11th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2007, Hammamet, Tunisia, 05-09 September 2007.

PROBABILITY ANALYSYS FOR ROLLING ROLLS CALCULATION AS PER PROBABILISTIC METHOD

Doc.dr. Mustafa Imamović
Mechanical Faculty Zenica
Bosnia and Herzegovina

ABSTRACT

Two calculation methods are mainly implemented during the construction as well as modeling of the rolling rolls. These are: deterministic (classical) and probabilistic – calculation based on reliability. When using deterministic method, starting point considers that the workloads as well as material specifications are invariable values. However, in reality, rolling rolls are burdened with variable workloads. Material quality is variable value as well. This includes the fact that the solidity of materials which are inputted into calculation is also variable value and that these materials have their own points of dissipation.

This paper is giving an option of probabilistic method application for calculations with rolling rolls based on their reliability. Proper workloads were analyzed as well as the practical application of the same as well as material solidness variability; this was the base for the calculation method introduction. Therefore, by applying the probability method, we are able to achieve more accurate results because we are incorporating stochastic variability of the calculation elements.
Keywords: *probabilistic calculation, rolling rolls, bending resistance, bending,*

1. INTRODUCTION

Initial dimensions for construction and modeling of rolling rolls are variable by nature, which means that these dimensions are not determined by unique value, on contrary, the entire spectrum of values applies. Therefore, if one desires to have a realistic overview of the calculation as well as an understanding that the calculation is applied to determine realistic and exact results, introduction of applicable values which are going to be used in the calculation by a means of probabilistic method (application of practical apparition probability of these values) is required.

Probabilistic method application during the construction of rolling rolls understands the determination of the workload spectrums (bending and twisting) as well as the operational solidness distribution (durability) of the rolls' material for given workload distribution spectrums. Dissipation of geometrical dimensions results must also be taken into consideration because these also have the distribution spectrum and therefore affect the calculation – results. Each calculation, as well as the probabilistic one, is preceded with detailed overview of rolling parameters, determination of the values with the greatest impact on the calculation as well as incorporation of the apparition probability of certain conditions during the working life. Therefore, application of probabilistic method requires detailed analysis followed by statistical processing of the results as well as determination of the applicable values for the elements of the rolling rolls calculation.

Application of this method of calculation results in more reliable rolling rolls; which implies implementation of controlled reliability during the exploitation.

2. ROLLING ROLLS

Rolls are basic elements of rolling stand used for plastic metal deformation; rolling process. Roll part used for rolling is called roll body and parts of roll leaned onto bearings are called bearing branches, figure 1. Different types of rolling stands use rolls which differ by size, shape and material. Rolling rolls body shape can also vary. Roll body can be smooth – smooth rolls, stepwise or calibrated.

Calibrated rolls are grooved with specific type of canal. When two such rolls are paired they form openings called calibers, which are used to shape rolling material. Calibrated rolls are used for simple and profiled rolling shapes, figure 2. Smooth rolls are used for rolling of flat profiles, sheets and strips. Main dimensions of the rolls are: diameter and length of roll body and bearing branch diameter and length. These dimensions are d[illegible] according to the calculations for applicable workload. [1].

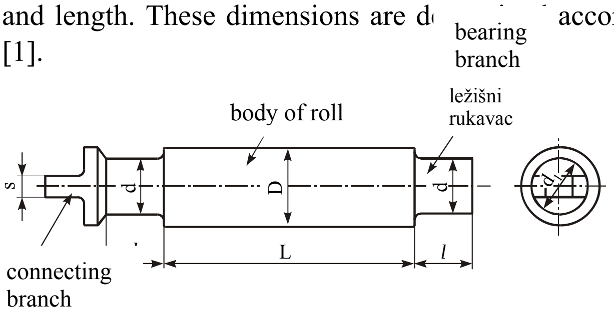

Figure 1. Rolling roll

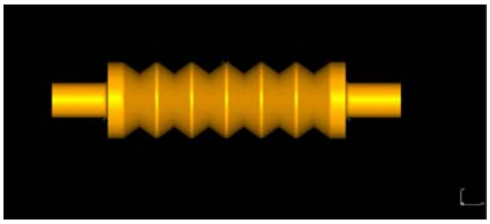

Figure 2. Calibrated rolling roll

Roll diameter D is not a constant since rolls are getting worn out during the operation (if rolls are calibrated then calibers are subjected to wearing) and once wearing reaches certain level the rolls must be cleaned – layer of working surface must be removed until clean working surface is achieved or until calibers are consistent with designed geometry. Thickness of removal layer is 1 – 5 mm for smaller and 5–10 mm for bigger rolls.
Rolling rolls take between 5 do 15% of total rolling production costs[2]. Therefore rolls do not require any special attention in a sense of dimensioning and material choice. These elements are directly impacted by level and form of workload. Determination of these elements for probabilistic method purposes is given in this paper.

3. PROBABILISTIC METHOD FOR ROLLING ROLLS' CALCULATIONS

3.1. Introduction of probabilistic calculation concept (method)

Probabilistic method for rolling rolls' calculations is developed according to theoretical knowledge and certain rules as well as experimental researches carried out within industrial fabrication conditions[3]. This method is being recognized more and more within the construction stage because it is certainly going to provide better results then methods broadly applied today. This concept gives an additional advantage because it can be used for additional calculations for any basic part of the rolling stand. This concept can be presented as a method given through several different steps supplementing one another.
First step for this concept is to determine basic characteristics of the rolling rolls (construction, material) which mean that the input information of the roll is inputted as well as other parameters determining the construction. This step can be differently defined for different rolling method. Next step is determination of the workload for the rolls. Workload can also vary in both shape as well as intensity depending of the purpose as well as working conditions for rolling operation. Workloads can be determined by analytical or experimental method. Analytical method of workload definition includes calculation of workload forces and rolling momentum as well as heat load per method. (Ekelund, Hill, Tjuganov - Golovin …). Such calculation is flawed by inaccurate calculation results. Different methods result in different results and question of method choice arises. Of course, these results must be statistically processed afterwards.
Experimental rolling rolls' workload definition is providing more accurate results however, these are taking longer time, special equipment is required and results are applicable only for the same or similar rolling rolls. Application of these results is, upon statistical processing, carried out through formed spectrums of workloads based on specific working conditions. In case of any changes in the working conditions, calculations and corrections of the workload spectrum must be applied as well.
Next step is determination of working stress considering the type of strain within critical section of the roll body; this method is used to form workload spectrums applicable throughout working life.
Critical load (working dynamical strength) is next element which definition is required for given calculation. Existing tabulated dynamical solidness values for certain materials (steel) can be used as

well as solidness for determined ratio of low and high stress levels $R=\sigma_d / \sigma_g$. However, if our goal is to determine timeline working solidness we can apply experimental method or throughout application of damage levels caused by material stress during the operation (Palmgreen, Miner, Corten, Dolan…).
After these steps mentioned above, it is required to determine interlinking levels of working and critical loads for rolling rolls – malfunction probability estimation. Method for the estimation; solution for general working reliability equation is given in this paper [3].
Application of this calculation concept gives malfunction probability estimation or probability of proper operation of rolling rolls. Determined value is comparable with defined values as contractual value.
If the final estimated value is acceptable it means that the rolling roll shall, in predetermined time under given workloads and determined quality of material, be more reliable then nominated. If the calculation results in lower value it means that certain steps require reduction in malfunction probability values (reduction of workload or increase of critical workload level). This procedure can be repeated numbers of times until the final acceptable values are determined. This method is also subjected to possible “incorporations” of reliability level values however, this causes the result to be directly subjected to quality of material as well as dimensions. Determination of method to be applied depends on predetermined calculation task.

3.2. Roll bending calculation
Since bending stress takes a dominant part in overall roll stress, details for this type of stress are given here.
Rolling roll can be observed as a simple billet loaded with one or more rolling forces with different stress locations, depending on the caliber used. Figure 3 shows roll load diagram [4].

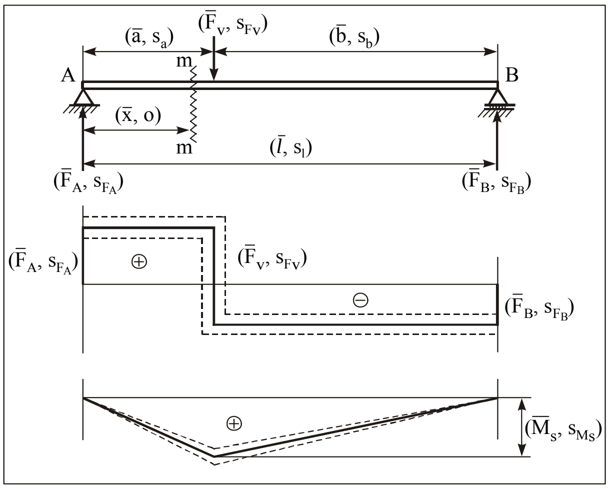

Figure 3. Rolling roll bending stress diagram

Force F_v, roll length l and position of force action a are variable values with certain median values and standard deviations $\left(\overline{F}_v,\ s_{Fv}\right)$, $\left(\bar{l},\ s_l\right)$ and $\left(\bar{a},\ s_a\right)$.
Reactions in bearing branches are given as:

$$\left(\overline{F}_A, s_{F_A}\right)=\left(\overline{F}_v, s_{Fv}\right)-\frac{\left(\overline{F}_v, s_{Fv}\right)\left(\bar{a}, s_a\right)}{\left(\bar{l}, s_l\right)}$$

$$\left(\overline{F}_b, s_{F_B}\right)=\frac{\left(\overline{F}_v, s_{Fv}\right)\left(\bar{a}, s_a\right)}{\left(\bar{l}, s_l\right)} \qquad \ldots(1)$$

Maximum momentums and bending stresses appearing in the rolling force action area F_v are determined as follows:

$$\left(\overline{M}_s,\ s_{Ms}\right)=\frac{\left(\overline{F}_v, s_{Fv}\right)\left(\bar{a}, s_a\right)\left(\bar{b}, s_b\right)}{\left(\bar{l}, s_l\right)} \qquad \ldots(2) \qquad \left(\bar{\sigma}_s,\ s_{\sigma s}\right)=\frac{\left(\overline{M}_s, s_{Ms}\right)\left(\bar{c}, s_c\right)}{\left(\bar{I}, s_I\right)} \qquad \ldots(3)$$

Where: $\left(\overline{M}_s,\ s_{Ms}\right)$ - bending momentum, standard deviation
$\left(\bar{c}, s_c\right)$ - distance between neutral axis and largest area of deformed fibers
$\left(\bar{I}, s_I\right)$ - inertia momentum of rolling roll cross section, standard deviation
Using the abovementioned calculations (3) we can determine median momentum values and bending stress as well as their standard deviations. These two elements are essential for probabilistic calculation.

3.3 Roll twisting calculation
Since rolling process requires rotational momentum, certain parts of the roll shall be subjected to twisting stress. Figure 4 shows roll twisting stress as well as roll distortion.

Tangent load in any roll cross section part is proportional with distortions and is determined as per:

$$\tau = \frac{1}{2} G \cdot \gamma = \frac{1}{2} G \cdot \theta \cdot d \;\ldots \qquad (4)$$

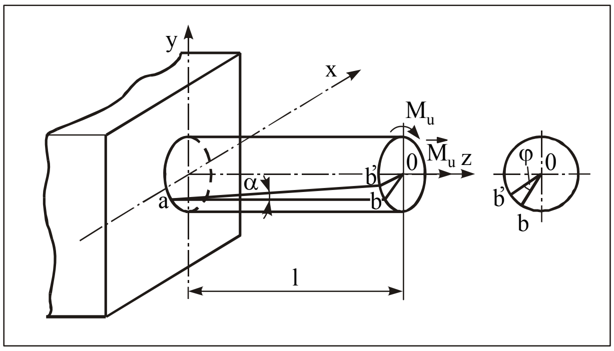

Figure 4. Rolling roll twisting load

Where: τ - tangential load
G – sliding shear module
θ - twisting level as per length unit
d – roll diameter
γ - slide

Which is:

$$\theta = \frac{M_u}{G \cdot I_0};$$ I_0 - polar inertia momentum

to je: $$\tau = \frac{16 M_u}{\pi d^3} \qquad \ldots(5)$$

Since parameters taken into consideration are randomly variable figures, tangential load is given as follows:

$$(\tau, s_\tau) = \frac{16(\overline{M}_u, s_{Mu})}{\pi(\overline{d}, \overline{s}_d)^3} \qquad \ldots (6)$$

τ - tangential load
s_τ - standard deviation

According to abovementioned, it is possible to determine tangential load in any given section of roll working part as well as bearing branches.

Since results of many researches have shown that the tangential load values are relatively low and do not affect rolling roll reliability, these values can be ignored in many cases of twisting loads. In the opposite case, reliability in comparison to bending and twisting can be determined.

4. CONCLUSION

- According to the research and analyses given in this paper I can conclude following:
- Since the rolling roll workload levels are variable, therefore applicable workload can be statistically defined into workload spectrum.
- Workload spectrum can be defined for bending and twisting loads of rolling rolls. Twisting load must be taken into consideration.
- Working dynamical solidness against bending and twisting (σ_s, τ) are next required elements of probabilistic method which can be shown as spectrums of critical loads.
- Comparison of working and critical loads enables determination of rolling roll malfunction probability. Desired (goal) reliability calculation is required for rolling roll dimensions determination.
- Shown procedures provide elements of probabilistic calculation for rolling rolls.

5. REFERENCES

[1] Целиков И., -.: Машины и агрегаты металлургических заводов, ТОМ 3, Москва,1988.
[2] Čaušević M.: Metal rolling processing, Veselin Masleša, Sarajevo, 1983.
[3] Imamović M.:"Construction aspects of choices and calculations of reliability for basic parts of rolling stand", Research thesis, Mechanical Faculty Zenica, 2004.
[4] Vujanović N.: Technical systems reliability theory, Military publishing center Belgrade, 1987.