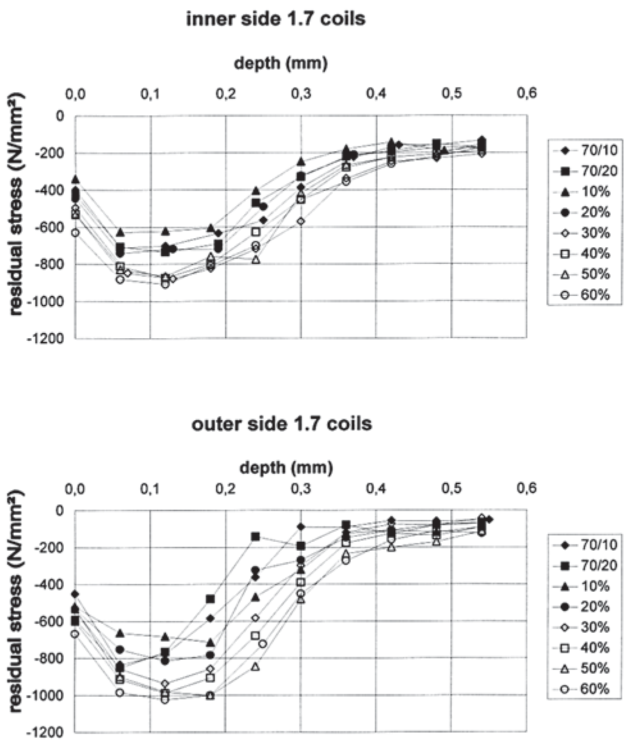

Fig. 4 — Compressive residual stress profile at 1.7 coils.

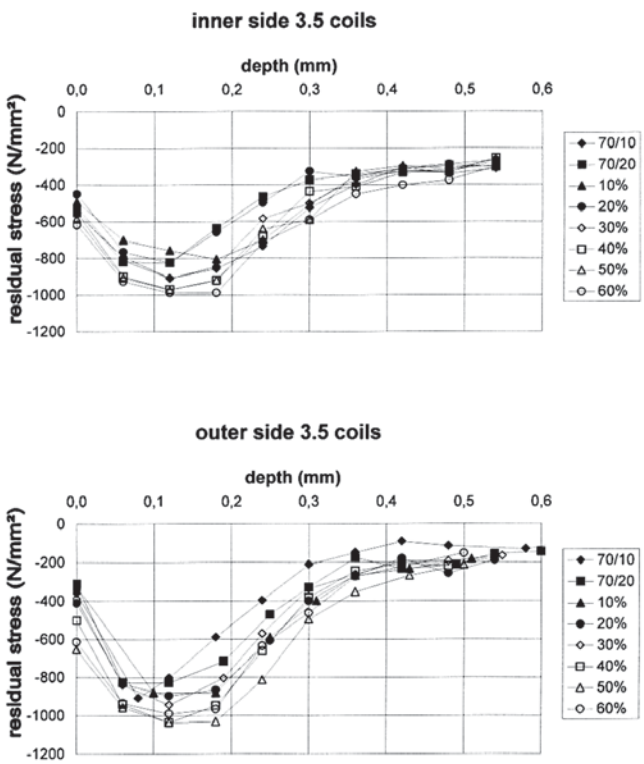

Fig. 5 — Compressive residual stress profile at 3.5 coils.

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. With this operation another step is performed to reduce the weight of the spring.

As a result, in combination with a higher tensile strength of the material, a weight reduction of 30% is possible. **WFTI**

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About the Bochum University of Applied Sciences...

Dr. Eckehard Müller** is a Professor at **Fachhochschule Bochum—Bochum University of Applied Sciences**. Founded in 1972, the university is a modern university of applied sciences, specializing in technology and economics. It has a long tradition of offering fast-track, student-centred vocational degree courses with close links to industrial and other organizations in the region of the central Ruhrgebiet (Ruhr area). Recruiting teachers directly from industry, the university has built and maintains a close partnership with the worlds of business and engineering. **www.fh-bochum.de