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Technical condition assessment and prediction of the survivability of the mill rolls

Belodedenko S. V., Yatsuba A.V., Klimenko Y.M.

National Metallurgical Academy of Ukraine, Dnepropetrovsk

Abstract

Ways for reduction of roll consumption connected with application to them service principles according to technical condition are considered. As far as the rolls are subjected to the complex of degradation processes, which cause numerous damages, for quantitative estimation of technical condition there developed a model on the base of risk-analysis. There considered the case of loss of rolls working capacity, which is connected with gradual increase of disk crack during cycling of fracture mechanisms. Then the number of rolls revolutions until fracture may be considered as the sum of persistency times. There developed a sequence of changing of normal and shear stress at rolls hazard zone per one its revolution. It has been established that the rate of development of circular defect in transverse plane of forming roll is mainly determined not by the level of load, but by the fracture mechanism. In the developed diagnostic algorithm roll run (total number of revolutions) is rather direct diagnostic parameter for estimation of its technical condition.

Key words: FORMING ROLL, LONGEVITY, FRACTURE, FATIGUE

Technical condition of rolls significantly conditions the economy of rolling process. Its decrease is connected either with rising roll consumption or with increase of their cost, which is eventually directed to cost containment. Besides, low cost (longevity) of rolls leads to increase of fault time and slowdown, which also affects economy negatively.

The problem of combination of cost and longevity of rolls may be solved by finding the minimum of flow intensity function on their maintain and repair, which corresponds to optimal life cycle. It is unusual for the staff to organize information collection (at least during regular preventive repair). There set consumption indices for rolls as they do not tend towards complication of the task. This process is fulfilled by mathematically statistical approaches on the base of annual quantity of outgone rolls. Such approach, from the one side does not give full information about real roll resource as it is practically taken out of service on the base of standard, though its wear may be controlled. From the other side, for grounded decisions concerning maintenance, it is required commanding statistical sampling, which is possible to be obtained only for rather cheap rolls and discardable ones under rather uncritical rejects. In other situations it is reasonable to apply probabilistic-physical input methods, which are similar to the methods used for grounding of rolls strength.

Mass of separate rolls is several dozens of tons and their cost - hundreds of thousands (sometimes more than million) euro. Due to roll inventory, damage by emergency outage is comparable with additional expenditure conditioned by premature (until exhaust of operation life) roll reclaiming. During increase of rolls cost and saving expenditures for their renewal, the part of the last decreases. This increases effective roll life, which falls on minimum expenditures connected with its maintenance. Management of most metallurgical enterprises sets as one of the most relevant objectives the reduction of roll consumption, which may be archived by various ways. One of it lies in application to the rolls the principals of maintenance according to technical condition, which is characterized by wide usage of technical diagnosis ways. This direction is relevant to large forming rolls and allows to reduce their consumption by means of estimation of their remaining life and reliability [1,2].

To have such opportunity during exploitation, one should prepare corresponding information base concerning roll property and its basic life on the stages of designing and manufacturing. This requires more detailed development of models of degradation processes, rather than it is made during calculation of strength reserves. In methodological aspect of reliability the roll possesses the characteristics of complex engineering system, as a range of damage processes affect it. Herewith not each of them lead to the loss of working capacity, but each of them lead to failed state of the roll, whereby the quality of rolled stock decreases. Working capacity of the roll is connected with volumetric developments: its complete fracture or flaking of large metal mass due to interior fatigue. Their danger is compounded by the absence of visible diagnostic features. Surface phenomena (wear-related, thermal) are successfully, though troublesome, diagnosed while operating. Using the notion of technical diagnostics, one may consider that good condition of the roll is supported by condition-based maintenance. But in general the rolls are being operated till normative recourse (achievement of minimal diameter due to wear and regrinding for geometry recovery). In such a way the strategy of maintenance and repair of rolls does not correspond to the strategy of their usage. This is explained by the complexity of diagnosis of working conditions and obviousness of diagnosis of operation conditions.

Not only high roll consumption negatively affects economics of production but also their unscheduled breakdown while operation. Failure analysis, fulfilled on the four continuous sheet mills, showed that approximately one third of failures, occurred in rolling mills and main lines, are conditioned by rolls destruction (table 1). Sometimes in bar-rolling mills the roll is weak link of the main line, which determines its “limit of accident-free work” [3].

The aim of the work is building of diagnostic algorithm for estimation of technical condition of forming rolls and forecasting of their remaining life. Its usage supposes increase of the degree of roll remaining life, both due to control of actual damage in separate stand and by optimization of rearrangement route of rolls along all the stands of continuous mill.

Table 1*. Emergency outage of continuous sheet mills connected with the rolls.

Mill	Observation time, month.	Blocks				
		Main lines and и working stands with rolls		Rolls as a set	Working rolls	Supporting rolls
		Total amount of maintenances	Among them failures			
2000	24	69 / 100%	10 / 14%	-	2 / 20%	1 / 10%
1680	54	367 / 100%	74 / 20%	-	25 / 34%	1 / 1%;
1700	12	-	51′	16 / 31%	2 / 4%	1 / 2%
2500	120	-	51″	8 / 16%	3 / 6%	1 / 2%

* data for analysis is provided by V.V. Verenev, D.Eng.Sc.,
′ - including the facts of band hanging in the rolls,
″ - entered failures due to workpiece damage only,
There given algebraic number of emergency outages in the denominator

Risk-analysis method for quantitative estimation of technical condition of the rolls

Generally, monoblock rolls are subjected to cyclic deformations of bending, torsion, transverse shift and bumping (compression of hollow working roll of multiroll stand), which lead to gradual fatigue damage accumulation in the roll heart. Among damages of working surface, as a rule, there dominate mechanical wear and also wear as a result of scale formation. Interaction of rolls against each other and with stock leads to surface fatigue, which is evident as surface chipping and case spalling. During braking of lubricant regime on the rolls surface there may occur films, which reduce rolled product quality in finishing mills and also are the fracture origin. As a consequence of departures from regulatory lubricant-cooling regime there appear thermo-fatigue cracks on the surface. Specified processes lead to the failures of gradual type. Failures of sudden type due to mechanical and thermal overloads (thermal stress) are usually explained by the violation of rules of technical specifications.

According to damage rate there are several zones of the roll. Except working part (body of sheet roll, roll passes), dangerous zones of monoblock roll are radiusing between body and roll neck, neck under bearings and also shank end for drive rolls. If one does not concretize the type of stand and working mill, one may consider that the roll is subjected to impact of more than ten types of damaging processes, which are concentrated along four dangerous zones. Consequently, the loss of working capacity and order of the roll is conditioned by polydegradation process leading to multifocal damage. For such objects it is efficient to apply multivariate model of failures. However in practice technical condition of the rolls is estimated under the principle of weak link as for simple engineering system. Such approach is rightful if the best part of failures is associated with the action of one damaging process in certain place. But for estimation of working capacity of rolls, considering their regular reconditioning (regrinding), receding damages from surface phenomena, the principal of weak link is of little promise, as “leader” among competitive degradation processes and zones is not obvious.

In this situation for estimation of technical condition one may apply the indexes of reliability, in particular, the probability of nonfailure operation (PNO) P for the system. It is determined according to the product rule of quotients P_{ij}: $P=\Pi P_{ij}$, where i – number of damaging process, j – number of dangerous zone. There is a disadvantage of this rule, which lies in experimentally unconfirmed steep decline of P while increasing the amount of system elements i and j. Various modifications of this rule do not improve it. Impossibility of correct determination of general PNO of the system according to quotients PNO of its system induces to estimate reliability of the object in common not dividing it into elements [4]. This returns the researcher to the level of mathematical and statistical approaches.

Evaluation of resource indexes of all technical system according to quotient indexes of its elements constituents is possible on the base of application of probabilistic physical models together with the concept of admissible risk. Than common risk of exploitation is determined by summing of particular risks: $\rho_{\Sigma}=\sum\rho_{ij}$.. General risk in its turn ρ_{ij} from *i-th* process for *j-th* place is evaluated through the damage d_{ij}. If the forecast of the guaranteed number of revolutions until failure n_{0P} (which considers randomness of loading process and statistical nature of structural resistance) is known and one will take corresponding failure as a unit, than the current value d_{ij} will characterize the degree of remaining life $r_{ij}=d_{ij}$. This confers a right on usage of linear addition of damages and as a diagnostic parameter it is appropriate to take roll lifelength n_{Σ} in the amount of its revolutions. Change of status and loading conditions as compared with foreseen ones is reflected in step-by-step correcting of the value n_{0P} [5-7]. Not resorting to direct estimation of damage caused by roll failure, current risk is calculated as $\rho_{ij}=U_{ij}\cdot d_{ij}$, where U_{ij}<1- value of failure. If for all types of damaging processes we accept $U_{ij}=1$, than the rule of risk summation will convert into the rule of damage summation, which lead to unduly pessimistic evaluation of technical condition and remaining life.

It is appeared to be inconvenient to evaluate technical condition controlling the risk ρ_{Σ}, as this index is low-sensitive to lifelength (as well as PNO). There is no such disadvantage in the security index β, which represents logarithms of guaranteed longevity reservoir and which is connected with current damage: $\beta_{ij}=lg(1/d_{ij})$ [7]. General index of roll safety according to the summation rule may be determined as:

$$\beta_{\Sigma}=\lg(\Sigma U_{ij}\cdot 10^{-\beta_{ij}})^{-1}.$$

Its current value reacts on the lifelength, the limit is equal to zero, remaining life may be rather easily determined according to current safety index: $n_r=10^{\beta_{\Sigma}}$. In such a way, development of resource models is the base for algorithm of diagnosis of roll working condition.

Resource models and rolls fracture mechanisms

Resource models built on the researches of roll wear resistance are the most widespread ones. Posteriori models of roll life, which are available for forecasting of roll resource of the mill only as the object of research, are obtained by mathematical and statistical approaches [8]. There is a necessity in posteriori models of working capacity, based on the probabilistic-natural approaches of reliability. Diagnostic algorithm, which is based on the probabilistic kinetic model of growth of roll radial wear, satisfies these requirements in many ways. With its help the questions of planning of sheet rolls stock, increase of their interrepair time and maximum possible recourse for required PNO are solved [9].

Methods of analytical and numerical estimation of metal strain-stress state in the roll body are worked out sufficiently detailed. Their results are used both to provide structural strength [11, 10] and to determine cyclic longevity [3, 12]. Herein there used main principals of calculations of machine components for high-cycle fatigue. If during calculation of strain-stress state along with mechanical loads, there considered the influence of thermal fields and residual stresses [10,14], than one should go over the deformational criteria of low-cycle fatigue [15, 14]. Such calculations give an opportunity to forecast longevity until crack appearance.

At the same time, resource of many rolls both before failed state and before their loss of working capacity is mainly determined by the period of microcrack development. It may appear as crack-like defect in a ready roll during its production. CM technique of the roll cannot find out all the possible defects. It is important these cracks did not develop during exploitation. That is why models of damaging mechanics for rolls became current. They connect limiting size of defect with its location and rolling force. Such models found their application from 1970s for designed sheet mill 5000 [16]. Force criteria of brittle failure are widely used at the present time to ground working capacity of rolls [22, 21]. In the specified models behavior of rolls is controlled by stress-intensity factor (SIF) for *I* mode of destruction in the view of normal fracture.

Studying physics of rolls failure , specialists concluded that significant role in the problem of durability play the processes of interaction of working rolls with metal and supporting rolls. Herein in the contact zone, along with stick region, there is sliding region, where there occur fretting processes, where beginning and development of failure goes according to *II* mode (transverse shift) [23]. It is stated that threshold value of SIF for steels $\Delta K_{thII} = 3 \ldots 6\ MPa \cdot m^{0.5}$, that is 1.5…3 times less than threshold value of SIF for *I* mode of failure (normal fracture) [23, 24]. During contact of rolls between each other in their subsurface layers there appear alternate (reverse) shear stresses, which make hundreds of MPa. As these stresses within contact area of the surface change cyclically, than for fracture initiation it is enough to have two decimal places of nonuniformity in millimeters or several structural units of material [23]. For such large machine parts as mill rolls, this means that the fracture begins from the beginning of exploitation.

Reverse stresses answer for appearance of internal checks, which lead to flaking of rolls metal (spalling), widespread type of failures of finishing mill rolls [17]. Presence of tangent friction force in contact areas lead to that shear stresses crop out of the depth. Especially bright it appears during rolling process abnormality in the form of band folding (cobble) [18]. As a result there appear backswept cracks, which go away from the surface at the tilt deep down the roll core [25]. Cracks of the *II* mode, which arise as a result of contact fatigue, cannot lead to roll failure, as while they are growing SIF reduces. This may be also referred to thermal fatigue cracks [22].

At some metallurgical enterprises the presence of surface cracks is not a rejection sign. For further development of such cracks there required additional conditions with new fracture mechanisms. For example, spalling of rolls (pitting) is connected with development of backswept crack under *I* mode because of its hydro- wedging from the side of lubricating and cooling fluid, which one uses for rolls reflux [25]. In particular conditions of deforming of real piece there may occur different cases of cycling of fracture mechanisms, due to which there form subsequent stage of resource [23]. This work is devoted to revelation of mechanism of final fracture of the roll after development in it the defects from surface phenomena.

In such a way early crack formation makes it reasonable to built diagnosis model of rolls on the base of fracture mechanics technology. There are sources causing appearance of macrocracks in the rolls.

1. *Nonmetallic inclusions* with the size from 10 to 60 microns in surface layer may develop due to shear stresses from changing contact interaction. Researches fulfilled by means of microcomputer tomography showed that in roller-bearing steel during contact fatigue in conditions of rolling the crack because of source defect starts growing not later than 10000cycles of loading, though fracture life in such regime is more than 1000000 cycles [26]. During roll pitting the change of fracture mechanism occurs in the following sequence: *II→I→I+II* [28, 27]. During spalling of rolls fracture mechanism alters in the following sequence: *II→I→I+II→II→I* [17, 25]. Initial phase of rolls damage in both cases is similar. However, further crack path depends on the correlation of acting SIF according fist K_I and second K_{II} modes. It may go from the depth on the surface, than there appear small dimple; or at high contact pressures it may grow in the depth parallel to roll generant, until it gets the conditions for entering the surface, than the large mass of roll flushes [28].

2. *Excessive local deformations* in the coating surface due to ratcheting (accumulation of residual strain) under the action of thermal or frictional strain lead to microdiscontinuity of surface [27, 29]. Experiments in thermal fatigue resistance imitating thermal regime in the rolls of hot rolling from high-chromium iron showed that thermal cracks appear after 500 cycles of thermal cycling (roll rotations) [30]. Similar results are given in the researches [31], where calculation for low-cycle fatigue proves that high-temperature cracks with the depth of 0.5 mm in the rolls of continuous hot strip mill form after 100-200 cycles.

3. In free from contact zones of roll (neck) there may appear surface defects of *corrosive and hydroabrasive nature* due to action of freezing liquid. Sulfides coming on the roll surface significantly reduce its resistance to fatigue [32].

In such a way, roll resource may be determined as the sum of crack development stages (its durability) under the action of changing each other damaging mechanisms (clean or mixed).

Peculiarities of stress state of the roll

II mode of damaging is not restricted only by contact areas. Its presence is conditioned not only by the fact that the roll represents a short beam working in conditions of transverse bend. From transverse forces there appear shear stresses, which in technical practice may be defined under shear stress $\tau_{sh}= P/2A$, where P – rolling force, A - area of cross section. For the roll loaded under classical scheme (fig.1), correlation between shear stresses from the rolling moment τ_{tr} and normal bending stress σ looks as follows: $\tau_{sh}/\sigma = 1/8\gamma_{lb}$, $\tau_{sh}/\tau_{tr} = 1/8\gamma_{lh}$, where $\gamma_{lb}=L/D$,$\gamma_{lh}=h/D$- coefficients of side wall under bending and torsion. For common rolls the value $\gamma_{lh}>1$ and τ_{sh} value can be neglected. Both for friction gearing and for forming rolls, the values of considered stresses become equitable.

As during calculation of forming rolls under strength factor there considered strain τ_{tr}, there is no foundation not to consider τ_{sh} strain. Especially since torsional tension changes occasionally depending on the metal fall from the rolls and the frequency of strain changes τ_{sh} relatively the defect both inside and outside of the core corresponds to the frequency of rolls rotation (fig.2,a). This is related not only to the roll body, where surface degradation processes are active.

In the roll necks normal stresses as a rule are insignificant and with the help of conventionally used model of roll strength in the form of resistance to combined bending and torsion it is complicated to explain damage in this areas. But just the condition of necks determines service life of the roll till its rejection as they are difficult to repair because of crack-like defects. All these speaks for urgent character of researches devoted to contribution of II mode of damage into resource of rolls.

Besides, striving of technologists to improve surface evenness of rolled stock by means of mill hardening, induces to use in roll support multi-bank bearings, the gaps of which are chosen under relatively small rolling force and further deformation of the roll occurs under the principal of fixed-ended beam. Though the roll is usually presented as gimbal-mounted beam in technical practice. As a result under the bearing the roll is subjected to extra fatigue process from loading by bending with rotation, amplitude of which is equal to bending moment in the roll body. As the diameter of necks is smaller than the one of the bodies, the strain and damage is higher here.

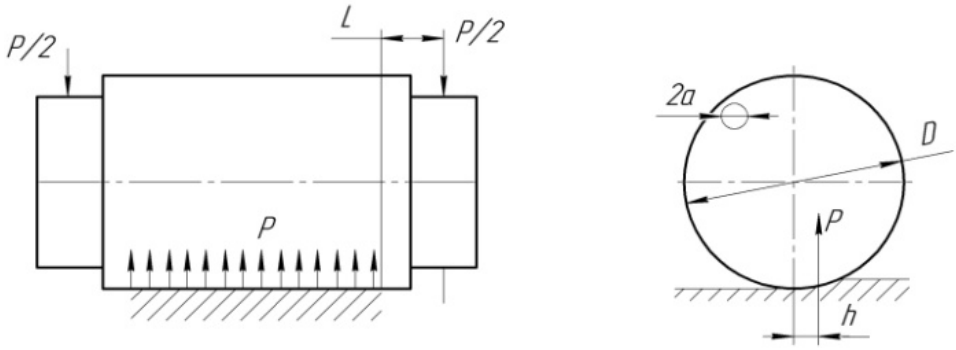

Figure 1. Loading scheme of sheet roll and location of spherical defect in surface layer.

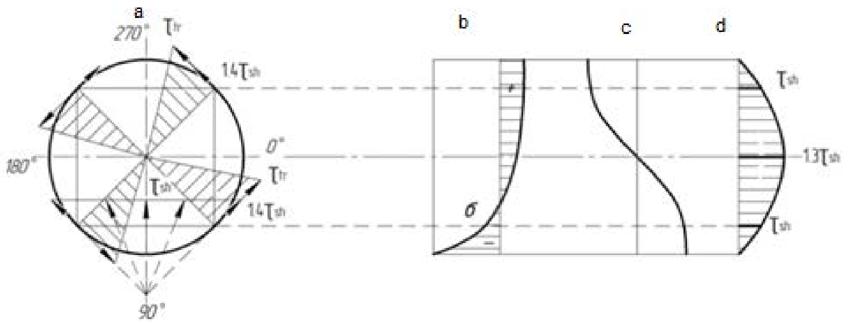

Figure 2. Distribution of tangent lines (a, d) and normal (b) strains, crooking of cross sections (c) in cross-section (a) and longitudinal section (b, c, d) of the roll under lateral bending.

Velocity determination of flaw growth and persistency time

Roll metal is in conditions of complex stress state, for which there usually determined equivalent criterion of limiting condition. For large cross sections such models are not always reliable. Today local-straining approach is more effective. It suggests that elementary unit of metal (defect) is sequentially subjected to various types of deformation, in result of which there forms combined (mixed) loading history. In this aspect there developed change history of loadings per roll revolution in the areas, where contact and residual stresses do not affect significantly (fig.3).

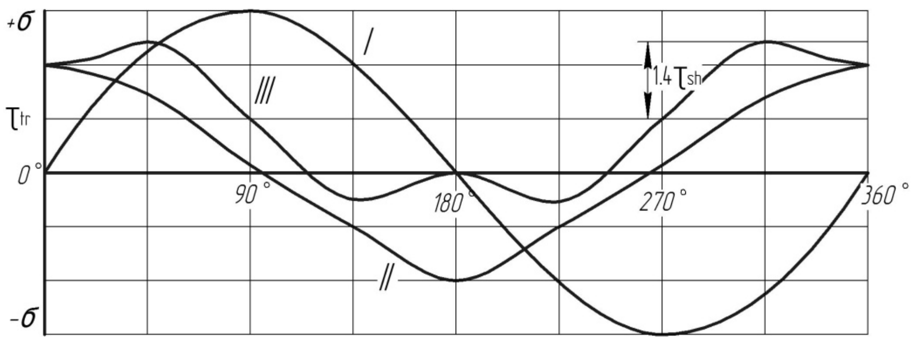

Figure 3. Change of stresses during mixed loading of the roll for *I, II, III* modes of damage.

For working rolls of four-high mill stand stresses of bending and section are determined according to forces of the system of anti-bending, and for supporting rolls of torsion stress they are determined by idling torque.

Upon integration of central block of the diagram of fatigue failure, one may obtain the dependence between crack growing period N and acting nominal stresses σ or τ. As the parameter here acts the diapason between initial and final size of the crack. By analogy with fatigue carve, such σ (τ) - N diagram one may define as endurance curve. Having obtained endurance curves for each destruction mode, one may calculate total longevity for combined nonsteady process summing relative longevities [23].

In analytic form specified integration may be fulfilled if calibration correction for SIF does not depend on the crack depth. In this case it is a circular crack, which in the context of rolls is accepted for the model of tolerance limit defect [16,19,21]. For roller materials there developed schematize diagram of fatigue failure for different modes. One may determine other parameters of diagrams, having taken threshold value for SIF for the second mode $\Delta K_{IIth}=4MPa\cdot m^{0.5}$, using obtained model. Found under set algorithm endurance curves are subjected to exponential equation $\tau^m\cdot N=const$ with inclination index $m=2$. Then for strain block with stage parameters τ_{shi} and C_i (relative duration) under the formula $\tau_{she}=\sqrt{\Sigma C_i\cdot\tau_{shi}^2}$ one may determine its equivalent value and after that one may find equivalent velocities of crack growth (table 2).

Equation of exponent of equation of endurance curve $m=2$ follows from the excepted models of crack strength. This conditions rather sharp inclination of endurance curves, which speaks for relatively weak influence of stresses during crack growth.

Developed diagnostic algorithm includes calculation of early radius of defect a_{0I}, a_{0II}, a_{0III} for each mode. Critical values of radius a_c in this case are set not under the criteria of fracture mechanics, but under the diagnostic capability – 100-fold increase of initial defect is usually found out and the roll is being rejected.

Table 2. Determination of rates of circular defect development for the area of roll, where γ_{lb}=0.25, at ,$\gamma_{lh}=0.0025$ and a_{cII}/a_{0II}=100.

τ_{she}, MPa	a_{oII}, mm	a_{oIII}, mm	$N_{II}\cdot10^{-7}$, rev.	$N_{\Sigma2}\cdot10^{-7}$, rev.	$v_{II}\cdot10^{10}$, m/rev.	$v_{\Sigma2}\cdot10^{8}$, m/rev.
5	40	148	38.5	30.4	2.8	1.0
10	10	37.0	9.6	7.6	2.8	1.27
15	4.5	16.7	4.1	1.9	2.98	2.2
20	2.5	9.2	2.4	1.9	2.8	1.27
25	1.6	6.0	1.5	1.2	2.85	1.28
30	1.1	4.1	1.1	0.9	2.8	1.25
35	0.8	3.0	0.8	0.6	2.8	1.2

Also according to the endurance carves one may determine the number of cycles N_{II} for the 1st period of destruction, when the defect increases only due to the II mode and number of cycles $N_{\Sigma2}$ for the 2nd period, when it is affected by the compound loading under II and III modes. At these stages there are different growth rates v_{II} and $v_{\Sigma2}$, but their values, basing on the results, don not depend on the level of shear stress. At the 1st period one may accept $v_{II}=2{,}8\cdot10^{-10}$ m/cycle, at the 2nd period - $v_{\Sigma2}=1{,}25\cdot10^{-8}$ m/cycle. This conclusion is of great practical importance. In working stand of continuous sheet mill (CSM) the rolls of breakdown mill usually rotate with low frequency, but they take greater rolling force, than rolls of finishing mills, which rotate with high frequency. There arises a question in what mills the rolls damage more actively. In the considered situation roll lifelength (general amount of revolutions) is rather right diagnostic parameter for evaluation of its technical condition.

Rate speed of the rolls of CSM is within the range from 20 to 500 min^{-1}. For the value $\tau_{she}=20MPa$, which is formed in the necks of supporting roll of CSM 2000 breakdown mill at the rolling force 30MN (rolling of “hard” stock) [19] according to the data obtained (table 2), remaining service life is from 1433 to 35833 hours. At $\tau_{she}=10MPa$ (rolling force 16MN – common stock), durability of supporting roll is within the range from 5740 to 143500 hours. Correlation of minimal durability to maximum is 1:100. Whereby contribution of load variance into this dispersal is insignificant - 1:4. Main part of dispersal is conditioned by variance of rate speed. This proves actuality of set task concerning the necessity of estimation of roll inventory damage and rational route of their motion along the mills.

Conclusions

1. Technical condition of forming rolls influences the economics of production, both due to influence on the quality (defects) of rolled stock and through costs for their maintenance, where diagnostic quantitative models play significant role. Also additory costs are

associated with unplanned stops brcause of emergency failures. Approximately one third of failures is conditioned by roll assemblies in main lines of working mills of continuous hot strip mills.

To improve the situation with rolls consumption is possible by application of maintenance principles according to technical condition, where diagnostic quantitative models play significant role. As the rolls are subjected to the complex of degradation processes, which lead to numerous damages, risk summation rule is effective to be applied for quantitative estimation of their technical condition. Calculation of general index of safety according to particular index of safety for degradation processes in break zones of rolls is based on this rule. These values of technical condition are obtained on the base of recourse probabilistic physical models considering the physics of failure, which does not require the presence of meaningful statistical sampling, which is being formed by the facts of roll service fracture.

2. In the forming rolls crack from the technological defects or service damages start growing almost from the beginning of exploitation. Having set the sequence of changing of fracture mechanisms for corresponding type of failure, the number of roll rotation may be considered as the sum of endurance periods. The case of loss of function of rolls, which is connected with gradual growth of disk crack during cycling of damage mechanisms under the formula $II \rightarrow II+III \rightarrow II+III+I$, is considered. The history of change of residual and normal stresses in the roll body from force parameters of rolling is developed for it.

3. There developed algorithm in this article for determination of resource for end longevity periods, when the crack goes out of the zone of influence of residual and/or thermal stresses and cannot be increased under their action. For the first time the attention is turned to the periodicity of change of cross section stress because of the rolling force towards transverse circular crack, which lead to formation of damage mechanism of II mode. In these conditions the rate of defect growth almost does not depend on its location inside the roll. In contrast to traditionally considered damage mechanisms according to I and II modes, this mechanism may be the reason for defect development, which is not at the surface but near the roll axis.

4. The rate of circular crack development in the transverse plane of forming roll is determined mainly not by the level of loading but by the damage mechanism. Rolling forces, on the same basis as crack resistance characteristics of roll metal, condition endurance period, at which corresponding mechanism (-s) of destruction act. Thereby they affect the longevity of roll.

5. In close continuous mills the roll rotate with different frequency, which increases from breakdown mill to finishing mill. Rolls in the mills, having similar nominal dimensions, are tuned for sensing of rolling force of the same kind. But as far as the influence of this factor on the rate of crack growth is small, endurance period, expressed through exploitation time of rolls, will be smaller in breakdown mill than in finishing mill. At the same place the rolls acquire surface cracks because of extreme operating conditions. That is why it is very important to smooth them out during reduction. Roll damages, obtained in breakdown mills and nor smoothed out during regrinding, will develop faster, if they are not set into finishing mills. Such route of removing is not effective.

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