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Comparison of the Residual Stresses Induced by Shot (Stress) Peening and Rolling in Spring Steel

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1 Introduction

Today, reduction of weight of material is an actual subject in wide areas of automotive and mechanical engineering. Several possibilities are available, like better utilization of the material by higher hardness or optimizing the construction by finite elements. Two further possibilities are rolling of components and shot peening or the later developed stress peening. Because it is possible to induce compressive residual stresses in dedicated amounts, it is used very often at tensile pulsating load to get a better utilization of the material. The two possibilities have different advantages, which are on the one hand cheaper realization and so huge amount of induced residual stresses like vice versa.

2 Basics

2.1 Shot Peening and 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 [Mü 93a]. In the surface layer (up to 0.5 mm depth) compressive residual stresses are induced. At lower hardness of the working piece, in addition, hardening is achieved. In order to get 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 now is achieved, is significantly higher than that gained by normal peening. The result depends on the (torsional-) preload (τ_{ks}) σ_{ks} during peening [1-12].

2.2 Deep Rolling

Deep rolling can be regarded as a continuously made plastic deformation of material near the surface. In this procedure a tool (ball, profile roll) is pressed against the work piece with a special pressing force. Here the important parameters are the pressing force and the overlap. This standard procedure is described many times, for example in [13–16].

3 Preparation of the specimens

The specimens (the values for rolled parts are in brackets) were pieces of flat steel, which is normally used for leaf springs, with a length of 360 mm (360 mm), a wide of 80 mm (75 mm), and a thickness of 11 mm (15 mm). The edges were rounded in accordance with DIN 59145. The material was normal spring steel 50CrV4 (55Cr3). The specimens were heated up to 880 °C and quenched in oil to get a martensitic structure. Afterwards, they were heat treated at around 460 °C to get a strength of R_m = 1530 (1420) N/mm^2. To avoid spreads of the hardness in the surface layer because of decarburization, the specimens were ground to remove a layer of at least 0.3 mm.

4 Experimental setup

4.1 Treatment of the Specimens

4.1.1 Shot Peening

In figure 1, the mounting device is shown, in which the samples are put for the further working steps. The sample could be loaded, which is not shown in the figure. The shot or stress peening was done with the help of this device. As shot, conditional cut wire with a nominal diameter of 0.8 mm was used. The peening was done in a shot peener with four wheels in different directions.

To verify the calculated loading stress in every sequence, an additional step of loading/unloading is inserted. After each step, the stresses at the surface were measured along and perpendicular to the axis of the specimens. The following basic sequence was carried out:

1. initial state, heat treated, ground, unloaded
2. specimen plastified at the calculated stress σ_b = 1800 N/mm^2
3. loaded specimen with the calculated stresses σ_{ks} = 0; 600; 1200; 1600 N/mm^2
4. specimen unloaded

4.1.2 Deep Rolling

The other specimens were rolled with the help of a device typ HG 6-9 from Ecoroll. It has a hardmetal ball of 6 mm diameter, which was used to induce the residual stresses. The pressure was p = 300 bar or p = 380 bar. The distance between the different rolling tracks was Δx = 0.02 mm (only 300 bar); Δx = 0.15 mm and Δx = 0.25 mm. The rolling area was 55 mm × 55 mm and was rolled in the way of a meander.

4.2 Measurement of the Stresses

With the help of an X-ray diffractometer (type Rigaku Strainflex MSF-2M) the stresses were determined. It was used as an Ω-goniometer with Cr-K$_\alpha$-radiation. In this case the distance bet-

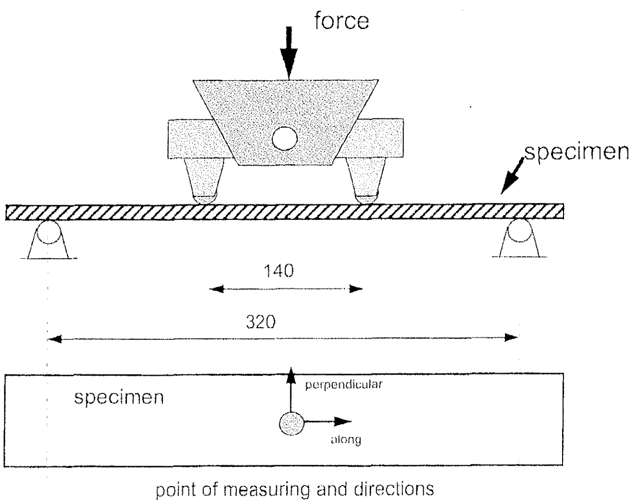

Figure 1: Mounting device and points of measuring for the shot peened specimens

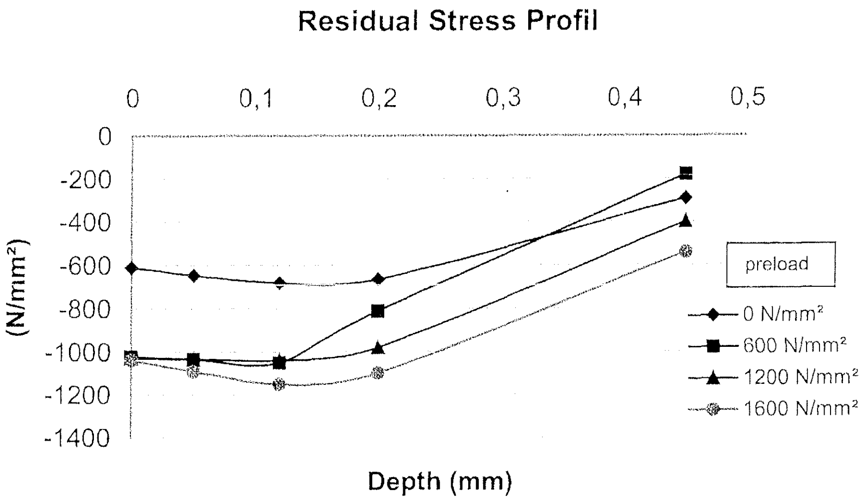

Figure 2: Residual stress profiles of the different shot peened specimens

ween the [h,k,l]-layers [2,1,1] is measured. The diameter of the X-ray spot on the surface was 7–8 mm. The determination was done with the help of the $\sin^2\psi$ -2Θ -method [17-19].

5 Results

5.1 Stress Peening

In Figure 2, the residual stress profiles up to a depth of 0.5 mm are shown in dependence of the (pre)load during peening. You obtain the typical distribution, achieved by Hertz pressure. The maximum of the compressive residual stress is at a depth of around 0.15 mm. Without any preload, the residual compressive stress at the surface has a value of $\sigma = 610$ N/mm², which increases to a maximum of nearly $\sigma = 700$ N/mm² below the surface. Up to a depth of 0.2 mm, the stress peened samples show compressive residual stress profiles with stress values around 400 N/mm² higher than that of the not preloaded specimen. At a depth of 0.45 mm, the amount of residual stress is due to the plastification of the samples before peening.

5.2 Deep Rolling

The results of the residual stress profiles are shown in figure 3. There is a great difference between the induced residual stresses along the rolling track and perpendicular to the rolling track, which equalize at a depth of 0.4 mm. The compressive residual stress has disappeared at a depth

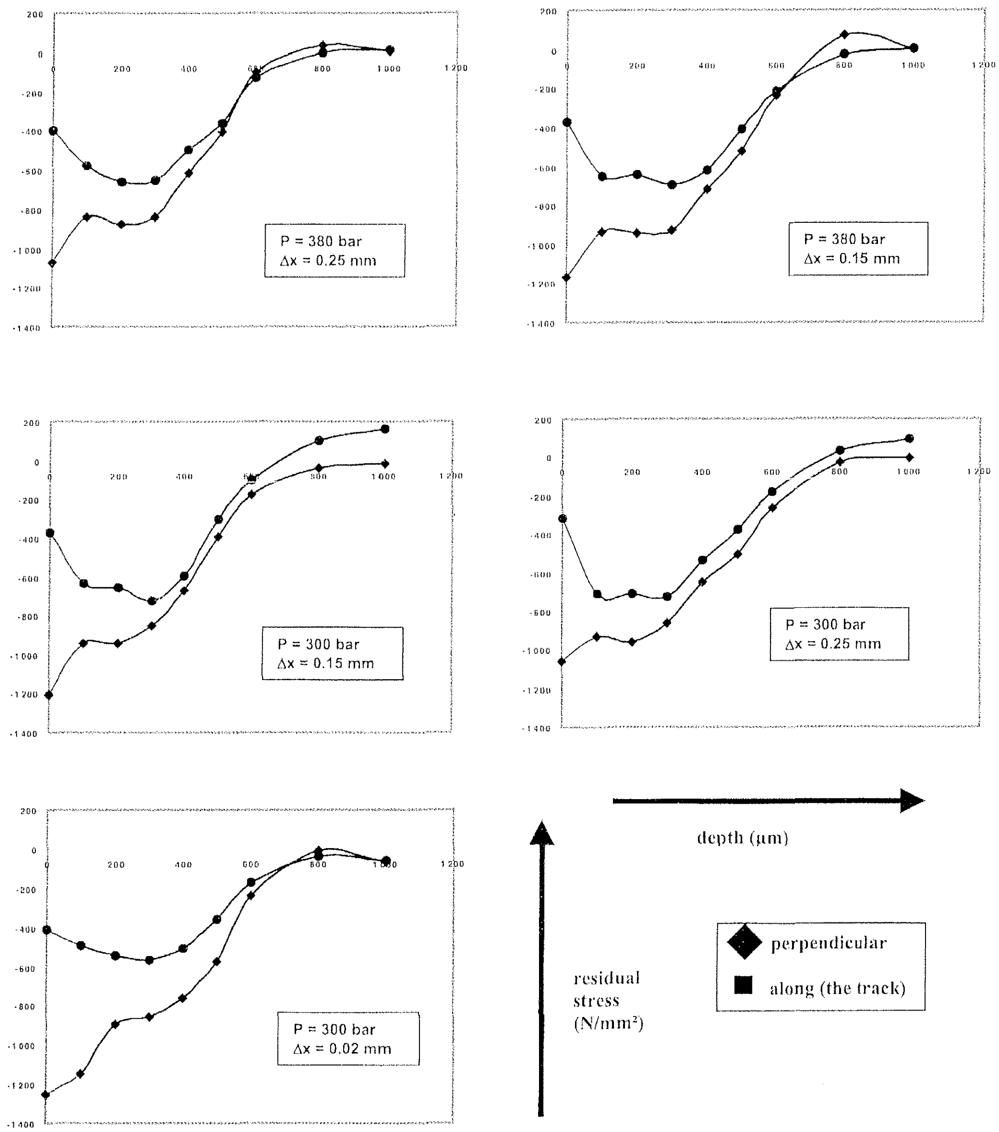

Figure 3: Different residual stress profiles induced by deep rolling

of around 0.75 mm. The higher pressure shows a slightly higher compressive residual stress and the nearer the tracks are the less compressive residual stress is induced along the rolling track. The residual stress along the rolling track has the typical profile of Hertz pressure, whereas perpendicular to the rolling track, the maximum of the compressive residual stress is at the surface.

5.3 Comparison between Shot Peening and Rolling

The residual stress distribution at the surface shows a similar shape between stress peening and deep rolling. Along the main loading stress during peening receptively perpendicular to the rolling track the highest compressive residual stresses are achieved (see figure 4). For deep rolling, the compressive residual stress perpendicular to the track is slightly higher than the compressive residual stress achieved by stress peening along the bending direction. In the two corresponding other directions the compressive residual stress is higher.

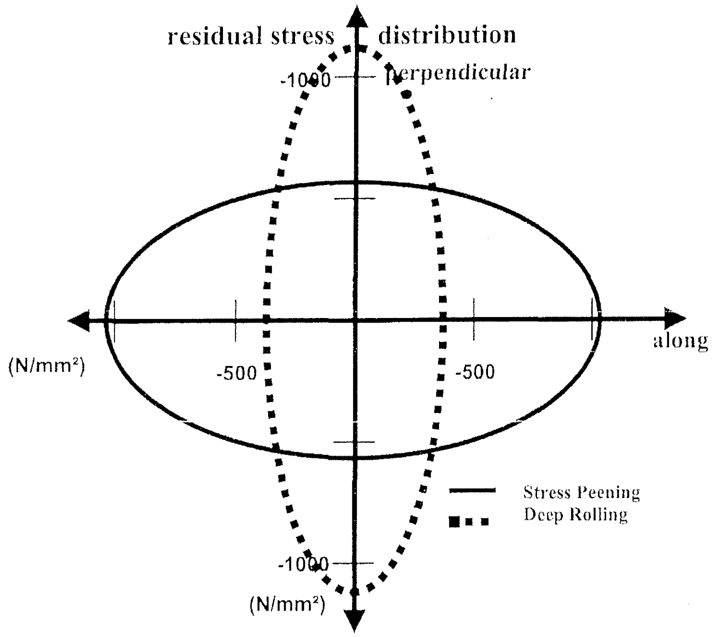

Figure 4: Comparison of the residual stress distributions at the surface due to deep rolling and stress peening

6 Conclusions

Deep rolling and stress peening give similar residual stress distributions at the surface. Deep rolling gives a more asymmetrical distribution. The compressive residual stresses after deep rolling are higher and deeper than after stress peening. However, under economical aspects, deep rolling is more expensive.

7 References

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