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Capture of an H-Beam Blank by the Rollers in the Reduction Stand of a 1300 Universal Beam Mill

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Abstract—The capture conditions for an H-beam blank by the grooved rollers in the 1300 reduction stand of a universal beam mill at Nizhny Tagil metallurgical works are considered. The stress–strain state of the metal in the deformation regions on rolling the beam in the roller grooves of the reduction stand is investigated. The calculation results are presented as the distribution of the contact normal and tangential stress in the deformation regions as the H-beam blank is captured by the rollers. The normal tensile stress in the wall of the H-beam blank is no more than 52 MPa. In the deformation regions of the crosspieces and at their junction with the wall, the normal contact stress is compressive. That indicates a stress state favorable in terms of H-beam quality, with high compressive stress. A method is developed for calculating the dynamic loads in the drive line of the 1300 reduction stand, with allowance for the gaps in the spindle joints.

Keywords: H-beam blank, reduction stand, rollers, deformation regions, capture, normal stress, tangential stress, dynamic load, gaps

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At Nizhny Tagil metallurgical works, Continuous-cast H-beam blanks are rolled in the 1300 reduction stand of a universal-beam mill [1–5]. It is very important to assess the capture conditions for an H-beam blank by the grooved rollers in the 1300 reduction stand of the universal beam mill and to know the variation and magnitude of the normal and tangential stress at the contact surface as the deformation region is filled with metal.

The rolling of an H-beam blank in the reduction stand of a 1300 universal beam mill may be simulated by means of ANSYS software [1, 6, 10]. A three-dimensional formulation is employed. We determine the stress–strain state and flow of the metal in the deformation regions on rolling 30Sh beam in grooves *1*, *2*, and *3* of the 1300 reduction stand.

In investigating the stress–strain state of an H-beam in rolling, we neglect the inertial and mass forces. The deformed metal is assumed to be incompressible. In writing the equations of state, we consider simple loading. We adopt a Prandtl–Reuss elastoplastic model for the rolled material.

In the first stage of simulation, we consider the capture of the metal by the rollers. In the second, we consider the steady rolling of an 09Г2 steel H-beam blank, for the three cases in Table 1.

Table 1. Parameter values of the H-beam blank and the groove in the simulation

Case	Blank dimensions before entering roller, mm						Groove dimensions, mm					
	B_b	R_b	$H_{w, b}$	$H_{cr, g}$	$h_{cr, g}$	a_b	B_g	R_g	$h_{w, g}$	$H_{cr, g}$	$h_{cr, g}$	a_g
1	336*	90*	65*	275*	85*	99*	336	90	40	255	60	99
2	336	90	40	255	61	99	348	75	30	236	52	77
3	348	75	30	236	59	77	362	60	23	227	49	65

* An asterisk denotes dimensions of the H-beam blank after the first pass in the first groove. Notation: *B*, width; *R*, internal rounding radius; *h*, wall width; *H*, crosspiece height; *a*, base thickness of flange. Subscripts: b, beam; w, wall; cr, crosspiece; g, groove.

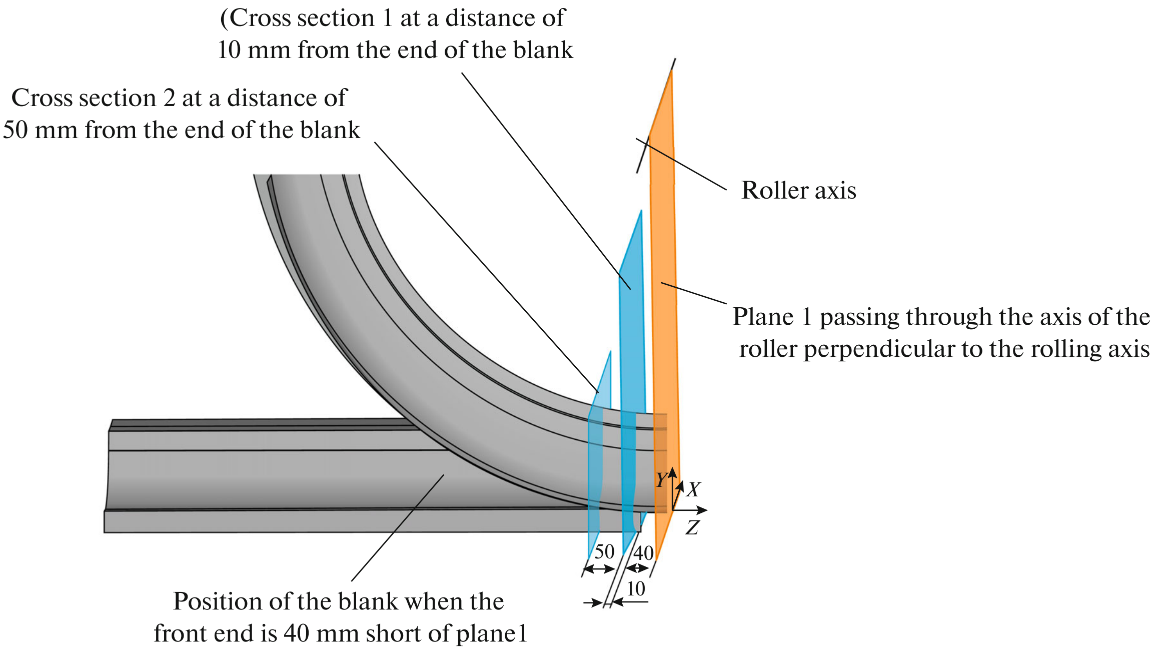

Fig. 1. Position of the plane passing through the axis of the roller perpendicular to the rolling axis and cross sections *1* and *2*.

The elastic modulus E is determined from the formula [1, 6]

$$E = -4.566\times10^5 + 160T + \frac{3.266\times10^8}{T}, \quad (1)$$

where T is the metal temperature.

The resistance σ_s to plastic deformation is calculated from the formula [1, 6]

$$\sigma_s = 288u_i^{0.107}(\ln\varepsilon_i)^{1.45}e^{-0.00235T}, \quad (2)$$

where u_i is the strain rate, s^{-1}; ε_i is the strain, %.

In accordance with the initial data adopted, we calculate σ_s for the H-beam wall, the crosspieces, and their junction region, for the given passes and temperatures. In all the grooves, the frictional coefficient is assumed to be 0.49.

In the initial state, to simulate capture, the front end of the beam is placed at some distance from the plane passing through the roller axis perpendicular to the rolling axis (Fig. 1).

The beam is represented by a three-dimensional solid model, while the groove is modeled by an undeformable solid surface. The finite-element model of the beam is formulated from three-dimensional 20-point solid elements SOLID186. In the final finite-element grid adopted for the calculation, the transverse dimension of the element is 2.5 mm; the dimension in the rolling direction is 5 mm. To see the calculation results more clearly, the deformation region is divided into three parts (Fig. 2). The calculations show that in capture of the beam by the groove, in all cases, the crosspiece in the direction of the OX axis is first captured. In all cases, the wall experiences tensile stress in the direction of the OX axis over its whole thickness (Fig. 3).

In Fig. 3, we adopt the following sign rule: quantities corresponding to tension are positive, while those corresponding to compression are negative. Table 2 presents the maximum (contact) normal and tangential stresses (MPa) in the deformation regions when rolling a 30Sh beam in grooves *1* and *3* for two cross sections. We see that the tensile normal stress in the wall in the direction of the OX axis (σ_x) is no more than 52 MPa. In the deformation regions of the crosspiece and the junction with the wall, the normal contact stress is compressive. That indicates a stress state favorable in terms of H-beam quality, with high compressive stress.

In determining the contact normal and tangential stress in capture of the H-beam blank by the rollers, we calculate the dynamic load in the drive line of the 1300 reduction stand.

We know that the large dynamic overloads in the drive line of reversible rolling mills are mainly due to the gaps in the spindle joints [11–14]. Accordingly, it is important to estimate the dynamic loads; to determine the collision speed of the masses in the gap as a function of the rolling parameters (which also determine the dynamic loads); and to adopt measures to reduce the dynamic loads. The gaps in the spindle joints of reduction mills are largely due to insertion of the blank in the rollers at speeds exceeding the roller speed and capture of the blank by the rollers with slowing of the drive motor [11–14].

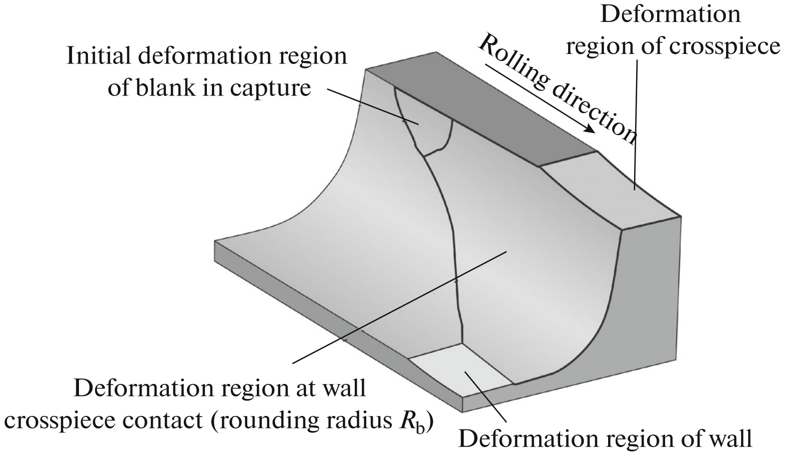

Fig. 2. Deformation region when the beam is rolled in the groove.

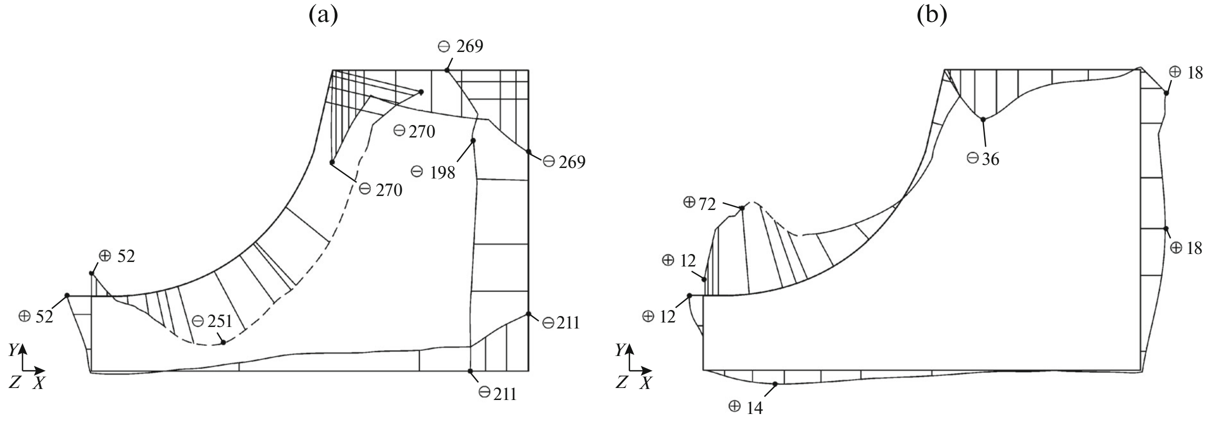

Fig. 3. Normal axial stress (a) and tangential stress (b) over cross section *1* (Fig. 2) in the rolling of 30Sh beam in groove *1* (second pass). Rolling temperature 1200°C.

We adopt a semideterminate two-mass model for the individual-drive line of the rollers in the reduction stand. The differential equation of motion of the roller and blank at the instant of gap selection in the spindle joint takes the form [11–14]

$$\left(J + \frac{GR^2}{2g}\right)\varphi + c\varphi = R^2\delta_1 B\tau_{\text{ta}}, \tag{3}$$

where J is the roller's moment of inertia, t m^2; G is the weight of the blank, kN; R is the roller radius, m; B is the width of the beam–roller contact surface, m; τ_{ta} is the tangential stress, MPa; c is the rigidity of the elastic coupling; δ_1 is the filling angle of the geometric deformation region at the instant of complete gap selection in the drive line for the motor's armature [11–14]

$$\delta_1 = \frac{\omega_0}{\beta_1}\sin\left(\sqrt[3]{\frac{6\Delta_0\beta_1}{\omega_0}}\right), \text{ rad.}$$

Here ω_0 is the armature speed, s^{-1}, and

$$\beta_1 = \sqrt{\frac{RBp\tan\alpha}{J + \dfrac{GR^2}{2g}}}.$$

In addition, p is the mean unit pressure, MPa; and α is the capture angle, rad.

Solution of Eq. (3) indicates that the maximum dynamic torque is

$$M_{\text{d}} = C\frac{\Delta\omega}{\beta} + R^2\delta_1 B\tau_{\text{ta}},$$

where $\Delta\omega$ is the collision speed in the gap of the spindle joint

$$\Delta\omega = \omega_0\left[\cos\left(\sqrt{\frac{6\Delta_0\beta_1}{\omega_0}}\right)\right].$$

Table 2. Maximum (contact) normal and tangential stress in the deformation regions when rolling 30Sh beam in the 1300 reduction stand

Groove and pass	Cross section	σ_x	σ_y	σ_z	τ_{xy}	τ_{yz}	τ_{zx}
Wall							
Groove 1 Pass 2	*1*	52	–116	–	12	14	6
	2	40	–77	–	14	11	30
Groove 3 Pass 1	*1*	27	–47	–	10	16	–
	2	32	–	36	–	–	–
Crosspiece							
Groove 1 Pass 2	*1*	–270	–291	–239	–36	–101	78
	2	–301	–383	–251	–48	–31	27
Groove 3 Pass 1	*1*	–212	–260	–236	–43	–77	–28
	2	–315	–434	–352	–57	–21	24
Rounding region between crosspiece and wall							
Groove 1 Pass 2	*1*	–251	–174	–159	72	–74	78
	2	–188	–115	–89	64	32	29
Groove 3 Pass 1	*1*	–189	–141	–157	65	–65	71
	2	–157	–97	–91	51	34	22

We calculate the parameter β from the formula

$$\beta = \sqrt{\frac{c}{J + \frac{GR^2}{2g}}}.$$

CONCLUSIONS

On the basis of theoretical analysis, we have determined the stress–strain state of the metal in the deformation regions on rolling an H-beam in roller grooves of the 1300 reduction stand in a universal beam mill.

We have developed an engineering method of calculating the maximum dynamic loads in the drive line of the 1300 reduction stand, with allowance for the gaps in the spindle joints.

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