ZESZYTY NAUKOWE POLITECHNIKI ŚLĄSKIEJ 1995

Seria: MECHANIKA z. 122 Nr kol. 1267

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MODELLING OF THE CONTROLLED WORK ROLL PRE-BENDING MECHANISM OF A FOUR-HIGH ROLLING MILL

Summary. Thickness accuracy of the rolling stock is one of principal parameters that determines its quality. Sheet thickness automatic control is carried out by the change of the work roll pre-bending. To investigate dynamical properties of a rolling mill stand and its control circuits the computer modelling method is suitable. The contribution deals with crucial properties of the real system and their consideration in the model.

МОДЕЛИРОВАНИЕ ПРОТИВОИЗГИБАТЕЛЬНОГО МЕХАНИЗМА РАБОЧИХ ВАЛКОВ КЛЕТИ КВАРТО

Резюме. Точноств толщины проката является одним из главных параметров, которые определяют его качество. Автоматическое управление толщины полосы производится изменением противоизгиба рабочих валков. Для исследования динамических свойств прокатной клети и её гидравлического управления метод компьютерного моделирования подходящим. Статья занимается существенными свойствами реальной системы и их включением в систему модельную.

MODELOWANIE STEROWANEGO URZĄDZENIA PRZEDZGINAJĄCEGO WALCARKI BLACH KWARTO

Streszczenie. Grubość blachy, walcowanej na walcarkach kwarto, jest jednym z parametrów, które decydują o jakości produkcji. Regulacja automatyczna grubości blachy realizowana jest zmiana tzw. przedzginania walców roboczych walcarki. Do przeprowadzenia badań cech dynamicznych walcarki oraz jej obwodów sterujących użyta została metoda modelowania matematycznego. W pracy przedstawiono wyniki badań podstawowych cech dynamicznych systemu rzeczywistego oraz ich wprowadzenie do modelu matematycznego.

1. INTRODUCTION

Rolling belongs to the most effective ways of metal forming. A principal requirement that is put on this proces is high quality of the rolling stock. It is a result of a number of mechanical, chemical and geometrical parameters. The accurate thickness is among them.

Automatic control of the sheet thickness can be carried out by regulating actions of a prebending mechanism to reduce the deflection of the work rolls during rolling.

Regular design of the control device is not possible without proper knowledge of dynamical properties of the rolling mill stand. The computer modelling method is one of the best approaches for the investigation. The whole procedure can be divided into two stages:
- investigation of the roll stand properties from the point view of is vertical vibration,
- interaction between the mechanical part of the stand and its hydraulic pre-bending mechanism.

2. MODELLING OF THE ROLLING MILL STAND VERTICAL VIBRATION

The proposed geometrical model of a four-high rolling mill stand is combined (Fig. 1). Some parts are represented by a system of point bodies connected together by massless elements to which stiffness and damping characteristics are assigned. Parts with exactly specified geometry (work and back-up rolls) are modelled by beam finite elements considering the influence of shear forces on their deformation.

Among others vertical vibration of the roll stand depends on the interaction between the strip and work rolls. Wrought metal is represented by a system of spring elements with viscous damping properties (Kelvin-Voight's material model). Its linearised stiffness and damping coefficients (k_m, b_m respectively) can be estimated from the expression for the infinitesimal change of the roll force:

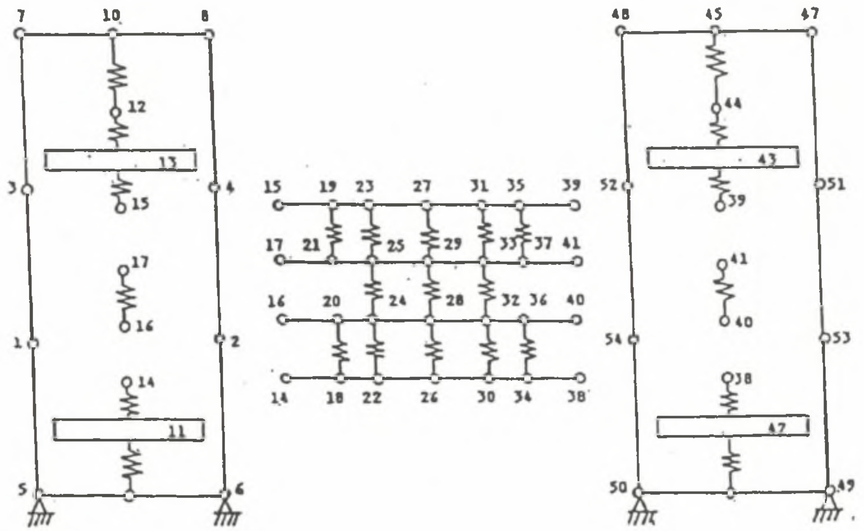
$$k_m = F_v \frac{m_2+0.5}{\Delta h}, \tag{1}$$

$$b_m = F_v \frac{m_3}{2h_0 u_s}, \tag{2}$$

where:

m_2, m_3 - material constants,
F_v - roll force,
h_0 - sheet thickness on the entry end of the stand,
Δh - absolute draft,
u_s - mean rate of deformation,

Stiffness of hydraulic circuits is derived form the bulk modulus of elasticity of the liquid and the wall flexibility of pipings and hoses is also taken into account.
All forces acting on the rolling stand are considered to be concentrated ones.



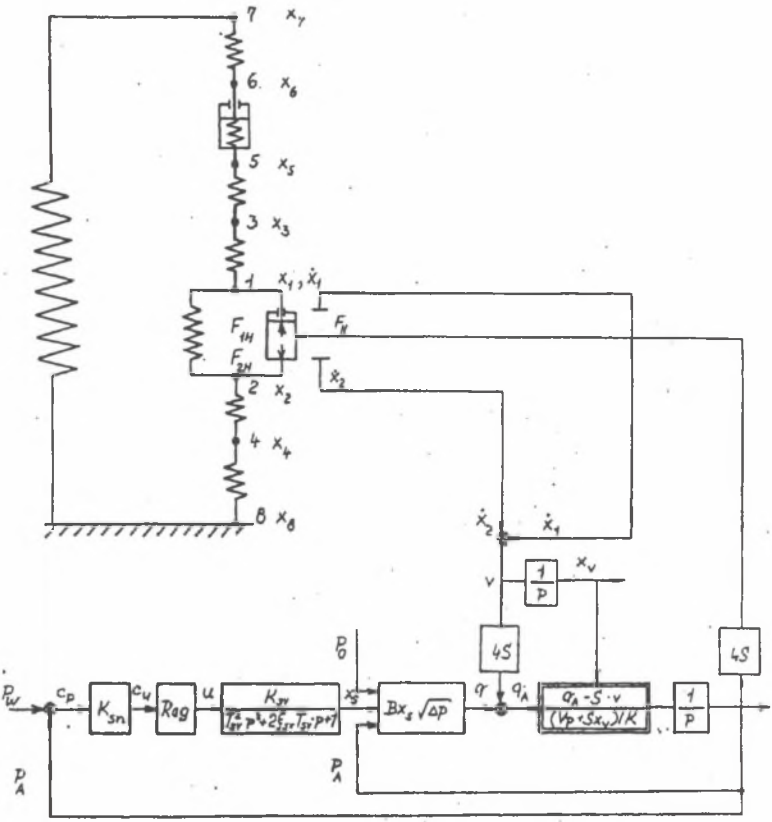
Rys. 1. Schemat modelu geometrycznego walcarki kwarto
Fig. 1. Scheme of the geometrical model of a four-high rolling mill

3. MODELLING OF THE PRE-BENDING MECHANISM INCLUDING ITS CONTROL SYSTEM

A special attention must be paid to the hydraulic circuits with pressure controllers. The mechanical part of the roll stand is modelled in a simplier way (Fig. 2).

The analog pressure control in hydraulic motors can be realized through an electrohydraulic servomechanism consisting of:

a servovalve, hydraulic motor, pressure meter and pressure controller.



Rys. 2. Schemat systemu modelowanego włącznie obwodu sterowania przedzginania
Fig. 2. Scheme of the model system including the pre-bending control circuit

Properties of the servovalve are described by a differential dependence between the relative position of the slide and control voltage and by the linearized rate of flow characteristic:

$$T_{sv}^2\ddot{X}_s+2\xi_{sv}T_{sv}\dot{X}_s + X_s + K_{sv}\,u, \tag{3}$$

$$Q_X = K_{QX}X_S - K_{QP}P_z, \tag{4}$$

where:

- X_s - relatively position of the slide,
- u - control voltage,
- T_{SV} - time constant of the servovalve,
- ξ_{SV} - decay,
- K_{SV} - amplification factor,
- Q_X - flow rate,
- p_z - traffic pressure,
- K_{QX} - flow rate amplification factor,
- K_{QP} - flow - pressure amplification factor,

Behaviour of the hydraulic motor is given by the equation of motion of its piston and by the equation for the change of the hydraulic liquid pressure

$$m\ddot{x} + b\dot{x} = Sp_A - F, \tag{5}$$

$$\dot{p}_A = \frac{K}{V_A}(Q_x - S_{\dot{x}}). \tag{6}$$

Modelling of the controlled work rolls pre-bending mechanism of a four-high rolling mill 1995, where:

- x - piston position,
- m - piston mass,
- b - viscous damping coefficient,
- S - cross section area of the piston,
- F - load force,
- p_A - pressure in hydraulic cylinder,
- p_A - first derivative of the pressure with respect to time,
- V_A - volume of the liquid in the cylinder,
- K - bulk modulus of liquid elasticity,
- Q_X - flow rate in the line,

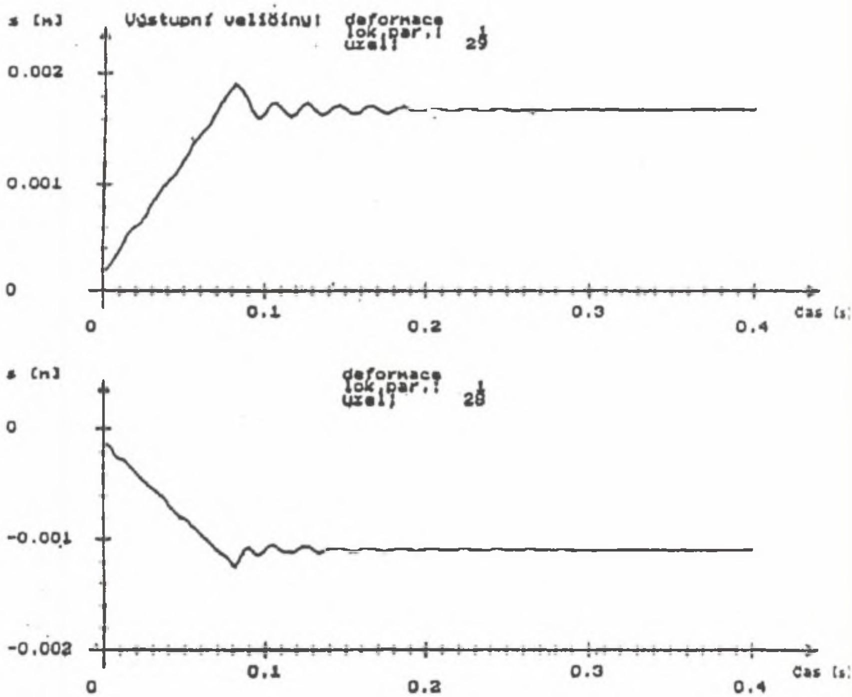
The controller id of PID type. The amplification of the meter is considered to be constant.

The interaction between the mechanical and hydraulical parts of the model system is given by pre-bending forces and relative velocities of the upper and bottom work rolls.

4. INVESTIGATION OF THE WIDE-STRIP HOT ROLLING MILL STAND IN VSZ KOSICE

Described computer models were used the investigation of dynamical behaviour of the wide-strip hot tolling mill stand in VSZ Kosice plant. The task was to prepare technical date for the proper design of the pre-bending device that would make possible perform the automatic strip thickness control.

Time history of the vertical displacements of the work rolls centres after the sheet entry into the stand are evident from fig. 3. The control system was turned-out in this case. The initial deformations are not zero because the stand had been loaded by pre-bending forces before the sheet entered into interroll gap.



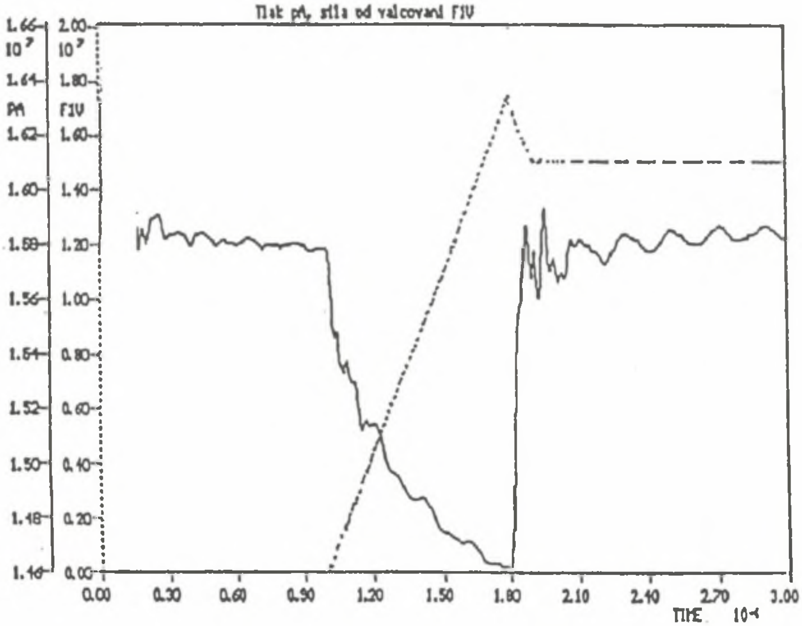
Rys. 3. Przebieg w czasie przemieszczenia pionowego środków walców roboczych po wprowadzeniu taśmy między walce walcarki

Fig. 3. Time history of the vertical displacements of the work roll centres after the sheet entry into the stand

The time history pressure in hydraulic motors of the pre-bending mechanism is drawn in fig. 4.

On carried out computer experiments it has been found out that:

- the proposed device does not influence negatively the history of transition phenomena during investigated traffic operations
- the pressure reduction does not drop below the minimum limit value
- the time of pressure equalising to the required value corresponds with technological requirements,



Rys. 4. Przebiegi w czasie ciśnienia cieczy roboczej w hydromotorach
Fig. 4. Time history of the liquid pressure in hydraulic motors

5. CONCLUSIONS

Device for automatic sheet thickness control by work rolls pre-bending are the necessary ones of all modern roll stands. The computer modelling method is an efficient instrument for investigation of their properties.

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Wpłynęło do Redakcji w grudniu 1994 r.