SIMULATION OF STRESS-STRAIN STATE OF ROLLING ROLLS

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Abstract

Simulation of the stress-strain state of the rolls with the active and the passive experiments needed to determine the stresses, strains and displacements of rolls of finishing stands UWRM -1700 used for the construction of the shape of the active generatrix of profiled work rolls needed to improve the profile and flatness hot rolling mills.

The main deformation of four-roll systems is sag and elastic compression of the support and work rolls. Key influence on the quality of hire has a value of deflection of the work roll.

The object of research is rolls of finishing stands of UWRM-1700 of JSC "ArselorMittal Temirtau". For calculation the mechanical properties of the rolls used in different versions: LPHNd-63, LPHNd-74, HiCr, ICDP, AS1180xx, HVS80.

In this paper we demonstrated the possibility of adaptation of mathematical models of the stress-strain state of the work rolls of finishing stands of UWRM. The impact of various technological factors on rolls necessary to improve the profile and flatness of the strip hot rolling mills was investigated. Deformation modeling deflection of the work rolls in the finishing mill stand was conducted. The model of the deformation of the rolls in the software package Deform-3D was investigated and analyzed.

Keywords: Rolling roll, stress-strain state, sag, Deform-3D, modeling

1. INTRODUCTION

Simulation of the stress -strain state of the rolls using active and passive experiments needed to determine the stresses, strains and displacements rolls of finishing stands UWRM-1700 used to construct forms of active generatrix profiled the work rolls, and it is necessary to improve the profile and flatness hot rolling mills. The main deformation of four-roll systems is deflection and elastic compression support and work rolls. Key influence on the quality of hire has the value of the deflection of the work roll [1-3]. Aim of this work is simulation of the stress-strain state of finishing stands rolls of UWRM-1700 with the production of the following particular tasks: determining the values of the deflection of the work rolls for different versions; construction of mathematical models describing the deflection roll when affected by various factors, the analysis of the stress-strain state in the program Deform-3D by performing passive and active experiments.

2. MAIN TEXT

2.1 Methodological bases

The object of research is rolls of finishing stands of UWRM-1700 of JSC "ArselorMittal Temirtau". For calculation the mechanical properties of the rolls used in different versions: LPHNd-63, LPHNd-74, HiCr, ICDP, AS1180xx, HVS80. For rolls of this marks were collected and statistically processed data of their mechanical properties which are presented in **Table 1** [4,5].

Table 1 Mechanical properties of work rolls of UWRM-1700

Rolls	$\sigma_в$, MPa	$\sigma_т$, MPa	$E_{рп}$, MPa	HS
LPHNd-63	500/360	370/320	$1.23 \cdot 10^5$	63-70
LPHNd-74	470/350	350/300	$1.34 \cdot 10^5$	73-85
HiCr	2400/1800	1600/1000	$1.54 \cdot 10^5$	68-78/60
ICDP	2300/1800	1200/1000	$1.48 \cdot 10^5$	78-83/60
AS1180xx	2500/2000	1600/1200	$1.88 \cdot 10^5$	60-85/60-70
HVS80	2600/2100	1800/1300	$2.02 \cdot 10^5$	75-95/60-70

To determine the effect of rolling forces, anti-bending and other factors on the roll deflection and a construction on the basis of these data the mathematical models describing the roll deflection are collected and statistically processed data of rolling process parameters. Technological parameters were determined by rolling protocols of Electronic Computing Center (ECC) of UWRM-1700. ECC protocols of UWRM-1700 allowed form the sample of following rolling parameters: temperature, width and thickness of the strip in the cage number 12, the rolling force and effort anti-bending in the stands №10-12; grades rolled strips, number of thin (up to 4 mm) and narrow (1100 mm) strips. Were used the technological parameters of rolling the following grades: steel 3ps, steel 3sp [6].

On the basis of statistical processing of the data collected for the roll stands № 10, 11 and 12 (forming a geometric quality of the finished strip) and rolling conditions of most problematic assortment 2 × 1250 mm was constructed multiple linear regression equation, which describes the effect of the following factors on the deflection roll: X_1 - anti-bending force Q, tf; X_2 - rolling force P, tf; X_3 - width of rolled strip b, mm; X_4 - the number of rolled metal m, t; X_5 - work roll diameter D, mm; X_6 - the thickness of rolled strip h, mm; X_7 - profiling of work rolls W, mm.

After the necessary checks were discarded insignificant factors, and the final form of the equation was $У = 0,119 - 0,059Q + 1,026P - 0,07B$.

Thus, these factors are taken as basic for further modeling of passive and active experiments.

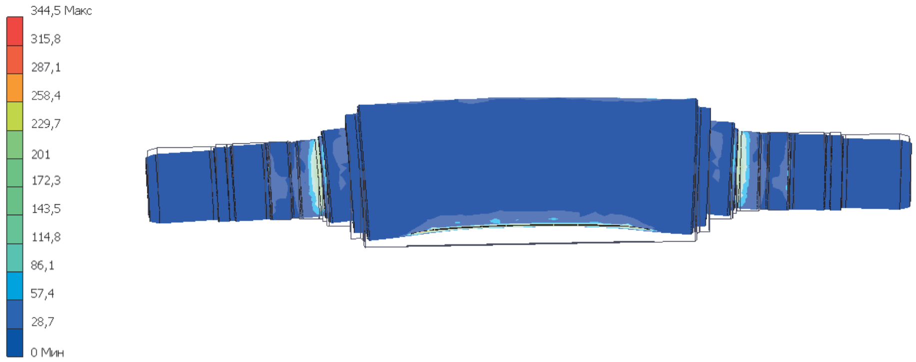
For all rolls of various designs, based on the collected statistical data on the rolled strip of steel 3sp in program MS Excel, using procedure V.P. Polukhin values were calculated deflection [1]. On the basis of calculations revealed that the work roll more bent during rolling of narrow strips thus precisely these conditions and is characterized largely defect band "nonflatness". This trend can be seen for all versions of the rolls, the rolls execution AS1180xx, used in the first finishing stand and rolls execution HVS80, used in the last finishing stand to have the least deflection under the same rolling conditions with efforts anti-bending without them.

2.2 Experimental part

Simulation of the stress-strain state of the roll system UWRM-1700 was performed by finite element method using complex software Kompas-3D, and then imported into the Deform-3D. On their basis the passive experiment was done [7].

For models were specified mechanical properties of the work rolls used in rolling stands № 9-12, and backup rolls of steel HiCr (**Table 1**). Obtained in the calculation data is presented in the form of drawings of rolls with pictures of distribution of stresses and strains (**Fig. 1**).

The maximum values of equivalent stress are observed in the middle of the roll (344.5 MPa) and on necks of work rolls (287.1 MPa) [2,3,8].



P, MN	13.83
Q, MN	0.66
B, mm	1262
σ, MPa	344.5

Fig. 1 Stress in work roll of stand №12 during the rolling strip width 1262 mm

2.3 Results and discussion

Using simulation results also were determined the values of the deflection rollers. The equations describing the dependence of the deflection of the roll width of the rolled strip (**Table 2**) [9].

Table 2 Depending of the deflection width of roll of the rolled strip

Equation	R^2	F_{CALC}	F_{TABL}
$У_{p}$=-0,0004x^2+0,9931x-627,95	0.8627	16.095	9.2434
$У_{i}$=-0,0005x^2+1,2788x-808,48	0.878	21.549	9.2434

The simulation results differ from calculated data 8-12 %. This is due to the fact that in the simulation process is not used such factors as the tension of the strip, thermal expansion of the roll and its profiling.

For the study of multifactorial systems more effective is the use of mathematical methods of experimental design [10]. For the experiment used three series of experiments (for 10, 11 and 12 frames) with the number of experiments in each series of $N=2^3$, with the following factors: rolling force, anti-bending force, bandwidth.

The modeling was applied the load: on barrel roll - rolling force; on roll neck - anti-bending force; also adjust the width of the rolled strip. For each of the factors were selected maximum and minimum data values are taken from the technological instructions, passports devices used for measuring the required parameters.

In rolling conditions with maximum values of variable factors on two levels band width 1524 mm, with a rolling force 15 MN and anti-bending force 1.5 MN; maximum value of the deflection of the work roll of stand 12 was 0.01 mm.

P, MN	15
Q, MN	1.5
B, mm	1524
y, mm	0.0099

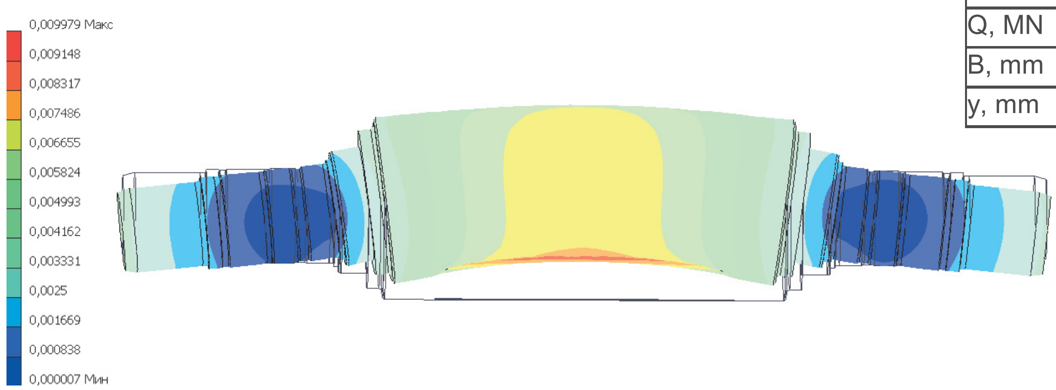


Fig. 2 Deflection of the work roll of stand №12 by rolling a strip of width 1524 mm

For each stand was received regression equations describing the effect of the rolling and anti-bending forces and rolled strip width on deflection of the work roll (**Table 3**).

Table 3 Depending deflection roll from rolling forces and anti-bending, the width of the rolled strip

№ stand	Equation	R^2	F_{CALC}	F_{TABL}
10	$У=0{,}015-0{,}0003\cdot X_1-0{,}012\cdot X_2-0{,}0002\cdot X_3$	0.82	1.4	3.05
11	$У=0{,}047-0{,}001\cdot X_1-0{,}007\cdot X_2$	0.86	1.92	3.05
12	$У=0{,}056-0{,}001\cdot X_1-0{,}009\cdot X_2$	0.88	2.48	3.05

The resulting regression equation describing the effect of the rolling and anti-bending forces, and rolled strip width on deflection of the work roll tested for significance and value, suggesting the possibility of their use in the production process in HRM-1 JSC "ArselorMittal Temirtau" [11].

CONCLUSION

1. Defined object of study - rolling rolls of UWRM -1700.
2. Were received regression equations relating the deflection of the work roll with the width of the rolled strip of most problematic assortment 2x1250 mm with rolling and anti-bending forces in stands №10, 11 and 12.
3. Chosen method of calculating the deformation of the rolls, designed the deflection for work rolls of various types. Revealed that an increase in the width of the rolled strip deflection decreases. When an anti-bending force is applied to the neck roll deflection is reduced by 35-56 %. When used steel rolls of performance AS1180xx HVS80 deflection is minimal, which allows to obtain a better quality metal.
4. Conducted finite element simulation of hot rolling in the software package Deform-3D. Based on modeling performed active and passive experiments, the results obtained are close to the theoretical data.
5. Regression equations describing the effect of the rolling and anti-bending forces, and rolled strip width on deflection of the work roll to the total output of rolled product.

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