Reduced Metal Consumption in Hot Pipe Rolling


Abstract — Means of reducing the metal consumption in the hot rolling of seamless pipe are considered. The most common is the use of square or round continuous-cast billet. The trimming required for Pilger mills may be reduced by preparation of the front ends of the sleeves in skew rolling and rolling of the rear end at the free section of the mandrel. To expand the range of pipe to $D/S = 15–30$ for the 200 system with a three-roller mill, grooves created with special liners in the gaps between the rollers have been adopted at OAO Interpipe Nizhnedneprovskii Trubopromkatnyi Zavod. In addition, the wall thickness is regulated by means of a hydro-mechanical clamp.

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A popular method of increasing the efficiency of hot pipe rolling is to reduce the losses of metal in the production process [1].

Along with the productivity, the metal consumption is the main characteristic of pipe rolling. The consumption coefficient $\lambda$ is the ratio of the mass of metal specified in production and the mass of the final product:

$$\lambda = 1/(1 - Q)$$

where $Q$ is the loss of metal in rolling a 1-t blank, consisting mainly of the losses on heating, the metal trimmed from the end sections, and the chip removed in the manufacture of special pipe (incised pipe, etc.). Besides these technologically unavoidable losses, there may be losses due to poor quality, disruption of the technology, unsatisfactory state of the equipment, etc.

The total metal losses for all the technological stages is

$$Q = \sum_{i=1}^{n} q_i,$$

where $q_i$ is the loss of metal in stage $i$, $t$, $n$ is the number of stages (operations).

We may express $\lambda$ as a product:

$$\lambda = \lambda_1 \lambda_2 \lambda_3 \ldots \lambda_n.$$  

Then we see that, in order to reduce $\lambda$, we need to reduce the number of stages $n$. This finding is taken into account in developing new methods of pipe rolling—for example, on a planetary mill. The mean values of $\lambda$ (t/t) in hot rolling of rolled pipe and oil pipe on different systems are as follows, according to data from the Ukrainian State Research and Design Institute of Metal Products:

<table>
<thead>
<tr>
<th>Type of pipe</th>
<th>140 automatic mill</th>
<th>350 Pilger mill</th>
<th>Three-roller mill</th>
<th>30–103 continuous mill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon steel</td>
<td>1.067–1.083</td>
<td>1.20</td>
<td>1.060</td>
<td>1.066–1.077</td>
</tr>
<tr>
<td>Alloy steel</td>
<td>1.087–1.103</td>
<td>1.24</td>
<td>1.080</td>
<td>1.087–1.091</td>
</tr>
<tr>
<td>High-alloy</td>
<td>1.107</td>
<td>1.32</td>
<td>1.100</td>
<td>—</td>
</tr>
</tbody>
</table>

According to these data, the losses are greatest for Pilger mills. This is associated with the input section and Pilger head removed in rolling and also with the use of steady-casting ingots as the initial billet.

Analysis of rolling on different systems shows that metal losses may primarily be reduced by improving the initial blank, reducing the trimming of the pipe and the rejection rate of unsatisfactory pipe, and improved monitoring of the losses in all stages (improved accounting).

The main stages in the production of hot-rolled pipe are as follows (Fig. 1).

Fig. 1. Stages in the hot rolling of pipe on equipment of various types.
(1) Preparation of the initial blank for rolling: (1.1) inspection; (1.2) quality monitoring; (1.3) repair; (1.4) layout; (1.5) monitoring of mass and heating.

(2) Production of a sleeve from a nonhollow (or sometimes often hollow) blank in one or two stages: (2.1) roller piercing, elongation; (2.2) piercing on a press, elongation; (2.3) helical piercing; (2.4) successive piercing on two skew-roller mills.

(3) Rolling the rough pipe from the sleeve in one or two passes: (3.1) on Pilger mill; (3.2) on automatic (tandem) mill; (3.3) on continuous mill; (3.4) on three-roller mill; (3.5) on rack mill; (3.6) on planetary mill; (3.7) on Disher mill.

(4) Producing the final pipe: (4.1) by single- or multiple-cell grooving; (4.2) reduction with tension; (4.3) helical grooving in single-cell mill; (4.4) helical grooving in multiple-cell mill.

(5) Straightening pipe: (5.1) hot straightening; (5.2) cold straightening; (5.3) measurement of pipe mass.

The division of the process into five basic stages permits detailed analysis of the defects in different subsystems and the adoption of appropriate measures.

**IMPROVING THE INITIAL BLANK**

The cost of the initial metal is 75–85% of the total cost of hot-rolled pipe. This calls for the use of cheaper pipe. However, the need for better quality of the blank tends to increase its cost. The quality of the blank must be elevated so as to increase the yield of fault-free products and reduce the overall metal consumption.

In pipe-rolling systems, the initial blanks are continuous-cast and rolled ingots and centrifugally cast sleeves. Rolled ingots are used everywhere except in Pilger mills. Globally, continuous-cast blanks are widely used, and the yield of fault-free products is 10–15% greater than for rolled billet [2].

Round or square rolled, forged, and cast blanks (in the form of rods) are used for the production of seamless hot-rolled pipe. Round or polygonal ingots (mass up to 7 t) are used in Pilger mills for rolling large-diameter pipe.

Centrifugal hollow castings (diameter up to 900 mm) are used for the production of high-alloy steel pipe and bimetallic pipe. Machining of the external and internal surfaces is required here.

The pipe obtained from ingots costs less, since the metallurgical processing cycle is significantly shorter. To obtain a continuous-cast billet, steel is mainly produced in converters and electrofurnaces, with subsequent ladle treatment and vacuum treatment. Globally, continuous-cast billet (diameter up to 250 mm) is used to replace rolled blanks.

The quality of square and rectangular continuous-cast billet is greater than for round billet. Rolled and forged blanks are produced in Ukraine and Russia from ingots of mass 3–15 t; elsewhere, they are mainly produced from continuous-cast metal. Cast blanks with a diameter greater than 150 mm and blooms with sides greater than 350 mm are employed. Rolled blanks with a diameter of 80–320 mm are used for the production of seamless pipe.

In rolling continuous-cast billet on Pilger mills, the metal losses may be reduced by 16–20% relative to steady-casting ingots. On other pipe-rolling systems, additional deformation of the continuous-cast billet on billet mills is required. To obtain steel of better quality, it is smelted in electrofurnaces with ladle treatment and vacuum treatment.

Analysis shows that there are many options for the use of continuous-cast billet in the hot rolling of seamless pipe: the production of a hollow blank (sleeve) on continuous centrifugal-casting machines and rolling to the final pipe; the rolling of continuous-cast billet on a pipe-blank mill and a pipe-rolling machine; the production of a continuous-cast nonhollow round ingot, with simultaneous intense reduction (on skew-roller, planetary, or Pilger mills or by radial reduction using shaped rollers); deformation of continuous-cast square or octagonal ingot to a round blank in a two-roller grooving mill, a roller press, a piercing mill, and an elongation mill.

At Volzhsk pipe plant, square continuous-cast billet (maximum side 360 mm) is used on the 159–426 mill [3]. At the Dalmine plant (Italy), square continuous-cast billet (sides 170, 210, 240, 280, and 320 mm) is used on the 400 mill. Thus, this is the main trend globally in the production of hot-rolled seamless pipe.

In rolling pipe with a diameter up to 150 mm, integration of continuous casting with preliminary deformation of the billet to enhance its quality is promising. This also permits significant energy savings [4]. On medium-sized 168–377 Pilger mills and large 320–600 Pilger mills, continuous-cast billet and steady-cast ingots are employed. A centrifugal hollow casting is effective in rolling high-alloy steel and bimetallic pipe.

**MINIMIZATION OF TRIMMING**

In the hot rolling of pipe, trimming is required by insufficiently rolled regions such as the Pilger head, defects, considerable nonuniformity of the deformation in rolling the end sections, and pronounced fluctuation in pipe-wall thickness. Thickened ends are formed in reduction.

Trimming may be minimized by the following means: use of better-quality blanks; reduced nonuniformity of the deformation over the pipe perimeter; reduced deformation of the end sections thanks to their preliminary preparation; and the use of optimal roller grooving and optimal rolling temperatures.

The metal losses associated with the ingot’s input end and its Pilger head amount to 8–10% of its mass (usually 3–4% and 5–6%, respectively) [5].