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Theoretical Research on the Pipe Rolling Process in Order to Determine the Deformation of the Pipe Billet and the Load on the Rolling Tool

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Abstract. The technology of the shell case rolling into the rough pipe on an automatic mill of the pipe-rolling plant PRP 220 was considered. In case of the pipe rear end stability losing for a special thin-walled assortment of rolling products the theoretical research was carried out based on the FEM. As the result of the research the nature of such flaw as a “fin” on the end of the pipe was investigated, the evaluation of the loading on the automatic mill for the PRP 220 was obtained for different process parameters.

Hot rolling of wide assortment of seamless pipes made of carbon, alloy and high alloy steels on pipe-rolling plants (PRP) with an automatic mill includes the following sequence of operations: furnace heating of a round billet, piercing, rolling on a short mandrel through an automatic mill, rolling through reeling machines, calibration or reduction and flattening [1]. The most important operation is rolling of the shell into a pipe with a given wall thickness on an automatic mill [2].

Rolling of the pipes through an automatic mill with a ratio of the outer diameter to the wall thickness of more than twenty five is accompanied by the formation of a defect at the end of the pipe in the form of a longitudinal fold [3]. This fold, shaped like a fin, is shown in Figure 1 (a). In addition, significant destruction of the end sections occurs (Figure 1 (b)). The consequence of this form change of the billet is an increase in the load on the working tool of the automatic mill and reeling machines, as well as their drivelines.

In order to analyze the shape change of the pipe billet when rolling through an automatic mill, three-dimensional modeling of the process was performed with a help of FEM software [4]. The calculation scheme of the mathematical model includes a viscous-plastic billet (pipe shell), absolutely rigid work rolls and a mandrel.

The calculation was made starting from the moment when the billet entered the rolls' opening and up until it was completely out of the rolls. As you know, rolling through an automatic mill is carried out in at least two passes. In this regard, the calculation was performed for two operations. For the second rolling operation through an automatic mill, the billet obtained after the first pass was moved to the input side of the rolls and turned over to an angle of up to 90°. Then, similarly to the previous calculation, the second pass was modeled in rolls of the same profile with the mandrel replaced.

a

b

Figure 1. Defects of end sections of thin-walled pipes after rolling through an automatic mill (a) and before flattening (b).

The performed theoretical study made it possible to observe a loss in the lateral stability of the end of the pipe when rolling, which begins with ovalization of the cross section of the billet, followed by the transition of metal into the roll gap and rolling of the metal into the “fin” (Figure 2). At the same time, the narrowed section pipe is put on the mandrel.

For a different assortment of pipes, the peak at the time the pipe exits the stand decreases with the increase of wall thickness. For thin-walled pipes in the indicated range, the peak goes up to 27.6% (of the average rolling force) and gradually smooths out. The graph of axial forces is also of a similar nature, which is also accompanied by a characteristic peak at the moment of “wrinkling” at the end of the pipe (14.2-22.9% of the average values of axial force for various ratios of the outer diameter of the pipe to the wall thickness).

During the second pass, depending on the tilt angle of the billet, an additional deformation is added to the existing loss of stability of the end of the pipe when it leaves the stand, due to the need to roll out the “fins” formed during the first pass. In the real rolling process, in the places of rolled “fins”, destruction of the pipe end appears (Figure 1 (b)).

Figure 3 shows graphs of the calculated forces taking place on the work rolls and the mandrel during the rolling process. At the same time, a new pair of "fins" is formed due to the transition of metal into the roll gap, which subsequently impedes the normal rolling process in reeling machines, significantly (up to three times) increasing the rolling force in the final part of the rolling.

To establish the relation between the size of the “fins” resulting from the second pass and the metal transition in the deformation zone in the transverse direction, a theoretical study examined various tilting angles of the billet between the passes.

The graphs of the forces taking place on the working tool during the second pass are shown in Figure 4.

It was established that this defect takes place in all cases, regardless of the tilt angle. The highest values of the force are achieved at a 90° tilting angle due to a larger reduction of the pipe wall in the rolls’ opening (the difference between the maximum average force at a tilting angle of 0° and 90° is 36.3%).

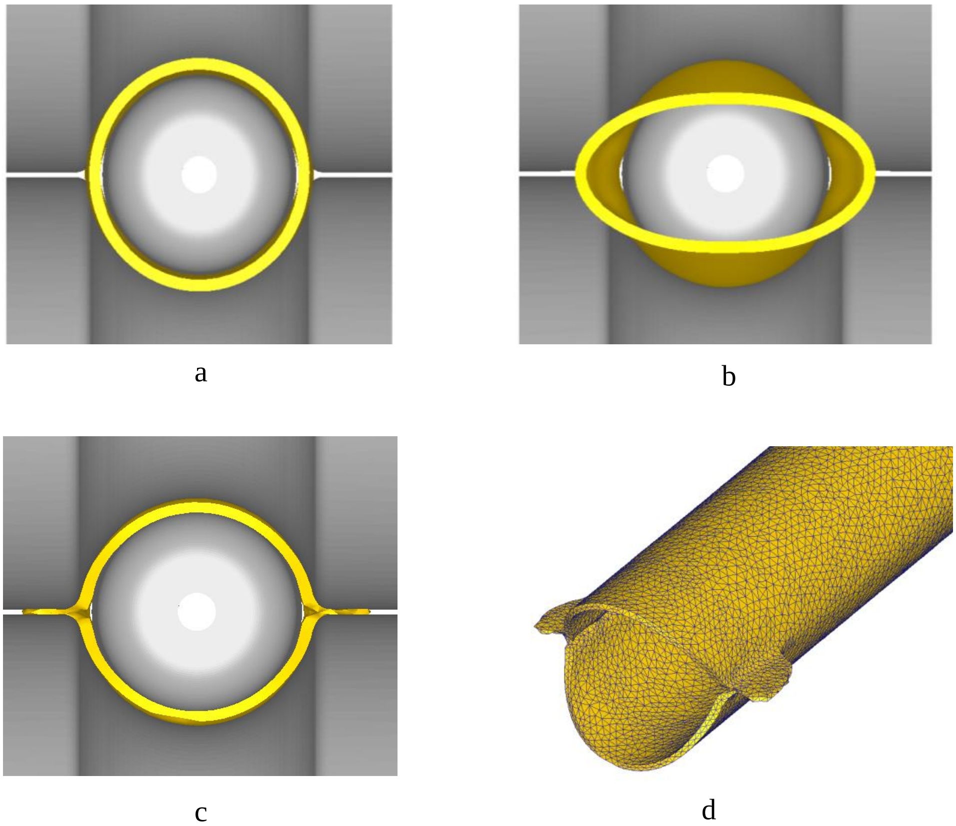

Figure 2. The end of the billet when rolling (a-c) the stages of stability loss of the billet end at the end of rolling (d) final form-change of the billet.

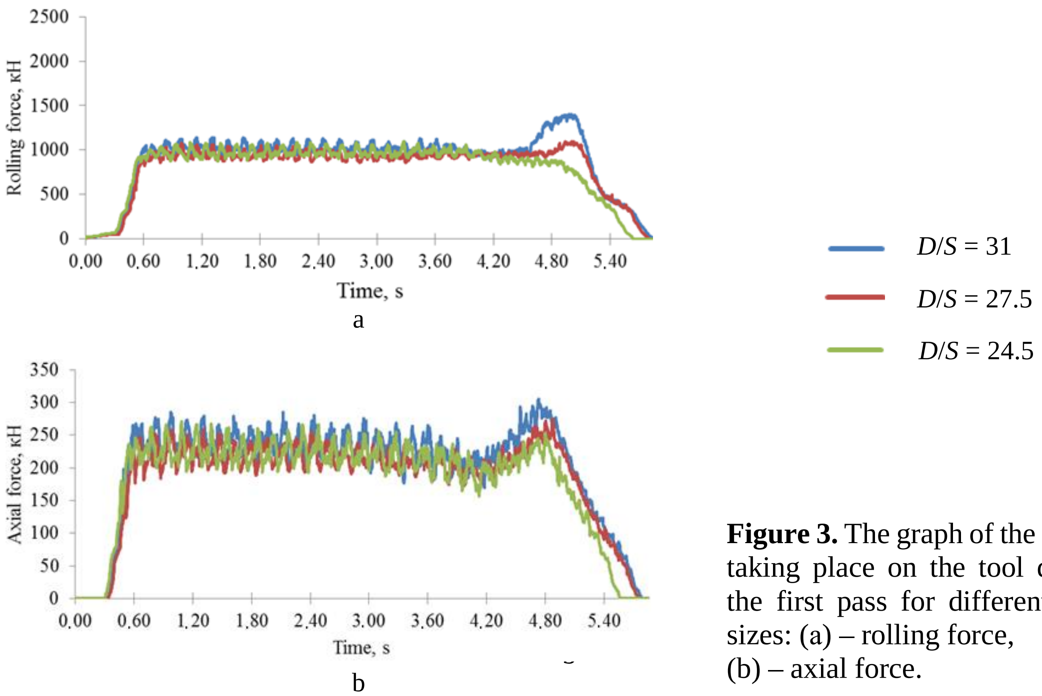

Figure 3. The graph of the forces taking place on the tool during the first pass for different pipe sizes: (a) – rolling force,
(b) – axial force.

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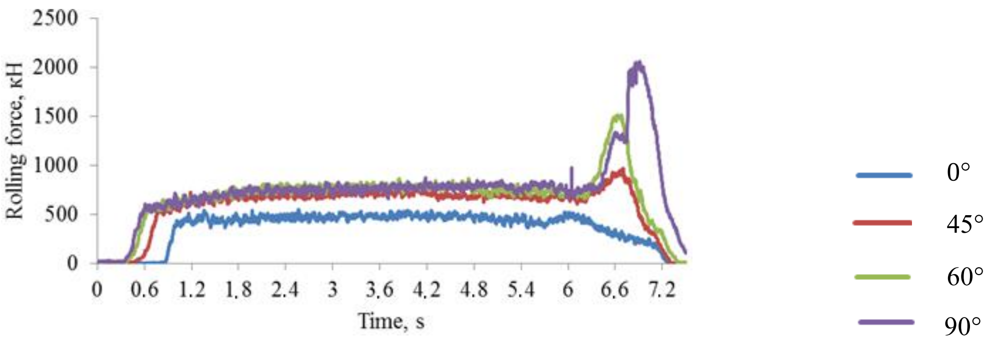
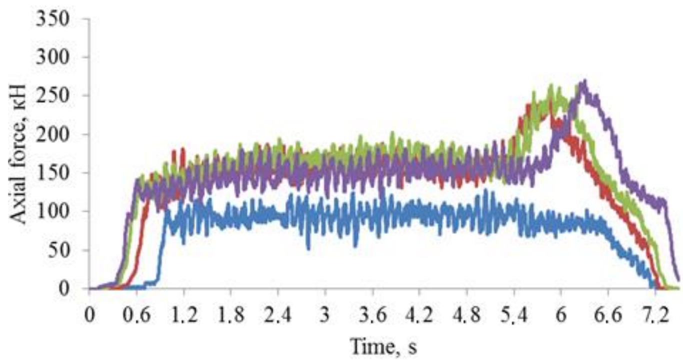


a



b

Figure 4. The calculated dependences of the forces perceived by the tool, as a function of the tilt angles: (a) – rolling force, (b) – axial force.

As can be seen from the graphs, the moment of rolling of the “fins” is accompanied by a ramp in the rolling force, which in turn is accompanied by an increase in axial force due to the putting of the pipe billet on the mandrel. The maximum ramp of the force is observed at a tilt angle of 90°, at which its value exceeds the average value of the rolling force by 2.78 times and the average value of the axial force by 1.80 times.

It should be noted that the minimum tilting angles increase the ovalization of the pipe (ovalization coefficient from 1.0 when tilting 90° to 1.04 when tilting is absent) and walls' thickness variation in the cross-section (from 4.8% at tilting angle 90° to 30% when there is no angle).

As practical tests have shown, the elimination of the formation of “wrinkles” in the form of “fins” at the end sections of thin-walled pipes with a diameter to wall thickness ratio of more than twenty five can be achieved by limiting the ovalization of these sections.

Conclusions

As a result of modeling the process of rolling the shell through the automatic mill of the pipe-rolling plant, it was found that the end of the pipe when rolling, due to reduced hardness, loses stability and ovalizes. This is accompanied by the transition of pipe metal into the roll gap and the formation of a pipe defect in the form of a “fin”. In this case the load on the working tool has stick-slip nature, and the forces significantly exceed their average values on the working tool during the rolling process.

Practical tests of additional measures to reduce ovalization of the end sections showed the possibility of eliminating the indicated defect and reducing the expenditure coefficient.

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