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SHAPE DEVIATIONS ANALYSIS OF THE ALIGNED BARS

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Abstract: *This paper analyzes shape deviations of the bar surface, which was straightened in the straightening machine. Computational modelling of the straightening process is solved numerically using the finite element method (Skalka et al, 2014). The outer diameter of the bar is 20 mm and its length is 6 m. The original curvature of the bar had a curvature radius R = 180 m. The shape deviations were analysed using the algorithm that was developed within the framework of the stress state analysis performed in ceramic heads of total hip replacement (Fuis et al., 2009 and 2011).*

Keywords: Oblique straightening machine, Finite element method, Shape deviations.

1. Introduction

Straightening of bars in the straightening machine is a technological standard way (Petruska et al., 2012). The principle of straightening is based on the passage of the bar through straightening rollers which alternately bend the bar. Computational modelling of straightening process is described in greater detail in the article (Skalka et al., 2014), including the setting of individual straightening rollers. A scheme of straightening is shown in Fig. 1 where the *x*-coordinate is given by the coordinate of bar axis. An analysis of dynamics and vibrations in the process of bar straightening are covered by the article (Lošák, 2014).

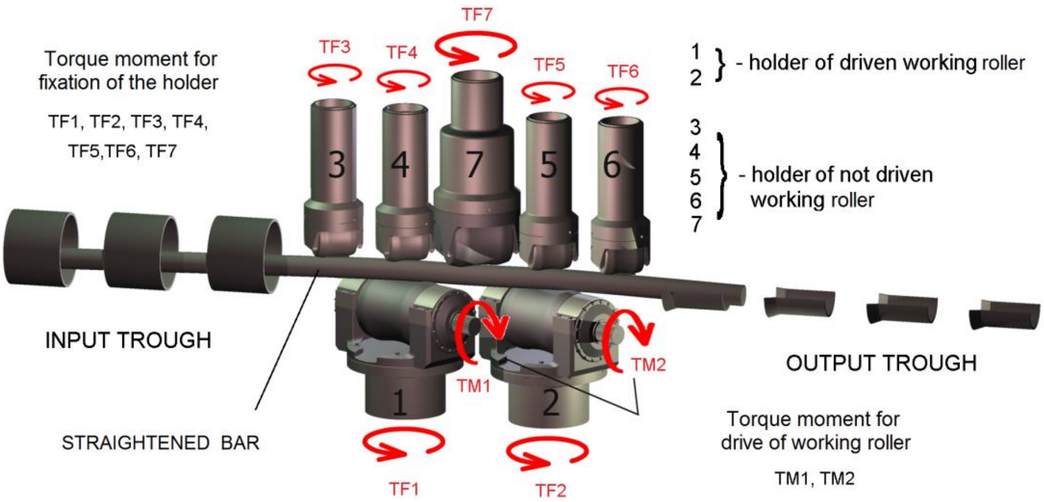

Fig. 1: Structure of oblique straightening machine (Skalka et al., 2014).

After the passage of curved bar (with model curvature R = 180 m and bar length of 6 m) through the straightening machine, it is possible to analyze both the macroscopic shape deviations from straightness (residual curvature) – Fig. 2, and also microshape deviations from a circular shape of the bar surface. These microshape deviations are caused by plasticization of bar surface layers. Fig. 3 shows the isosurfaces of von Mises equivalent stress in the straightened bar. It can be seen that on the surface there occur the regions with high values of stress (which acts only on the surface of the bar (under the surface are the value of the stresses low – Figs. 3 and 4); these regions are alternately repeated. High values of equivalent stress on the surface will also affect the final shape, which will not be circular any more, but microshape deviations will occur in it.

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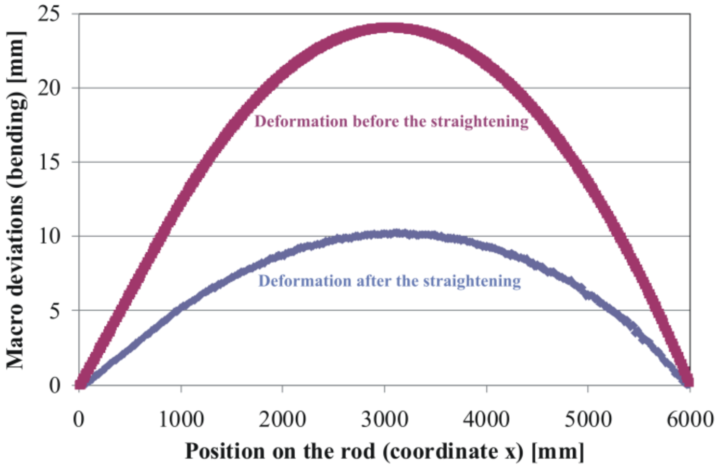

Fig. 2: Deformation of the bar before and after the straightening.

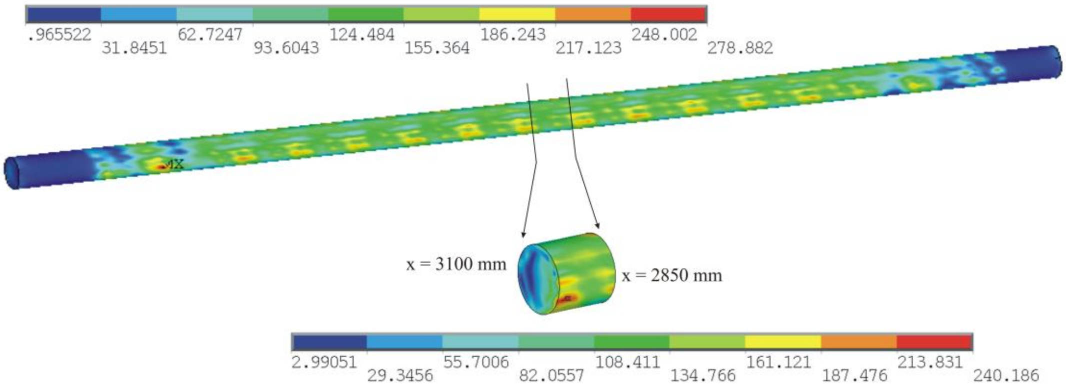

Fig. 3: Isosurface of Von Mises equivalent stress in the bar after straightening [MPa].

2. Methods

Microshape deviations on the bar will be analyzed by methodology that was developed for the analysis of the influence of shape deviations on the tapered surfaces of the head and stem of total hip replacement (Fuis et al., 2009 and 2011). In the first phase, a macroshape deviation of bar will be compared (deviation from straightness) before and after the passage through the straightener - Fig. 2. The maximum deviation before straightening was about 24 mm; after passing through the straightener, it was reduced to 10 mm.

In terms of microshape deviations we will focus on the centre of the bar, where between the coordinates *x* (2850 mm - 3100 mm) the values of equivalent stress on the bar surface are significantly changed (Fig. 3). Fig. 4 shows how a equivalent stress acts to the depth of the bar in the individual cross sections.

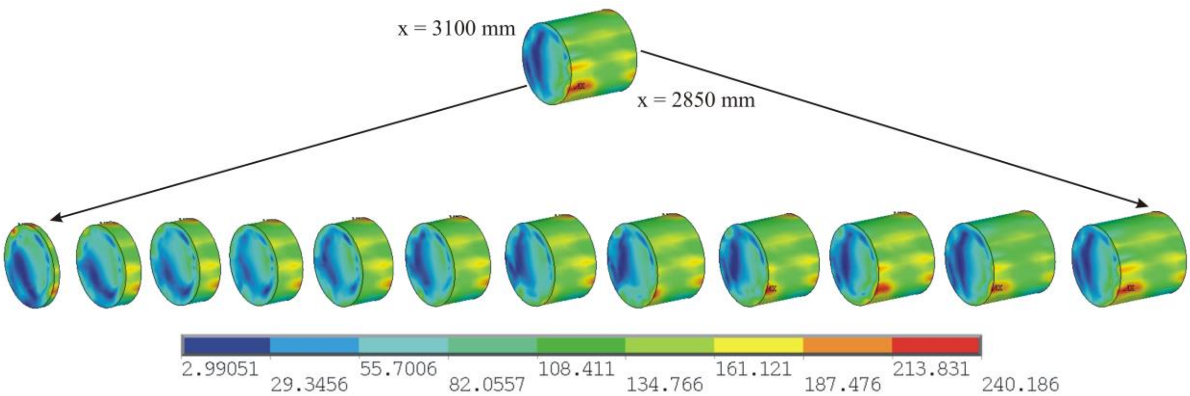

Fig. 4: Isosurface of Von Mises equivalent stress in the some sections of the bar after straightening [MPa].

3. Results and Discussions

Microshape deviations in the individual cross sections are shown in cylindrical coordinates (r and φ – Fig. 5) in order to compare them. These deviations are always quantified in the local coordinate system, which was newly created for each cross section (each *x*-coordinate). The reason is that after passing through the straightening machine, the bar is not straight (see Fig. 2) and thus it is not possible to use a global cylindrical coordinate system. The local cylindrical coordinate systems that were created from the nodes lying in the given plane show, however, deviations in the order of hundredths of degree (local axis z). This deviation is the most apparent in Fig. 5, where, in the given cross section, in addition to the radius, the value of axial displacement *uz* is also plotted (displacement in the direction perpendicular to the cross section and the extreme values *uz* are almost similar in absolute value). The deviation of normal (local axis z) causes the mean value of points of the outer surface of the bar (radius *r* in the Fig. 5) in the given cross section to oscillate circumferentially (along the angle φ – Fig. 5).

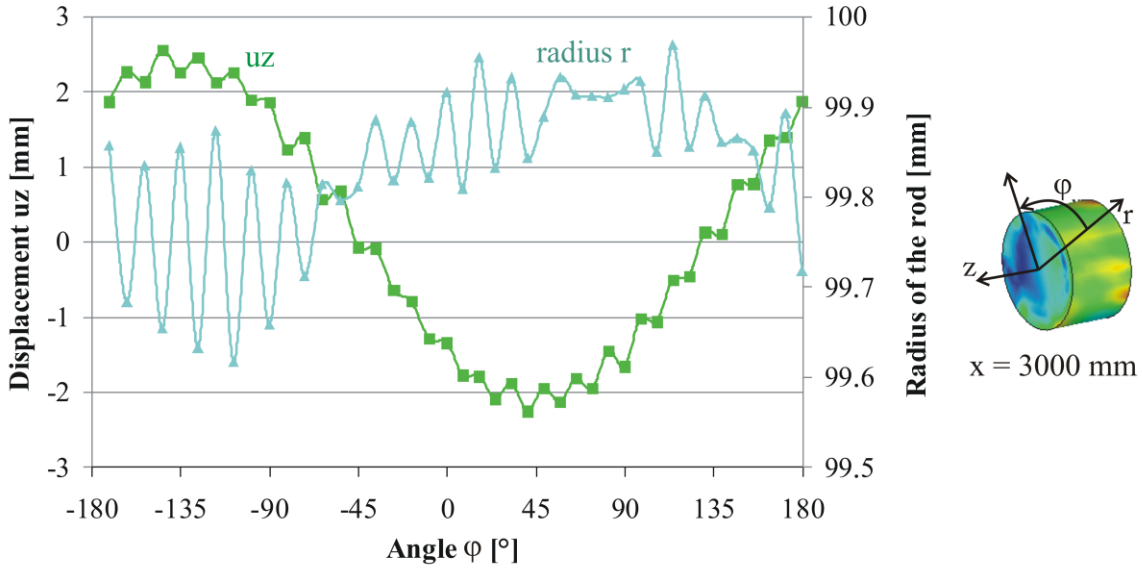

Fig. 5: Shape deviations (r and uz) of the bar's surface in the local coordinate system.

If the determined values of the radii are fitted with polynomial curve, we will obtain a curve that corresponds to the mean value of the radius – Fig. 6. If the local coordinate system is created exactly, this mean value of radius will be constant; however, this is not our case. Therefore, it is necessary to determine the value of the radius for a given angle φ as the distance from the mean value of radius - see Fig. 6. Thus we will obtain a course of radius value depending on the position (angle φ) for each cross section (in our case only for section *x = 3000 mm* – Fig. 7).

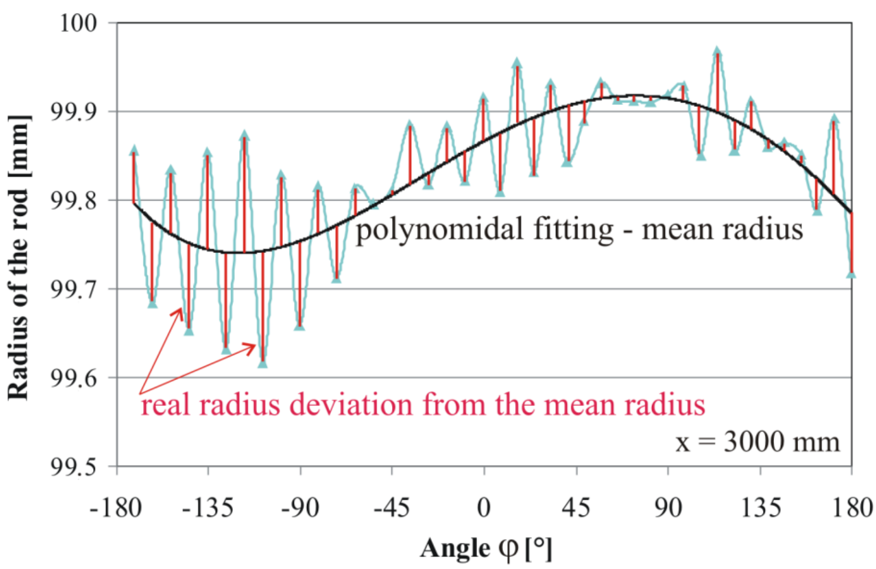

Fig. 6: Radius of the bar's surface in the local coordinate system and polynomial fitting.

Fig. 7 illustrates the high variability of the radius for different φ angles in the given cross section and a respective course of equivalent residual strains. The analysis of this figure shows that the radius of the bar in the given cross section can be found in a certain zone (zone width changes from -0.3 mm to 0.05 mm (minimal and maximal radius deviation – Fig. 7)) and it is oscillating a great deal, which may be caused by numerical calculation or by the vibrations of the bar during the straightening process. Moreover, no correlation has been proved between regions with high value of equivalent stress and the corresponding change in radius.

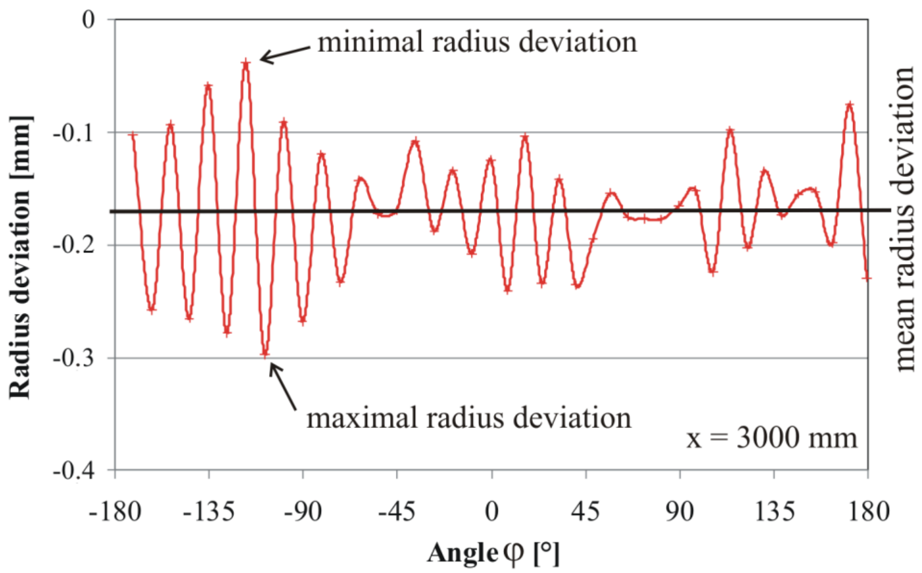

Fig. 7: Radius deviation around the cross section.

4. Conclusions

The performed analysis of reduced stress in the bar straightened in the straightener shows that the straightener was improperly set and this caused a non-uniform plasticization of the bar. The analysis of deviations of bar radius shows that it does not correspond to the reduced stress at the given location, which confirms the above conclusion.

Acknowledgement

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References

Skalka, P., Sobotka, J. (2014) Analysis of dynamic loading of bar straightening machine components. In: Proc. 20th Internat. Conference Engineering Mechanics, Svratka, Czech Republic, pp. 564-567.

Lošák P. (2014) Identification of vibration causes based on spectrograms during the straightening process. In: Proc. 20th Internat. Conference Engineering Mechanics, Svratka, Czech Republic, pp. 368-371.

Fuis, V., Koukal, M., Florian, Z. (2011) Shape Deviations of the Contact Areas of the Total Hip Replacement. In: Proc. 9th Inter. Conference on Mechatronics Location: Warsaw, Poland. Mechatronics: Recent Technological and Scientific Advances, pp. 203-212.

Fuis, V. (2009) Tensile Stress Analysis of the Ceramic Head with Micro and Macro Shape Deviations of the Contact Areas. In: Proc. 8th Inter. Conference on Mechatronics, Luhacovice, Czech Republic, Recent Advances in Mechatronics: 2008-2009, pp. 425-430.

Petruska, J., Navrat T., Sebek, F. (2012) A New Model for Fast Analysis of Leveling Process, In: Proc. 2nd Internat. Conference on Advanced Materials and Information Technology Processing (AMITP 2012), Taipei, Taiwan, Book Series: Advanced Materials Research, Vol. 586, pp. 389-393.