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Relationship of Deformation and Kinematic Parameters of Rolling

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The analysis of kinematic and deformation characteristics of metal flow in the deformation zone during rolling is carried out, the characteristics of metal flow in the range of large and small values of the reduction ratio are revealed. Analysis of the kinematic features for large values of the reduction ratios can broaden our understanding of the metal flow laws and enables to obtain additional information to the disclosure of the unsolved questions in rolling theory.

Keywords: ROLLING, PARAMETERS, DEFORMATION ZONE, STICKING, FORWARD SLIP, REDUCTION RATIO

Introduction

The rolling process contains a variety of volume developing processes, and at the same time rolling theory includes a limited number of parameters which characterize metal flow within the deformation zone. The limited number of volume parameters testifies to insufficient level of knowledge of nature of volume transformations in the deformation zone, in particular, existing interconnections between deformation and kinematic parameters of rolling. Rolling process is rather difficult, the volume transformations are hidden and impossible to study directly, for this reason many conclusions concerning the volume disalignments are based on the contact interaction laws [1, 2, etc.] . Data about volume transformations in the deformation zone at rolling obtained on the basis of contact interaction of metal and roll are incomplete, and conclusions not always adequately cover the phenomena that take place in the deformation zone. As a result there are debatable provisions, contradictions and unsolved problems in the present-day theory of rolling [3, 4, etc.].

The task of present research is analysis of kinematic and deformation features of deformation zone during rolling as well as study of metal flow regularities. The physical signs of metal flow at rolling and specified concepts about kinematic interaction of metal and roll are in the basis of suggested approaches. It is possible to investigate rolling theory issues in more details by establishing interconnections between deformation and kinematic parameters of rolling.

Results and Discussion

Conditions of volume maintenance and constancy of second volumes as well as form-factor in some measure are among the volume parameters of rolling process. In the strict sense, the first condition is not a technological parameter as it starts with properties of material. Form-factor (ratio of deformation zone length l_d to average hight of hot-rolled breakdown h_a) is a classification sign and gives an idea about the relative height of deformation zone, it is not used in technological calculations.

Condition of second volume constancy is as follows [5]:

$$V_o\, F_o = V_\varphi\, F_\varphi = V_1\, F_1 \qquad \text{(Eq. 1)}$$

It is usually applied in the form of equality of two extremes

$$V_o\, F_o = V_1\, F_1 \qquad \text{(Eq. 2)}$$

which enables to use the next formula:

$$V_o = V_0\, F_0 \,/\, F_1 = V_0\, \lambda \qquad \text{(Eq. 3)}$$

It is possible to call the condition of second volume constancy as conditional volume parameter as it includes square, and the volume does not enter into condition of second volume constancy. It would be more exact to call equations (1) and (2) constancy of second squares. In other aspect (equality of the first and average or average and third terms) the condition has restricted application as there is no interconnection between speed and cross-sectional area of hot-rolled breakdown within the deformation zone.

The reason of mentioned above differences in opinions often consists in that the researchers give generalizing conclusions based on results applicable for special cases - for conditions in which the results are obtained. In particular, the majority of researchers carried out experiments using a restricted range of drawings λ = 1.2-1.5. The specified range is the most practical, it is of the greatest interest, so acts of researchers for this reason are completely justified. But at the same time, the details of the known kinematic features are hardly noticeable in the specified range. Such features are kinematic processes on the contact - sliding and sticking. At large gripping angles and small elongation ratios the difference between metal rate at the entry in the deformation zone and horizontal projection of roll speed is insignificant. This enables to consider the existing explanations of specified kinematic processes convincing enough. It is accepted in rolling theory that entry section of rolls is pushing metal in the deformation zone, the excess of pushing forces is realized in the form of forward slip. The fact that speed of rolls (and in particular its horizontal projection) is almost always higher than metal rate, and that rolls cannot create the frictional adhesion with metal is less taken into account. But explanations include the fact that the mentioned difference of speeds is insignificant and becomes even less due to forward slip. Having mentioned widening, the explanation takes the complete form. But it becomes insufficient for explanation of regularities covered in [3, 4].

When solving this problem we will not impose restrictions in the range of change of investigated parameters, we will use only possible intervals, in particular, grapping conditions. Simultaneously we will reduce the number of parameters to those having the most influence on deformation-kinematic situation. Thereupon among deformation parameters we will distinguish elongation ratio λ, and among kinematic ones – metal rate V and roll speed V_R. The horizontal component of roll speed will be: V_R α - in the plane of entry in the deformation zone, V_R - in the plane of exit from deformation zone. Accordingly, the horizontal component of metal rate: Vo – at the entry in the deformation zone, V_1 – at the exit from deformation zone. The fundamental rules of rolling theory are obtained without account of volume metal flow in the deformation zone, it is one of reasons of contradictions in theory mentioned in [3, 4]. The author [4] notes unestablished interconnections between forward slip, broadening and drawing: "Despite numerous investigations in rolling theory there are still contradictions concerning interrelationship of key parameters of the process". The author also covers the issues of sticking in the interconnection with mentioned above parameters. Concerning dependence of forward slip on reduction of cross-sectional area [4]: " … Abnormal growth of forward slip at increased reductions which cannot be explained in view of current rolling theory is determined". Based on above mentioned we assume that there is no forward slip (S = 0). Thereby we introduce an error commensurable with the forward slip value. This error is predicted enough by value. On the same basis we accept that there is no broadening, i.e. $\Delta b = 0$.

$$\Delta b = 0\,,\ \lambda = \frac{h_0}{h_1} \qquad \text{(Eq. 4)}$$

In its turn

$$\lambda = \frac{h_1 + \Delta h}{h_1} = 1 + 2\,\frac{R}{h_1}(1 - \cos\alpha) \qquad \text{(Eq. 5)}$$

Equation (5) enables to construct diagrams shown in **Figure 1**. Dependence of elongation ratio λ on rolling parameters - gripping angle α and ratio R/h_1 is covered in these diagrams. The diagrams are constructed for the range of elongation ratios most commonly occurring in practice $\lambda \leq 1.5$. Curves 1-9 in **Figure 1** describe deformation of rolling process, change pattern of horizontal projections of roll speed at the entry in the deformation zone is defined by ratio

$$\frac{V_B}{V_{B\alpha}} = \frac{1}{\cos\alpha} \qquad \text{(Eq. 6)}$$

Comparing ranges of λ and $V_R / V_{R\alpha}$ change it follows that they are incommensurable by numerical value. The range of elongation ratio change can be much more than presented in

Figure 1. The maximum value of the right part of equation (6) in most cases does not exceed 1.155 (contact angle 30 °) while the elongation ratio can exceed the specified number in 10 times. Diagrams shown in **Figure 2** are for cases of rolling with high elongation ratio ($\lambda_{max} \leq 5$). The qualitative picture (excess of elongation ratio over the ratio $V_R / V_{R\alpha}$) remains in the whole range of change of gripping angle α and ratio R/h_1.

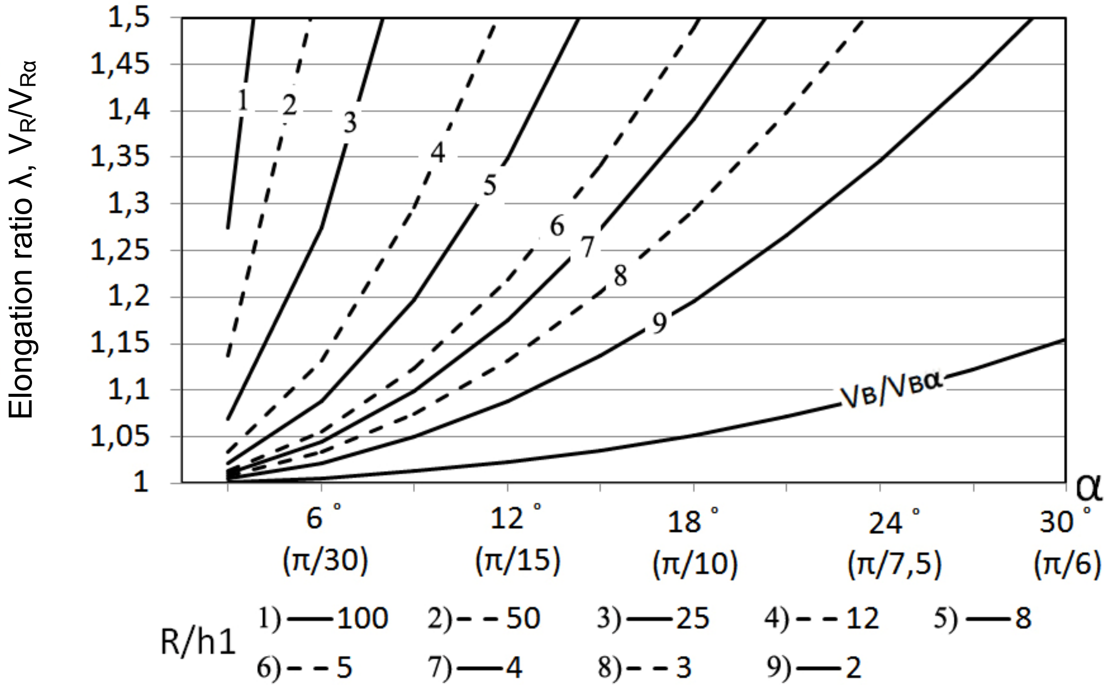

Figure 1. Dependence of elongation ratio λ and ratio $V_R / V_{R\alpha}$ on rolling parameters. Area of small and average elongation ratios ($\lambda \leq 1.5$)

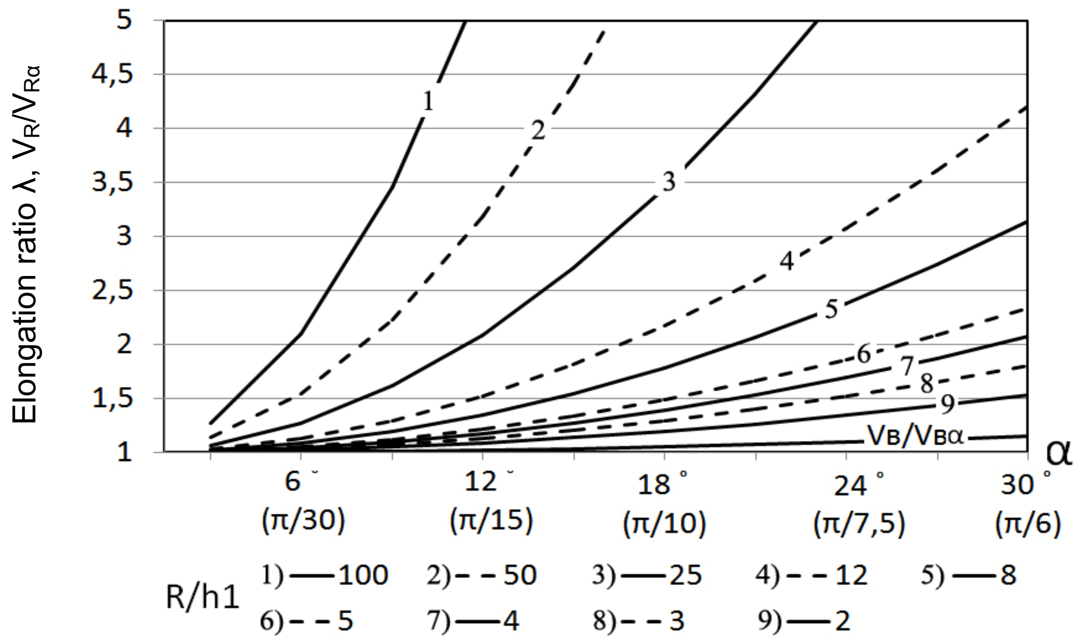

Figure 2. Dependence of elongation ratio λ and ratio $V_R / V_{R\alpha}$ on rolling parameters. Area of high elongation ratios ($\lambda \leq 5$)

When comparing ranges of λ and $V_R / V_{R\alpha}$ we have to stress that metal rates and roll speeds are always comparable, i.e.

$$\frac{V_M}{V_B} \approx 1 \qquad \text{(Eq. 7)}$$

Elongation ratio can exceed ratio $V_R / V_{R\alpha}$ in several times and this excess cannot be completely realized in the form of metal forward slip, otherwise it would repeatedly exceed the roll speed. Forward slip mechanism in certain areas of the range of possible drawing and high-speed regimes can have the features and depend on determined interconnections. The revealed interconnections enable to receive additional information to solve the problem tasks covered in works [3, 4].

Having determined the interconnections between parameters of deformation zone, it is possible to establish new interconnections and consider issues of sticking and forward slip. Specified phenomena are necessary to study not only from positions of contact interaction of metal and roll but also on the basis of volume flow of metal in the deformation zone. And the physical essence and mechanism of sticking should be considered first as forward slip is in many respects secondary factor in relation to sticking. The next stage is determination of new regularities in the interconnection with broadening. These issues are beyond the scope of present research.

Conclusions

Analysis of kinematic and deformation features of metal flow in the deformation zone at rolling is carried out, the features of metal flow in the range of great and small values of elongation ratios are determined. It is established that explanation of deformation and kinematic features of rolling give incomplete and not always fair presentation about specified features. Analysis of features of kinematic processes in the field of great values of elongation ratios enables to receive additional information to solve tasks of rolling theory. On the basis of determination of regularities of deformation and kinematic parameters of rolling it is possible to clarify certain issues of rolling theory. Using established regularities enables to study the physics of rolling process, to formulate entry conditions and raise accuracy of calculations of kinematic parameters of rolling.

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Взаимосвязь деформационных и кинематических параметров прокатки

Огинский И. К.

Выполнен анализ кинематических и деформационных особенностей течения металла в очаге деформации при прокатке, выявлены особенности течения металла в диапазоне больших и малых значений коэффициентов вытяжки. Анализ особенностей кинематических проявлений в области больших значений коэффициентов вытяжки позволяет расширить представления о закономерностях течения металла и получить дополнительную информацию к раскрытию нерешенных вопросов теории прокатки.