20th International Conference
ENGINEERING MECHANICS 2014
Svratka, Czech Republic, 12 – 15 May 2014

ANALYSIS OF DYNAMIC LOADING OF BAR STRAIGHTENING MACHINE COMPONENTS

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Abstract: *The oblique bar straighteners are rotary forming machines, which are used for straightening of round bars designed for further processing. During straightening the bars are rotating among hyperbolic rollers, which are held by holders. The bottom rollers are driven by electric motor connected with a gearbox and cardan shafts. During the straightening the machine is loaded with enormous forces and torque moments. This paper is focused on determining torque moments, which are required for design of straightening machine. The straightening machine described below has 7 rollers and it is designed for bars with a 200 mm diameter.*

Keywords: Oblique straightening machine, Finite element method, Plasticity.

1. Introduction

The bar straightening is based on their bending among the straightening rollers. The bending moment, which evokes in the bar during the straightening, must be large enough for plastic strain initialization in the bar. The bending moment is created by adjusting of three rollers (number 3, 6 and 7 Fig. 3) towards the straightening bar (Fig. 2). In the case of the oblique straightening the translation motion of the bar is dependent on the rotation of straightened bar. Plastic strain is initialized on the bar surface by bar rotating. Plastic strain is necessary for bar straightening. The rollers have the shape of rotational hyperboloid. For bar straightening it is necessary to know the values of torque moments, which are evoked in the holders and torque moments needed for the driving of rollers. Required values were obtained by numerical simulations (Finite Element Method). Before their use the experimental verification needs to be done.

Fig. 1: Bars before straightening.

2. Oblique Straightening Machine

The structure of straightening machine (Fig. 3) consists of two driven and five not driven working rollers, straightened bar and input-output trough. The input dates: Working rollers can rotate around axis of their rotation and they are set at the angle 26° and 30° to the axis of straightened bar (Fig. 2). The working rollers are modelled as rigid and they are positioned in fixed holders. The diameter of straightened bar is 200 mm, curve radius - 180 m and length - 6 m. The material of straightened bar is named 30CrNiMo8+QT. The yield stress

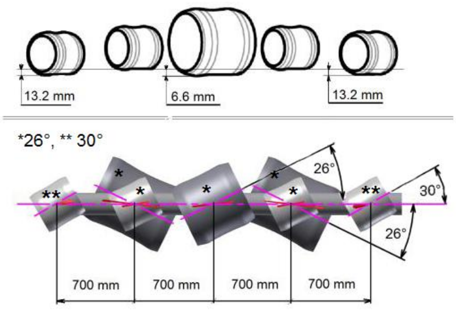

Fig. 2: Setting of rollers.

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of this material is approximately 1000 MPa. The model of plasticity was used with isotropic hardening. The rotation of driven working rollers was 40 rpm, friction between the rollers and the bar - f = 0.2 (var. a), f = 0.1 (var. b), and the gravity acceleration - g = 9.81 m/s^2.

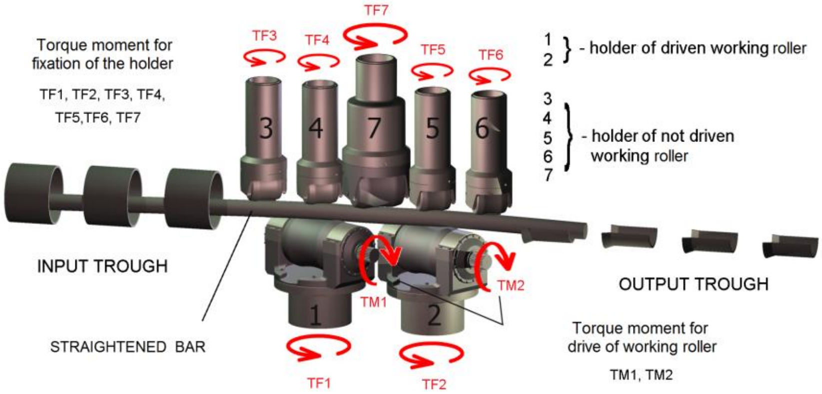


Fig. 3: Structure of oblique straightening machine.

The processes: Input and output troughs are used for a transport of the straightened bar. The bar is driven by trough rollers. When the bar is among working rollers (number 1, 3, 4 and 7), the rollers of the trough are diverted. Then the straightened bar is driven by working rollers of straightening machine. When the bar straightening is finished, rollers of output trough move the bar into the feeder.

Detail analyses of dynamics and vibrations in the process of bar straightening are covered by the article (Lošák, 2014). The analysis of the shape deviations of the aligned bar is in (Fuis, 2014), which is based on (Fuis et al., 2009 and 2011).

3. Numerical Simulations

Numerical simulations were focused on:

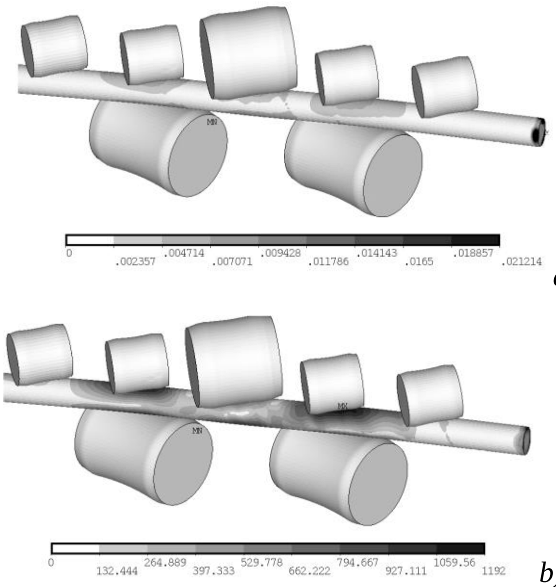
a) determining stress-strain state during the straightening process,

b) determining torque moments for fixation of holders (1-7),

c) determining torque moments for drive of rollers (1 and 2).

4. Results

Stress-strain state of straightened bar (in the fifth seconds of the straightening process) is shown in Fig. 4.



a)

b)

Fig. 4: Contours of: a) equivalent plastic strain [-], b) equivalent stress [MPa].

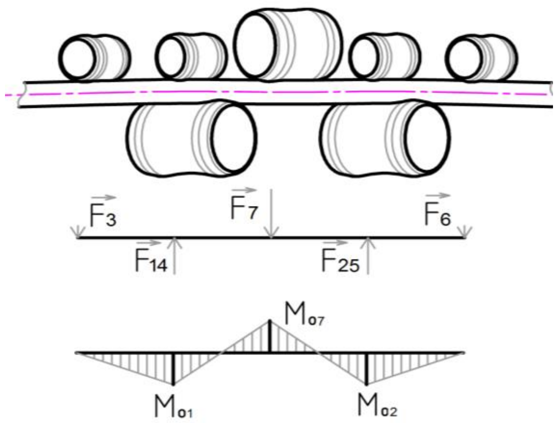


Fig. 5: Forces and bending moments acting on a bar.

The highest value of equivalent stress is approximately 1192 MPa (Fig. 4) in the place with largest bending moment (Fig. 5) during the straightening. The highest value of equivalent plastic strain (approximately 0.007 [-]) is in the same place (Fig. 4). The value of equivalent stress and equivalent plastic strain is the same for both solved variants of friction (*f* = 0.2, *f* = 0.1). The highest value of torque moments for holder fixation is on the roller 1. The second highest value is on the roller 7 (see Fig. 6 - top). These values are approximately 125000 Nm (roller 1) and 80000 Nm (roller 7). These rollers are most loaded. The gradual inclusion of rollers in the straightening process is shown in Fig. 6. The torque moment for drive of working roller 1 and working roller 2 is approximately 85000 Nm (roller 1) and 60000 Nm (roller 2) - see Fig. 6 - bottom.

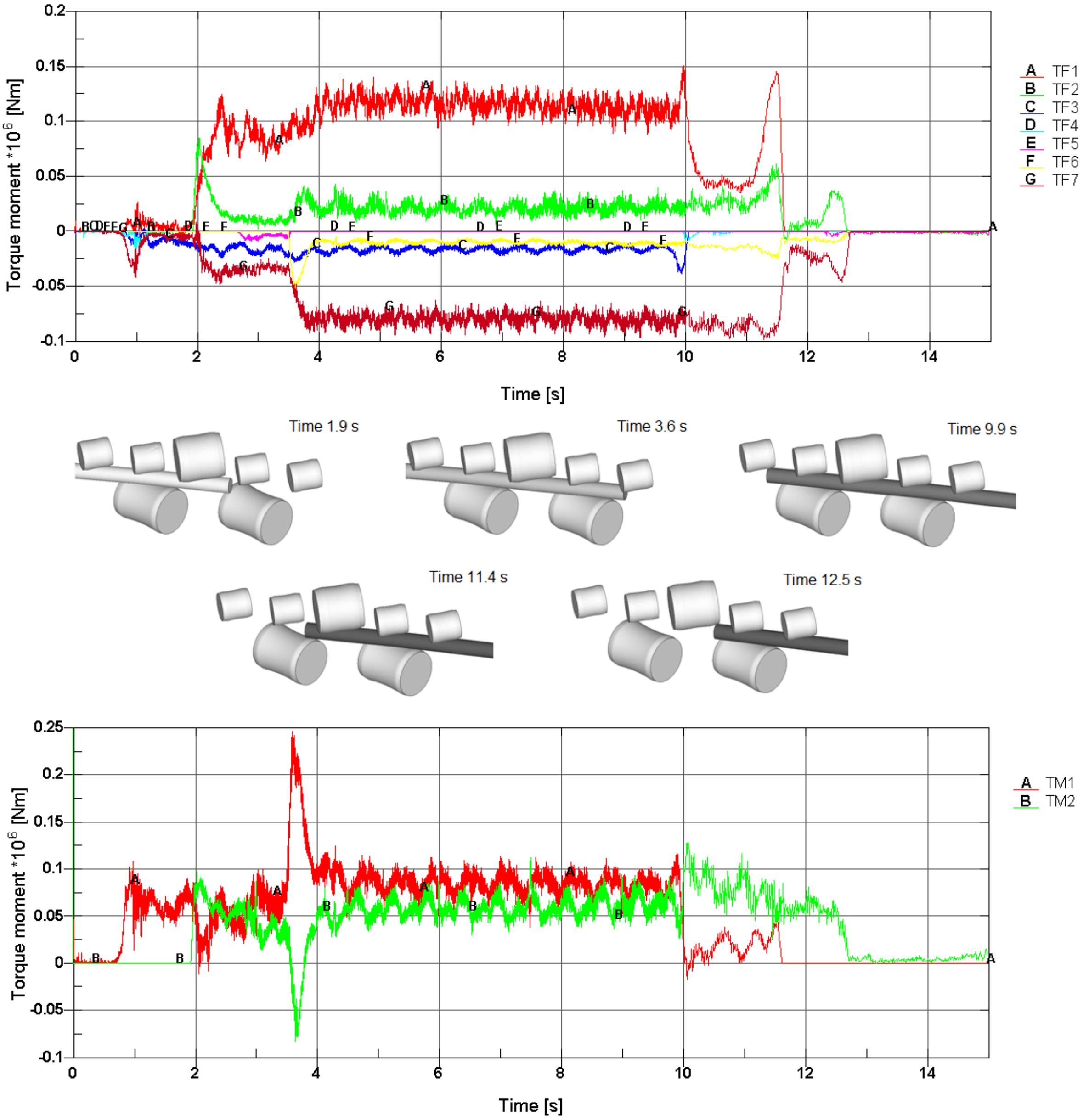


Fig. 6: Torque moments for fixation of holders (top) and for drive of rollers (bottom), f = 0.2.

When the friction coefficient is equal to 0.1, we can say: the highest value of torque moments for fixation of holders is on the roller 1. This value is approximately 100000 Nm (roller 1) - see Fig. 7 - top. The second highest value of torque moments for fixation of holders is on the roller 7. This value is approximately 80000 Nm (roller 7) - see Fig. 7 - top. The torque moment for drive of working rollers (1, 2) is approximately 70000 Nm - see Fig. 7 - bottom.

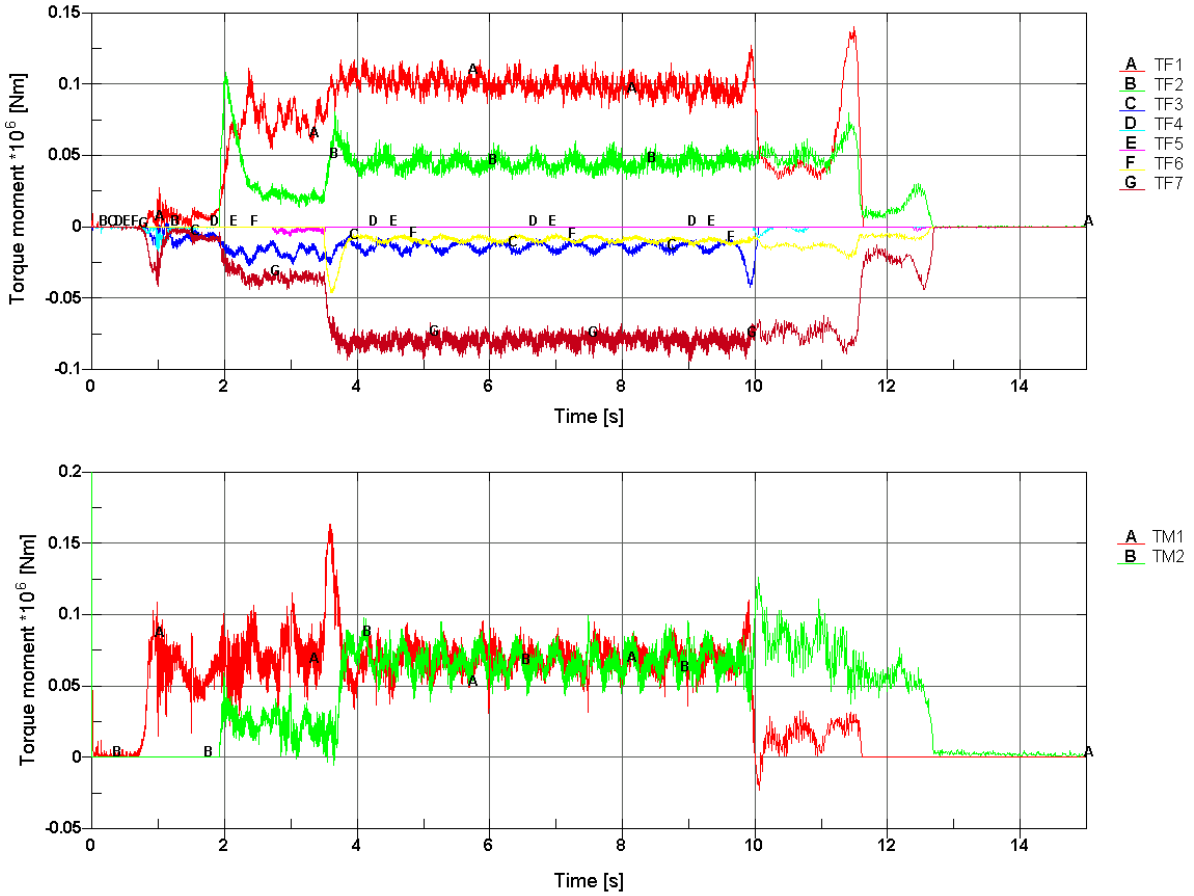


Fig. 7: Torque moments for fixation of holders (top) and for drive of rollers (bottom), f = 0.1.

4. Conclusions

By comparing two variants of friction (that we have solved), we can say, that the lower friction reduces torque moments for drive of rollers and for fixation of holders. During the bar straightening torque moments for drive of working rollers will increase to the value of 250000 Nm (f = 0.2, see Fig. 6 - bottom) and to the value of 165000 Nm (f = 0.1, see Fig. 7 - bottom). This increase of torque moments occurs when the straightening bar comes into the contact with the roller number 6 (see Fig. 6, Fig. 7 – time 3.6 s). The further increase of torque moments is connected with the loosing contact of the bar with the roller number 3 (see Fig. 6, Fig. 7 – time 9.9 s).

Acknowledgement

This work was supported by Grant Specific Research FSI-S-14-2311.

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