Modeling of Strain-Stress State Of Heavy Duty Stands Elements Of Multifunctional Longitudinal-Wedge Mill

Serik Mashekov[1], Adilzhan Nurtazayev[1], Erkin Nugman[1], Bakhyt Absadykov[1], Maxim Rakhmatulin[1], Andrei Poleshchuk[1], Aigerim Mashekova[1]

[1]Institute of Industrial Engineering, Kazakh National Research Technical Univeristy named after K.I. Satpayev, Almaty, 050013, Kazakhstan

Abstract

It is shown that under real operating conditions, the rigidity of the existing rolling mill stands is not enough to get finished rolled without breaking the flatness and gage interference of the bands. A multi-longitudinal wedge mill of new design is presented. The analysis of the mathematical modeling results of stress-strain state (SSS) of the stands of new mill is shown. For modeling the finite element method and model deformation strength of the metal were used. The effect of changes in the diameter of the work rolls and temperature of rolled strips on SSS of heavy duty elements of mill stands is defined. It is shown that the new mill has a high rigidity of stands design and satisfy the strength requirements. It is noted that rolling strips on the proposed mill does not lead to the producing of finished steel with longitudinal and transverse gage interference. As a result of the modelling of SSS of heavy-duty elements of the new mill stands the measures for their modernization are developed.

Keywords**:** multifunctional longitudinal-wedge mill; rolls, stands, strain-stress state; thin strip, gage interference; flatness.

1. Introduction

Improvement of the quality of the thin strips made of steel and alloys plays a great role in the modern rolling production [1]. Degree of accuracy of thin strips is important gquality characteristics of the rolled strips. Longitudinal and transverse gage interference and flatness of the sheet metal are the main features of their quality.

Many studies [2,3] suppose that the flatbed band is an absolutely flat strip, without any geometrical defects. To date, it is identified that the following factors lead to a breach of flatness of sheet products: gage interference of semi-finished rolled stocks, uneven compression along the width of deformation zone. It should be noted that the reason of uneven compression is the elastic bending of roll system, roll vibration, thermal side strain of the rolls, flattening and runout of the body roll, etc.

Today, large-spread opinion [4,5] that the flatness defects occur due to the uneven distribution of the coefficient of extraction at the deformation zone width, as well as due to differences in the relative transverse gage interference at the entrance and exit of the rolls. It is known that highly rolled down parts of the strip are stretched along its width by a greater extent than slightly neck down portions. Parts deformable by big compressions are entailed parts deformable by a small compression. These lead to tensile longitudinal stresses in the last parts. Similarly, longitudinal compressive residual stresses arise in the parts of the band deformable by the high rolling down. The reason is the deterrent effect by small compression of deformable parts.

According to work [5], in case of the exact set position of the adjusting screws, the reason of the longitudinal gage interference is the change of the conditions of rolling along the length of the strip. This change leads to a change in pressure of the metal on the rolls, and hence to change the elastic deformation element and the roll cage. In the end, all this leads to a change in the distance between the rolls and the strip thickness.

The authors of [6,7] believe that the transverse variation in thickness associated with non-uniform strain along the width of the deformation zone. The reason of such unevenness is elastic bending of the rolls, roll vibration, thermal side strain of the rolls, flattening and wear of body rolls, etc.

It should be noted that the decrease in flatness and gage interference is also dictated by consumers of thin sheet, who produced products from it by pressing and other forming operations [8]. Poor flatness and gage interference of the strips from steels and alloys, used in the TV and electronic equipment and other industries, lead to disruption of the stable operation of devices and increased consumption of electricity adversely affects the processes of manufacture of body parts of motor vehicles, etc. Irregularity of flatness and gage interference of sheet metal during rolling leads to the rejection of a product or remedy such defects in the correct units. Correcting of the defects increases the cost of sheet metal by factor of 2 times.

The current development of rolling manufacturing is mainly aimed to improving the quality of rolled strips through the development and introduction of fundamentally new equipment and technology to ensure minimal gage interference and flatness [1].

In recent years, modern rolling equipment, new construction of stands are used to produce bands with a predetermined thickness, profile and gage interference [9]. This equipment effectively acts on the thickness, profile and flatness of the strip. Thus, the leading metallurgical and engineering companies carried out work on modernization and construction of new rolling equipment, as well as to improve the process of rolling process. However, it should be noted that many mills due to the complexity of their designs have not found widespread use in their production.

It is known [4], that widely developed methods of transverse gage interference and flatness regulation of rolled strips are contouring of body of rolls, regulation of thermal side strain, anti-crossbreak of working and backup rolls, reducing the vibration during rolling, regulation of rolling down modes of the rolled strips, etc.

However, the above methods have the disadvantages [4]. For example, the profiling of the rolls is only applicable for the strips of a particular size. Thermal regulation has considerable persistence. Application of anti-crossbreak to the working and backup rolls leads to increase of the load on the bearings of the roller block and intensive wear of the body of roll.

New multi-function continuous five-stand longitudinal-wedge mill was designed for rolling thin strips from metal and alloys [10].

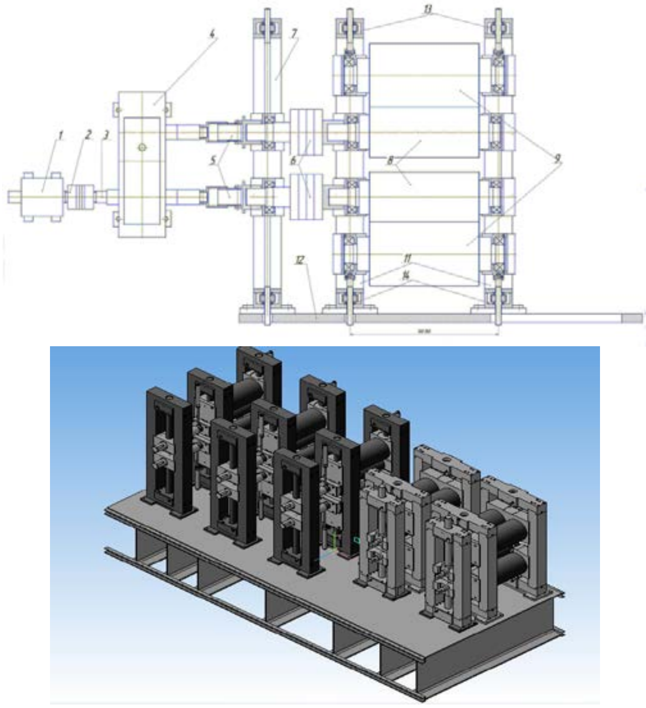
The aim of this work is to develop an algorithm for constructing a computer model of the new multi-functional longitudinal-wedge mill and then through the use of this model adjustment of the construction of multifunctional longitudinal-wedge mill

2. Equipment and the method of the experiment

In order to avoid the above problems and to obtain high-quality sheets, as well as reducing the power parameters, the multi-functional longitudinal wedge mill of new design for the hot rolling of thin strips from steel and alloys (Figure 1) is proposed [10].

Multifunctional longitudinal-wedge mill for rolling sheets from steel and alloy contains motors, gearboxes, pinion stand, universal spindles, couplings, stands with working and backup rolls (Fig. 1). Two backup rolls are set in the first three stands, and four backup rolls are set in the last two stands. Rotation of the working rolls decreasing in the rolling direction is carried out through the bearing cages by five gearmotors with angular velocity $\omega = \upsilon \cdot R$ (where υ - the rolling speed in each mill stand; R - the radius of the working rolls in each mill stand). The distance between the stands are increased by the amount of forward flow and adjustment of the distance between the working rolls is performed through the screw-down gear located above and below the trails of the mill and bearing cages.

Rolling of the strips from steel and alloys on the multifunction longitudinal-wedge mill is conducted as follows. Reeled off or continuously teemed light-gage slabs (thickness of the thin slab must correspond to the maximum angle to capture the rolls installed in the first stand) enters the uncoiling machine or the entry section for the rolling. Beginning of thin slabs get through the pulling and straightening rollers of the welding machine, the looper with the hinged wagons, pullers, as well as through the devices for thickness measurement, and finally it supplies to the first stand of the proposed mill. There is a reduction of the height and attainment of the required thickness of the strip during rolling through the stands located successively in the direction of the rolling, and the distance between the work rolls of which increase from one stand to another by the value of forward flow.



1 - gear motor; 2 – gear; 3 – roll; 4 – pinion stand; 5 and 6 – main spindle; 7 – bearing stand; 8 – working rolls; 9 (fist three stands) and 10 (last two stands, not shown) – backup rolls; 11 – foundation slab; 12 - workframe; 13 and 14 – screw down mechanism
Fig. 1. Multifunctional longitude-wedge mill for strips rolling

It should be noted that the working rolls in each stand have a constant diameter, whereas there is a reduction of the rolls diameters in the direction of rolling in the sequentially arranged stands. At the exit cutting or reeling of thin strip occur.

Reduction of the diameters in the direction of rolling allows significantly decrease the pressure of the metal on the rolls in the last stands of the mill and consequently increase the rigidity of the mill. Reducing the force acting on the rollers, as well as the expansion of the mill rigidity allow on one hand to reduce the size of the stands and power of the drive, on the other hand rise the accuracy of the rolled strip.

Increasing the distance between the working rolls from one stand to the other by the amount of forward flow allow to decrease interstand tension till the required value. This is achieved through strict implementation of constant-second volumes while rolling in different cages. Reducing interstand tension to a predetermined value allows to avoid tearing strips during rolling, on the one hand, and to reduce energy and power parameters of rolling on the other hand.

The rolls are rotated through the AC five gearmotors from the five pinion stands that makes the minimum value of industrial noise during rolling of strips from steels and alloys.

Rolls of the working stands rotated through the five bearing stands allow to locate the main spindle strictly horizontally, that in its turn contribute to transfer rolling torque to the working rolls of the mill stands without vibration load. All this contributes to obtaining strips with precise geometric dimensions.

Production of the first three mill stands with two supporting rolls and the last two mill stands with four supporting rolls ensures minimal elastic deformation of working rolls of the last mill stands and thus allows to obtain strips with a minimum gage interference.

Adjusting the distance between the rolls by the uniform worm mechanisms, arranged above and below of the foundation slab and bearing stands, will allow to roll the strips strictly symmetrically with respect to the rolling axis. This allows to produce the strips without bend and breaking with minimal variation in gage interference.

For proper adjustment of the structure of the new mill is necessary to determine the elastic deformation and vibration of the rolls, and also to calculate the stress-strain state (SSS) of the individual structural elements of the stands, as well as components of their interface with different types of impacts and stress levels.

In this paper, MSC Nastran multifunctional software package was used to solve the problem of elastic-plastic by the finite element method in the bulk formulation.

To solve the problems of designing the stands of new multifunctional mill the following properties of the selected system are the most important [11,12]:

- opportunity to create solid models of the mill stands in a single integrated design environment, in addition to calculate SSS at each point of the heavy duty element of the mill;
- the function to model the assembly of individual components and the entire mill as a whole;
- opportunity to receive working drawings in compliance with the rules of unified system of design documentation by the models and in an automated mode;
- availability of standard products, materials and textures libraries, so the users do not need to search in reference literature and the input data such as Poisson's ratio, elastic modulus, tensile strength of the materials, etc.

Patran Nastran software of finite element analysis was used to establish the method of SSS and elastic deformation calculation [13,14]. Patran Nastran computer modeling system allows exploring kinematics, dynamics of mechanisms with the possibility of calculating the stress-strain and thermal states as individual units, and the mill as a whole.

During design of the working stands in the Patran Nastran program, the following operations was run [11-14]:

- creating of the geometrical model of each stands and assembly of the units of the working stand;
- choose of the details material, its mechanical and physical properties (modulus of elasticity, mass density, Poisson's ratio, tensile strength, etc.);
- formation of the kinematical and statistical edge conditions;
- creation of the finite elements lattice of the details of the new mill stands;
- determining of the SSS of the mill stand details;
- assessment of the obtained elastic deformations and stresses in the volume of each stands details relatively to the requirements of stiffness and strength, furthermore introduction of relevant amendments to the mill construction (solid model of the mill).

Initial data for calculation are solid geometric shape of the new mill construction, the forces applied to it and fix conditions, as well as the conditions of integration of kinematic pairs of the stands design.

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 10, October 2016
ISSN (Online) 2348 – 7968 | Impact Factor (2015) - 4.332
www.ijiset.com

The assembly three-dimensional geometric model of the mill was constructed in the COMPASS CAD program, and by using built-in translator imported into PATRAN NASTRAN with the adopted kinematic constraints. This approach allows improving communication-aided design phases of complex mechanisms. To be able to automatically correct the mill model geometry, geometric design method parameterization size was used. This method allows to make appropriate changes in the design of a new multi-function mill stands according to the results of the strength calculation.

Fig. 2 presents a three-dimensional model of the third and fourth stands of the multifunctional mill with the division into finite elements.

6- and 8-node three-dimensional finite elements was used to simulate the construction of a new mill stands, moreover twelve types of hardness were exploited to define rigid characteristics of the main parts of the mill.

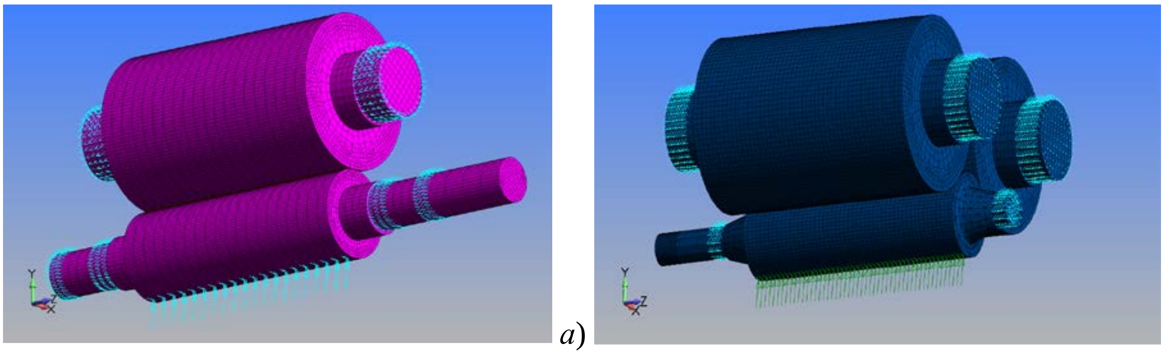
It is noted that in more detail the supports of the roll node were simulated. The computational model of each spherical roller bearing includes three types of components: an outer, an inner ring and two rows of 18 rollers in each.

During developing the design scheme, condensed finite element mesh used in places of supposed stress concentration.

The stress state in the heavy-duty detail of stands (backup and working rolls, bearings, pads, bushings) was calculated by applying the rolling force and the effects of thermal stress.

The kinematic connection between the heavily loaded elements was simulated by the kinematic pairs of rotating and sliding for the common integration. At the same time collision and friction in the rollers, pads, bearings, and so on were taken into account.

In PATRAN NASTRAN heavy duty parts are made absolutely rigid and ensure the properties of thermal conductivity and heat transfer, so only thermal conductivity, specific heat and density were taken into consideration. Density and thermal properties for the material of stands details were designated by default.



a)
b)

a – third stand; *b* – fourth stand

Fig. 2. Calculation schemes of the finite element model of multifunctional longitudinal-wedge mill

Interaction between the rigid backup and working rolls and the deformed material of the workpiece is modelled by the contact surfaces, which describes contact conditions between the surfaces of the backup and working rolls, and surface of the thin strip. During simulation the contact conditions is constantly refreshed, indicating rotation of the backup and working rollers and deformation of the material, that allow modelling sliding between the backup and working rollers, as well as the material surface of the processed workpiece. Contact between the working rolls and the thin sheet is modeled by Coulomb friction and was adopted as 0.5. In this case the friction force between the rolls taken equal to 0.0868.

Operating temperature mode during rolling on the proposed mill consists of the exchange of heat between the rolls, the thin workpiece and the environment, as well as a thermal effect due to metal deformation. Rolling process takes place at a different temperature. However, the initial temperature of the rolls taken equal to 20 ° C.

It should be noted that the rolls were attached to the supporting necks of the bearing nodes by the three degrees of freedom T_x, T_y, T_z. 9X1 steel has been accepted as roll material with the following mechanical properties: modulus of elasticity - 2.1 + 11 Pa; Poisson's ratio - 0.283; the shear modulus - 8.1839 + 10 Pa.

The strength and stiffness of working and backup rolls of the multifunctional mill was studied during cold and hot rolling of the strips from D16 alloy with the dimensions of 0.7 × 400 *mm*. Semi-finished rolled stocks with the thickness of h_0 = 3.5 mm were used as an initial preform.

Table 1 shows the initial data entered for rolling the strip in the first, second, third, fourth and fifth stands.

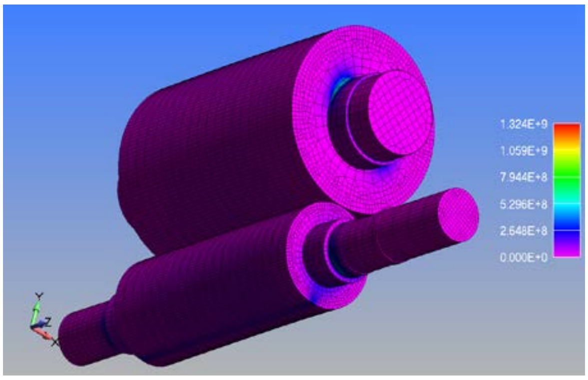
Table 1. Initial data for simulation

Initial data	Stand 1	Stand 2	Stand 3	Stand 4	Stand 5
The strip height after rolling, *h, mm*	2.576	1.708	1.148	0.84	0.7
Absolute reduction, Δh	0.924	0.868	0.56	0.308	0.14
Single reduction, *ε, %*	26.4	33.7	32.8	26.8	16.7
Strip velocity, $\upsilon_1 = h_5 \cdot \upsilon_5 / h_1$, *m/s*	0.5	0.68	1.03	1.526	2.085
Maximum rolling force, *P, MH*	0.251	0.224	0.192	0.141	0.087
Maximum torque on a single work roll, M_{TR}, *kH·m*	2.8	1.8	1.23	0.81	0.36
Maximum difference of front and back tensions applied to the two working rolls, *T, kH*	5.23	4.213	3.534	2.628	1.943
Diameter of the backup roller, D_{BC}, *mm*	220	220	220	220	220
Diameter of the working roller, D_{WR}, *mm*	180	150	125	106	94

3. Results and discussion

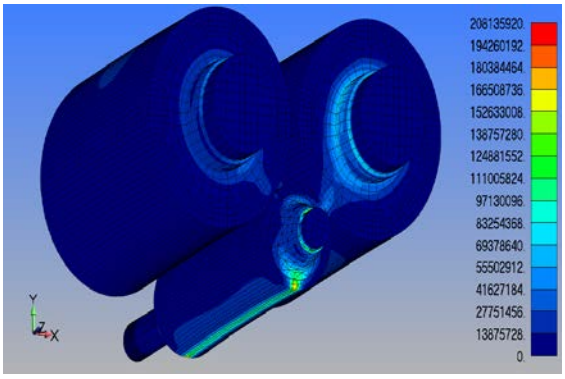
The calculations carried out on the finite-element models of new mill stands show that:

- the maximum von Mises equivalent stress in the body of backup rolls varies from 55.5 MPa to 264.8 MPa, and for journal backup rolls - from 329.6 MPa to 69.4 MPa at the rolling strips in the first, second, third, fourth and fifth stands of the proposed mill (Fig. 3). The maximum von Mises equivalent stress in the body of the working rolls varies from 208.2 MPa to 132.4 MPa, and for the journal working roll - from 290.5 MPa to 69.4 MPa and by rolling strips in the first, second, third, the fourth and fifth stands of the proposed mill (Fig. 3). It should be noted that the maximum von Mises equivalent stress mainly occur in the journal of the roll. During rolling in the first, second, third, fourth and fifth stands the received maximum values von Mises equivalent stress, that equals to 329.6 MPa do not exceed the maximum allowed for the material value of the ultimate strength of the rolls;



a)

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 10, October 2016
ISSN (Online) 2348 – 7968 | Impact Factor (2015) - 4.332
www.ijiset.com

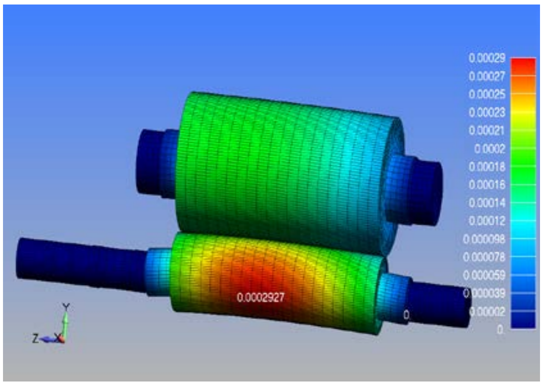


b)

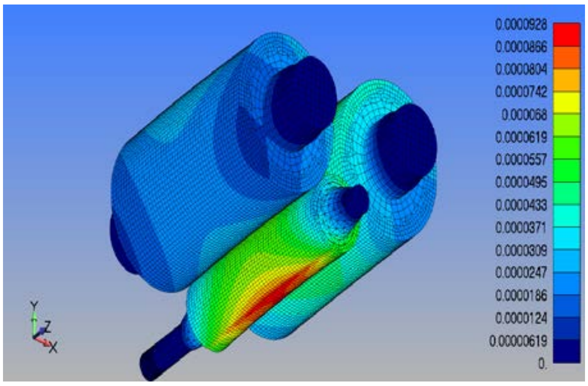
a – third stand; *b* – fourth stand

Fig. 3. The picture of von Mises equivalent stress distribution

- under the influence of applied vertical forces the rolls bend in the direction of force action. Therefore, the body and journal of the rolls are elastically deformed in the same direction. During rolling in the first, second, third, fourth and fifth offered mill stands the maximum displacement values from 0.0001733 to 0.0000433 *mm* arise in the body of backup rolls, and from 0.046 to 0.018 *mm* in the journal of the backup rolls (Fig. 4). It should be noted that the maximum value for the displacement amount are from 0.2927 to 0.0928 *mm* for the body of the working rolls, and from 0.0247 to 0.12 *mm* for the journal of the working rolls during rolling in the first, second, third, fourth and fifth stands of multifunctional longitudinal-wedge mill.



a)



b)

a – third stand; *b* – fourth stand

Fig. 4. The picture of displacement of the rolls elastic deformation

Note that the resulted calculated value of von Mises equivalent stress does not exceed the upper limit of permissible contact fatigue stress. This fact suggests that even a small deviation from the process will not lead to the appearance of defects on the surface of the rolls: cracking, chipping, splits.

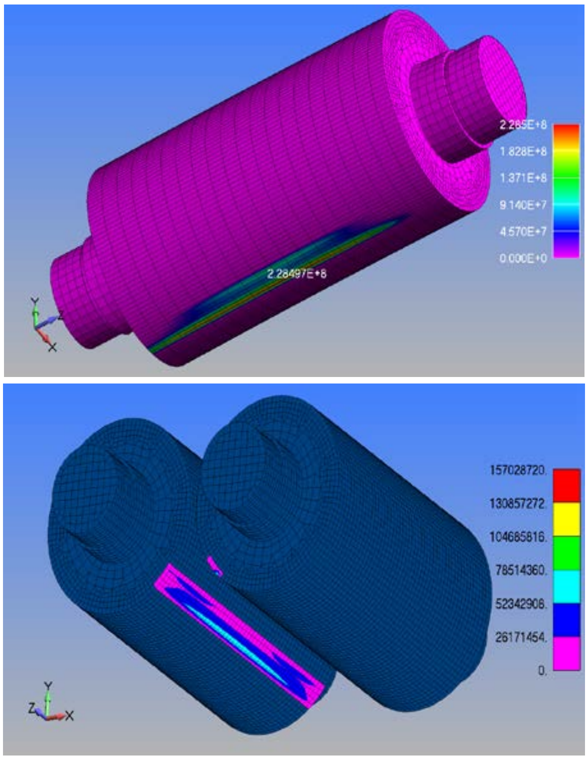
In general, the magnitude of the elastic deformation of the rolls elements is small, indicating a sufficiently high rigidity of the working stand rolls unit. This guarantees a transverse gage interference and flatness of rolled strips within the required tolerances.

During rolling thin strips in the stands of new mill, the length of the deformation zone reduces because of the decrease of capture arc length during the transition from the first stand to the last stand. Such reduction of the length of the deformation zone has the advantage of the proposed process of rolling over the conventional rolling process. Advantage of the rolling process on new mill is that considerably drop the pressure of the metal on the working and backup rolls (Fig. 5, 6). This can significantly reduce metal consumption of the rolling equipment when designing and launching of a new rolling mill constructions.

Thus, during rolling on a new multifunction longitudinally-wedge mill as a result of pressure reduction the elastic deflection goes down particularly of the last mill stands rolls, and consequently decreases the transverse gage interference and improves flatness of rolled strips (Fig. 4).

Maximum forces, arising in the direction of the Y-axis another words in the vertical direction, give rise of maximum deflections in the same rolling direction (Fig. 4).

Small forces, occurring in the direction of the rolling axis, i.e. *X*-axis, lead to a small elastic movements of the rolls material in the same direction. In this case the elastic move of the rolls material in the X-axis direction is slightly larger while rolling in the stands with two backup rolls compare with a rolling in the stands with four backup rolls.

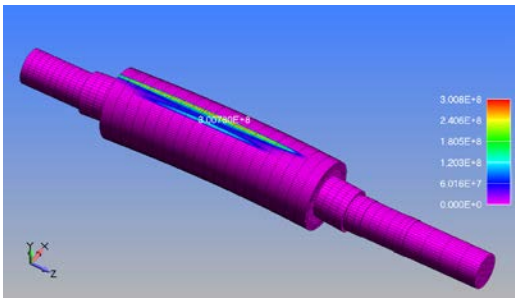


a)

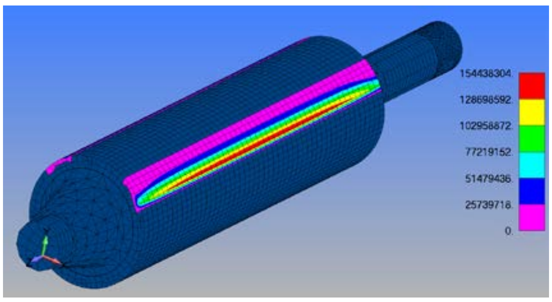
b)

a – third stand; *b* – fouth stand

Fig. 5. Picture of the distribution of the working rolls contact pressure on the backup rolls



a)



b)

a – third stand; *b* – fourth stand

Fig. 6. Picture of the contact pressure field distribution of the backup rolls on the working rolls

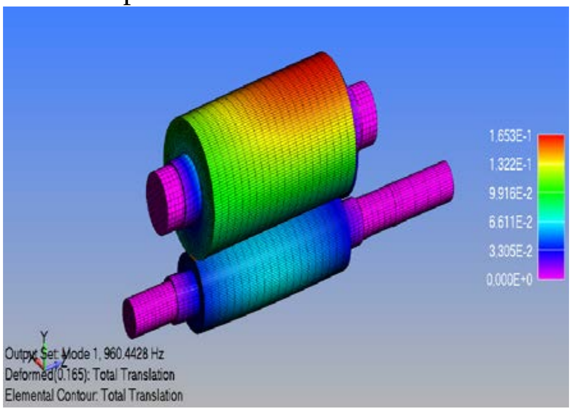
So, the greatest movement for all the working rolls mill stands are along the rolling force application, i.e., in the direction of the rolling force action (along the Y axis).

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 10, October 2016
ISSN (Online) 2348 – 7968 | Impact Factor (2015) - 4.332
www.ijiset.com

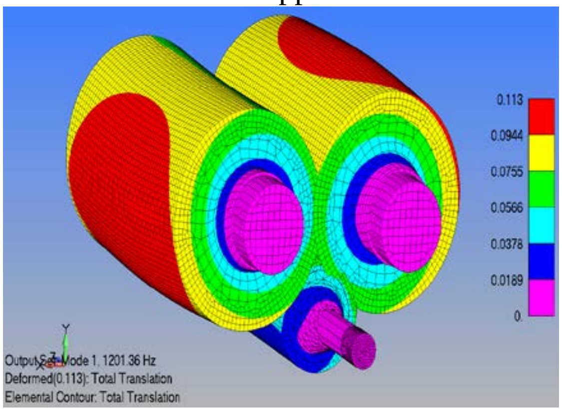
Movements along X and Z axes are virtually equal. For backup rolls substantial is deformation along the X and Y axes, while for the working rolls and bearings is along the Y and Z axes.

The analysis revealed that the major technological details is the working rolls, which are cylindrically shaped body of small length, and they are generally suffer from bearing deformation of the surface in the contact zone with metal. The value of the bearing deformation reaches 0.004 *mm* in the direction of rolling force action.

With an increase of the rolling speed of the new design mill, a relatively small increase of the dynamic loads in the main nodes of stands and the drive line are occured. Mechanical vibrations of the stands nodes and line drives are the cause of small by the value vibrations. Studies have shown that in comparison with the last two stands, the large vibration magnitude appear in the first three stands of the new mill (Fig. 7). This is due to two backup rolls in the first three stands. In the last two stands four support rolls are used.



a)

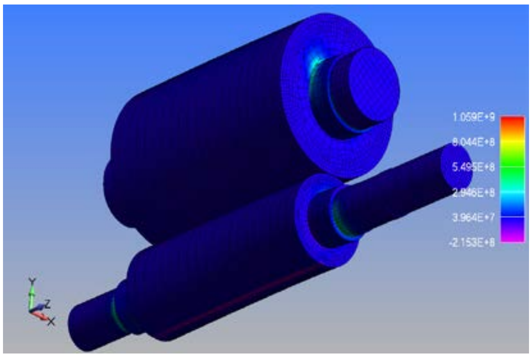


b)

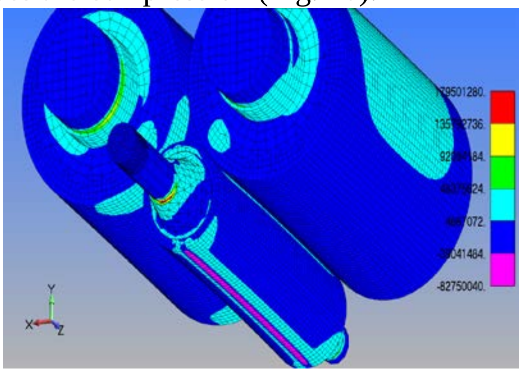
a – third stand; *b* – fourth stand

Fig. 7. Shape of the rolls fluctuations from the vibration load during the rolling strips on the multifunction longitudinal-wedge mill

Calculation of the stress tensor components showed that the value of the principal maximum stresses in the working and backup rolls do not exceed 209.1 MPa during rolling in the first, second, third, fourth and fifth stands of the proposed mill (Fig. 8). During rolling on the mill of new construction, the maximum tensile principal stresses occur in the main roll journal. Main minimum stresses in the backup and working rolls are compressed (Fig. 9). Their major level are below the maximum of stresses approximately tripled. It should be noted that the main average voltage in most cases are compression (Fig. 10).

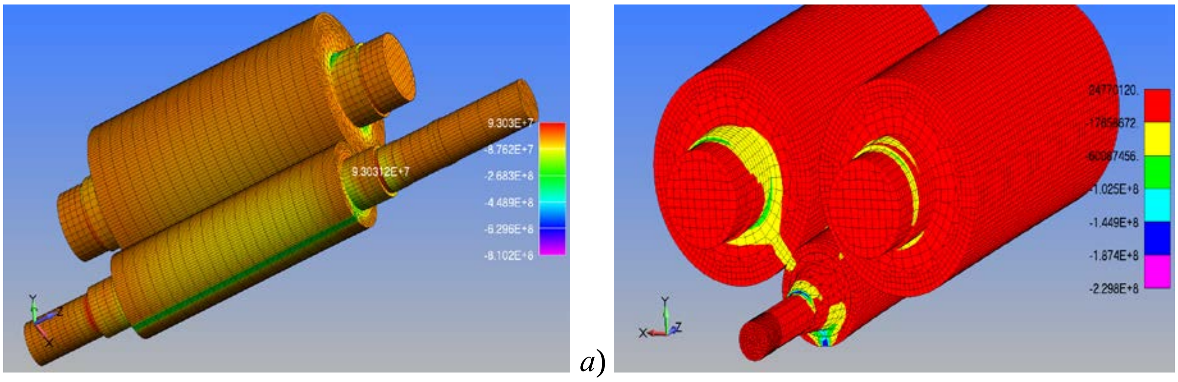


a)



b)

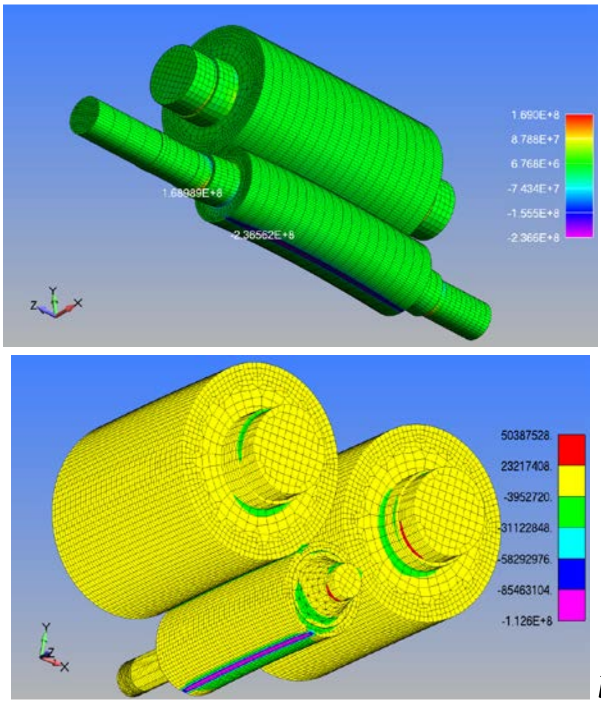
Fig. 8. The picture of the main maximum stresses distribution of the rolls system of the third (a) and fourth (b) stands of the multifunctional mill



a)
b)

Fig. 9. The picture of the main maximum stresses distribution of the rolls system of the third (*a*) and fourth (*b*) stands of the multifunctional mill

The calculation results show that the stress tensor components arising in the details of stands construction during rolling have a value within the permissible.

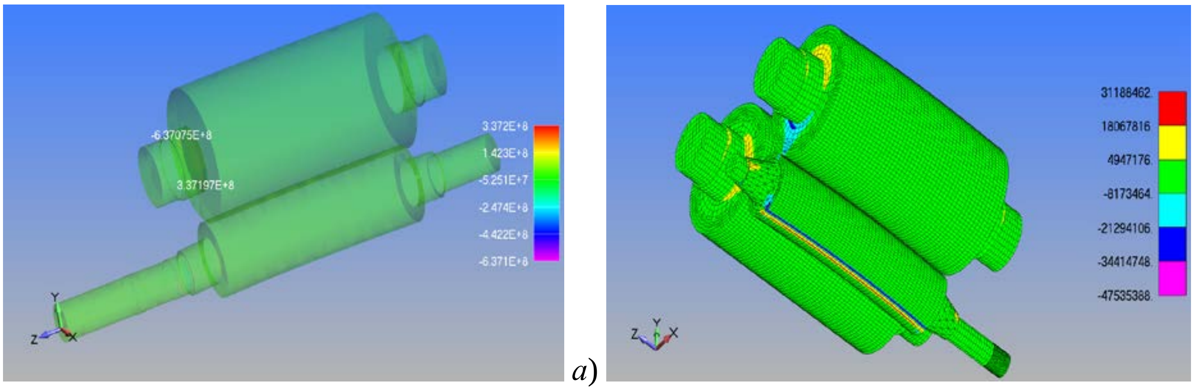


a)
b)

Fig. 10. The picture of the main maximum stresses σ_2 distribution of the rolls system of the third (*a*) and fourth (*b*) stands of the multifunctional mill

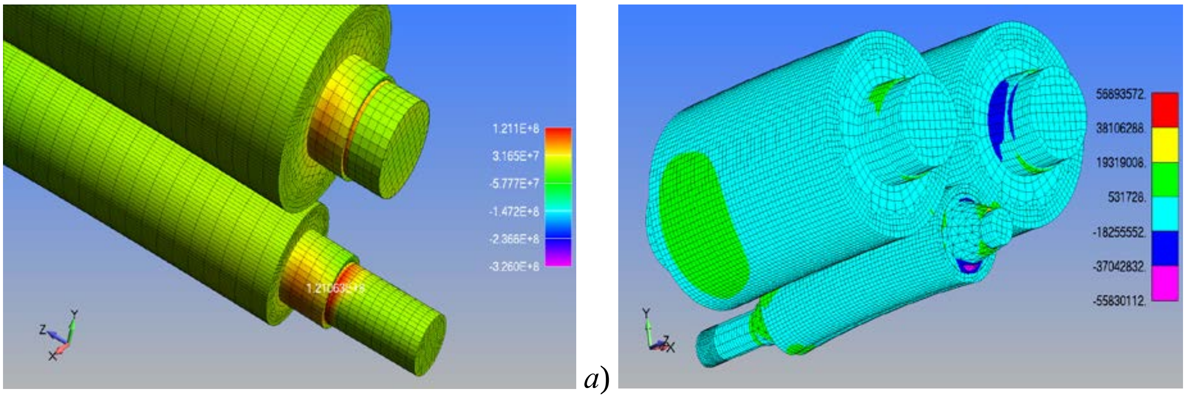
Using the results of calculations it was found that during the rolling of the strips of alloy D16 shear stresses in the XY plane varies from 337.2 MPa (roll neck) to -52.51 MPa (roll body) (Fig. 11) in the first, second, third, fourth, and fifth stand of multi-functional longitudinal wedge mill. It should be noted that the shear stresses in the YZ plane have values from 19.32 to 121.1 MPa in the roll necks, and the minimum value of the roll body (-57.77 MPa, Fig. 12) during the rolling the strips in first, second, third, the fourth and fifth stands of multi-functional longitudinal wedge mill. The resulting values of shear stresses do not exceed the maximum value of the ultimate strength allowed for this material.

It should be noted that the use of only two back-up rolls has certain influence on the elastic deformation of bearings. However, the use of four back-up rolls in the last two stands of the mill reduces both the value and area of elastic deformation of the rolling bearings. The outside rings of bearing have maximum deformation. Meanwhile, decreasing diameter and increasing number of back-up rolls lead to shifting the area of maximum elastic deformation of the bearing to inner side of the roll neck, because of change of load application schemes in the rolls assembly of multi-functional longitudinal wedge mill.



a)
b)

Fig. 11. The distribution of shear stresses in the XY plane of the roll system of third (*a*) and fourth (*b*) stands



a)
b)

Fig. 12. The distribution of shear stresses in the YZ plane of the roll system of third (*a*) and fourth (*b*) stands

During the simulation process of strength and rigidity of the stands of new multi-functional longitudinal wedge mill, the influence of temperature fluctuations in the rolled strip mill stands on the SSS has been investigated. The SSS is calculated at various rolling effort.

The results of SSS calculation at different temperatures have shown that increasing temperature of the deformable strip on 50 °C leads to reduction of elastic deformations of heavy-loaded components of stands on 5 – 9%, and increasing temperature on 100 °C – the reduction on 20%.

It should be noted that during the rolling a minor bending of working rolls occurs in the plane, which is perpendicular to the rolling axis. Such bending depends on the temperature of rolling and amount of back-up rolls. The bending of working rolls varies from 0.0067 to 0.0096 mm. The elastic deformation of bearings can range from 0.008 to 0.009 mm.

Roll carriages, which include roll necks inside, can be elastically deformed in the vertical and horizontal plane and rotated relatively the rolling axis. The elastic displacement in direction of loading action for roll carriages, located on gear side of the roll is in 1.2 times more than for the roll carriages located at the opposite side of the roll.

Thus, the strength of heavy-loaded elements of stands are relevant to technical requirements established for the mills. At the same time, the new multi-functional longitudinal-wedge rolling mill has enough high rigidity design of stands. Based on the results of the study it can be noted that rolling the strips on the proposed mill will not lead to the production of finished steel with longitudinal and transverse polythickness.

According to conducted research the measures for modernization of stands of multi-functional longitudinal wedge mill have been developed. It is found that a hydraulic pressure device must be installed in fourth and fifth mill in order to control the roll gap of the working rolls. To ensure uniform distribution of load and enlarge life of bearings, it has been offered to strengthen the rolls by free-floating roll carriages. It has been also offered to replace the double row spherical roller-bearings to one tapered roller-bearing with larger capacity in the fourth and fifth roll carriages of the stand. The proposed design solutions will reduce strain rate of the stands.

4. Conclusion

1. Based on the simulation results proved that the stressrates arising in the construction components of stands of multifunctional longitudinal wedge mill during the rolling process do not exceed the maximum allowable stress.

2. It is found that during the rolling in proposed mill, the maximum principal stresses in the heavily-loaded elements appear in the direction of rolling force.

3. It is shown that during the rolling in proposed mill, the increased values of stress-deformed state appear in contact zone of working and backup rolls.

4. It is found by calculation that the reduction of the rolls diameter in the rolling direction has significant impact on the reduction of elastic deformation of the heavy-loaded elements of stands of multifunctional longitudinal wedge mill, with the use of four backup rolls in the last two stands of the mill leads to reduction both value and square of the elastic deformation of bearing of roller junction of the mill.

5. It is proved that the strength characteristics of the new mill stands satisfy the conditions of strength of the mills. At the same time, the construction rigidity of stands of multifunctional longitudinal wedge mill complies with state standards.

6. As a result of the simulation of the SSS of heavily-loaded elements of mill stands, the rational structural dimensions of the basic units of new rolling mill are defined and the SSS distribution patterns in the elements of rolling mill of new designs are received.

7. It is proved that the amount of elastic deformation of roll elements is small, this indicates sufficiently high rigidity of roll unit of working stand. This guarantees transverse polythickness and flatness of rolled strips within the required tolerances.

8. The new multifunctional longitudinal wedge mill is proposed, designed and manufactured.

Reference

[1] V.L. Mazur, and A.V. Nogovitsin, Theory and technology of sheet rolling (Numerical analysis and technical applications), Dnepropetrovsk: PBA "Dnipro-VAL», 2010.
[2] V.N. Vydrin, “On foundations of the strip flatness theory”, in Theory and technology of rolling: collection of scientific papers, 1972, pp. 208-219.
[3] E.A. Maksimov, “Improvement of strip flatness”, National Metallurgy: Equipment. No. 1, 2005, pp. 22-27.
[4] E.A. Maksimov, “The use of rolling stands with regulating roll gap profile”, National Metallurgy: Equipment. No. 11, 2006, pp. 60–65.
[5] E.A. Maksimov, “Improving the quality and flatness of stainless steel strips during self-regulation process of asymmetric rolling”, Technology of metalls. No. 9, 2010, pp. 19–24.
[6] V.E. Lunev, I.G. Shubin, M.I. Rumyantsev et al. “The management of tapes roughness using asymmetric rolling”, Rolling production, No. 6, 2003, pp. 28-29.

[7] E.A. Maksimov, “Flatness of sheet metal. Correlation of deformational and new kinematic criteria of flatness during the rolling strips”, National Metallurgy: Equipment. No. 9, 2006, pp. 45–51.
[8] O.E. Braunstein, “The analisys of reasons of polythickness sheets and the remedies for it”, in Bulletin of the mining and metallurgical section of RANS. Department of Metallurgy: Collection of scientific papers, 2001, Vol. 10, pp. 94-99.
[9] L.M. Ageyev, “Controlling impacts on the shape of strip during the rolling”, in Collection of papers of IV Congress of millers, 2001. Vol. 1, pp. 192-197.
[10] S.A. Mashekov, E.Z. Nugman, A.S. Mashekova et al. Continuous mill for rolling strips of steels and alloys (Patent No. 20969), Astana: Ministry of Justice of Kazakhstan, 2009.
[11] D. Kopanev, Solving the problems of nonlinear statics in MSC.Patran-Nastran: User guide, Moscow: MSC.Software Corporation, 1999.
[12] D. Kopanev Solving the problems of dynamics by MSC.Patran-Nastran: User guide, Moscow: MSC.Software Corporation, 2010.
[13] E.K. Rybnikov, S.V. Volodin, R.Y. Sobolev Engineering calculations of mechanical constructions in MSC.Patran-Nastran system. Part I. Textbook, Moscow: MSC.Software Corporation, 2003.
[14] E.K. Rybnikov, S.V. Volodin, R.Y. Sobolev Engineering calculations of mechanical constructions in MSC.Patran-Nastran system. Part II. Textbook, Moscow: MSC.Software Corporation, 2003.