PHYSICAL MODELING OF SEAMLESS TUBES PRODUCING

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Abstract

Applied research and experimental development in forming processes used in metal forming technology of seamless tubes in the past took place in the Czech Republic in the workplace VSB-TU Ostrava. The main tools of modern research on this issue are conducted mainly in two directions mathematical modeling, which also includes the numerical simulation of those processes and physical modeling. Besides the more general use of mathematical modeling physical modeling is likely the most appropriate procedure of a complex process of cavity formation during axial rolling of seamless tubes for laboratory research and development of those processes. The conducted experimental development can proceed to the simplest experiment which is a technological test directly on production equipment. This can be carried out but only to a limited extent, because the preparation and implementation of such an experiment is reduced production and is associated with loss of the line performance. Experimental device enabling deformation of steel billet should meet several similarity criteria between the physical model and the actual process. Within investment of Regional Materials Science and Technology Centre (RMSTC) project was created new comprehensive workplace focused on physical modeling of seamless tube production. The laboratory is divided into two workplaces namely rolling mill so called “Universal rolling mill for production of seamless tube” and heat treatment of ring of tubes.

Keywords: physical modeling, seamless tube, experimental equipment

1. INTRODUCTION

The main tools of the modern research of the issues of forming processes in seamless tube production technology are divided primarily into two directions, namely into mathematic modeling including numerical simulations of these processes and physical modelling. Besides the more general use of mathematical modelling (e.g. FEM), physical modelling is likely the most appropriate procedure of a complex process of cavity formation during axial rolling of seamless tubes for laboratory research and development of those processes. This article focuses on specification of the equipment for physical modelling of the actual seamless tube rolling process in MATERIAL & METALLURGICAL RESEARCH Ltd. based in Ostrava (CZ).

Production of rolled seamless tubes is based on multi-stage technologies - it is a sequence of at least two consequent different technological processes, e.g. in the case of the so-called Mannesmann method consisting of a piercing machine (cone-type rolling) and pilgrim mill (special type of longitudinal rolling on a mandrel). This method is suitable for rolling of medium and large diameter tubes with thicker walls. Other methods consist of combination of a piercing machine of various arrangements and designs combined with subsequent elongation by cross rolling or longitudinal rolling in round passes. The oldest method of production of seamless tube is Mannesmann rolling. Tenaris is the global leader in production of seamless tubes; another leading producer is Valorec & Mannesmann, which produces tubes in Europe in seven plants in France and Germany. There is a great number of tube rolling pilger mills in Russia [1]. Mannesmann rolling method is also used in Japan in Nippon Steel Corporation and JFE Steel [2 and 3].

In recent years, fierce competition between individual manufacturers of not only metallurgical billets has caused development of methods supporting development and optimisation of the forming process. These
methods may be divided into two groups. The first is based on mathematical apparatus and calculation methods, which allow formation of mathematical models of the forming process and is called mathematical modelling. The second group is based on experiments, whereas the most important area is physical modelling and simulation [4 - 6].

With regard to the unique process of axial rolling of seamless tubes, which uses the effect of formation of cavity in the centre of a cylindrical blank, the so-called Mannesmann effect, which is further developed by the piercing mandrel, it is necessary to search for suitable experimental processes which would sufficiently truly model the actual processes during deformation. As a part of implemented experimental development, it is possible to implement the easiest and the most exact experiment which is the technological experiment, i.e. technological test directly on the production equipment. This may be implemented only to a limited extent, as preparation and implementation of such experiment limits the production and is associated with the loss of output of the line.

2. EXPERIMENTAL EQUIPMENT

Implementation of laboratory equipment modelling actual technology of piercing, or elongation is a technically demanding project when a fully universal character of the equipment (in relation to the modelled technologies) may not be achieved. The obtained experimental results need to be transferred back to the real processes. The scope of possible transfer of results (values) of experiments at laboratory equipment to the actual equipment is characterized by the so-called conditions of similarity between the physical model and the actual process. The most important general conditions of similarity for forming processes are as follows: plastic, elastic, temperature, friction, geometric, dynamic condition of similarity.

The first four conditions are the most important, but may be met all at once only with difficulty. Therefore, only the conditions most important for the given process are often selected [4]. In practice, sufficient geometric similarity of the model and the object during modelling is achieved by means of geometric similarity of rolls, mandrels and guides, the same relative reduction, the same chemical composition of the formed metal; further it is necessary to observe similarity of chemical composition of rolls, mandrels, guides and quality of their surface, conditions of heating of the blank (furnace atmosphere, heating time), rolling speed. The selection of modelling scale is in practice limited by several factors. When opting for a substantial reduction, difficulties with too thin walls of rolled shapes occur, measuring inaccuracy is increased and it is more difficult to maintain geometric accuracy of working tools. If a small reduction of the model is chosen, it is necessary to use powerful equipment, which is costly and the test pieces are heavy (difficult handling). According to [7] a scale of k=1/5 to 1/7 is suitable for heavy rolling mills with the diameter of rolls from 650 to 950 mm; k=1/3 to 1/5 for medium rolling mills with the diameter of rolls from 400 to 600 mm. With these scales, the results should be satisfactory if the rolling speed Vmodel corresponds to Vmodel=k·Vobject. In the case of a model rolling mill with the diameter of rolls from 200 to 240 mm, the scale according to [7] will be k=1/2.7 to 1/4.75, which corresponds to the scale for medium rolling mills and is near the limit value k=1/5 for heavy rolling mills. Observance of similarity of plastic deformation, i.e. the same course of recrystallization and strengthening processes depending particularly on the actual deformation process means slowing of the actual model piercing. On the contrary, achieving of temperature similarity for small rolled pieces means acceleration of the whole piercing process. These two conditions are contradictory and they highlight the substantial limitation of application of modelling of deformation behaviour.

In the case of rolling mills for cross rolling, it is not usual to monitor the force parameters of the forming process. The only indicator which helps us when estimating the course of deformation is the intensity of current and current characteristic of the drive. With regard to this fact, monitoring of various dependencies is more suitable for laboratory test plants, which allow detailed measuring within a wide scope and analysis of individual characteristics.
In the past, similar plants were constructed in the Czechoslovakian Republic in the 1970s at the Department of Metal Forming at VŠB in Ostrava. The characteristic parameters of the three-roll machine were as follows: diameter of working rolls max. 170 mm, length of rolls 250 mm, speed 30 to 112 min\(^{-1}\), roll axis angle 0 to 12°, rolling angle 0 to 3°. The diameter of input material was 40 to 70 mm and the length was 100 to 400 mm. The design of the rolling mill was adjusted for integration of sensors for measuring of force parameters of cross rolling. This cross rolling mill was fitted with sensors for measuring of forces on all rolls, always on the front and rear adjusting screw, measuring axial force on the mandrel, axial force on the mandrel carrier, torques of all drive spindles, power of drive motor, speed of work rolls and temperature of the rolled material [8]. At the beginning of 1990s all equipment was discarded including the majority of measured data due to termination of research.

Within investment of Regional Materials Science and Technology Centre (RMSTC) project, a new comprehensive workplace was created in MATERIÁLOVÝ A METALURGICKÝ VÝZKUM s.r.o. (MMV) focusing on physical modelling of seamless tube production. The actual laboratory is divided into two workplaces namely rolling mill, the so-called “universal rolling mill for production of seamless tubes” and the heat treatment workstation.

### 2.1 Universal rolling mill for production of seamless tubes

The plant consists of the mechanical part, drives, hydraulic system and the control and regulation system. The mechanical part may be divided into the drive consisting of three or two electric motors with Cardan shafts driving the working rolls and the input part – introduction of the hot blank to be engaged by the work rolls. When passing the rolling gap, the rolled product is intercepted in the output part of the mill where guides of the job are placed, mandrel bar support bearings and output cooling grate with ejector. Movement in this area is secured by roller track.

The rolling mill has a modular design, i.e. its configuration may be changed as necessary from a two-roll arrangement (fig. 1) to a three-roll arrangement. In the case of the two-roll arrangement it is possible to select the methods of supporting, either by support (not driven) roll or ruler from both sides or only from one side (the piercing axis thus is then above the axis of work rolls). Based on concept according to [7], the following force parameters were selected for monitoring: thrust of work rolls (each roll separately always on the front and rear mounting), thrust of the blank between the rolls; measuring of drives: driving torque of work rolls and speed of work rolls (each is always done separately); temperature measuring: temperature of blanks and rolled products. The important technical parameters are as follows: angle between rolls 0 to 75°, roll thrust max. 300 kN, work rolls diameter 200 to 240 mm. The main drive is secured by three asynchronous electric motors with the input of 37 kW provided with a frequency converter; work rolls speed may change within the scope of 0 to 180 min\(^{-1}\). The dimensions of the input material may vary as follows Ø 50 to 70 mm, length 200 to 400 mm, i.e. weight about 9 kg. Heating of the blank is realized in the heating furnace by controlled heating according to the set curve up to 1350 °C. Handling between the furnace and the hydraulic feeder is manual.
3. MILLING ON THE UNIVERSAL ROLLING MILL FOR SEAMLESS TUBES IN A TWO-ROLL ARRANGEMENT

As part of first experiments realized on the rolling mill, hot rolling with piercing mandrel was realized. The objective of this rolling was primarily to verify the course of the piercing process and operability of the equipment, possibly establish insufficiencies based on results and propose their correction.

3.1 Course of tests

The input material for the tests were rolled bars of carbon steel C10 (0.1 wt. % C, 0.2 % Si, 0.5 %Mn). In all, four samples were rolled with the dimensions Ø 60 mm, 200 mm long. The diameter of the piercing mandrel was 35 mm and its position was selected so that the tip of the mandrel was 30 to 35 mm before the passing plane. The speed of rolls ranged between 96 to 120 rpm (see tab. 1). The position of the piercing mandrel and the speed of rolls changed for each sample. 8 mm reduction, 5° movement angle and 0° forming angle remained the same for all samples. Temperature of sample was set to 1320°C with the minimum dwell at temperature at 1 h. The course of rolling is documented by fig. 2, the condition of mandrel tip is shown in fig. 3 and the rolled products are shown in fig. 4.

Table 2 Setting of piercing process for individual samples

<table>
<thead>
<tr>
<th>sample</th>
<th>roll axes angle [°]</th>
<th>rolling angle [°]</th>
<th>mandrel position [mm]</th>
<th>reduction [mm]</th>
<th>speed of rolls [rpm]</th>
<th>elongation [-]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>0</td>
<td>30</td>
<td>8</td>
<td>96</td>
<td>1.675</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>0</td>
<td>35</td>
<td>8</td>
<td>96</td>
<td>1.725</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>0</td>
<td>35</td>
<td>8</td>
<td>108</td>
<td>1.740</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>0</td>
<td>35</td>
<td>8</td>
<td>120</td>
<td>1.825</td>
</tr>
</tbody>
</table>

3.2 Course of tests

There were no problems during actual rolling. In the case of tests with greater speed of rolls (108 rpm and more) the rolling process showed signs of instability (increased vibrations of the rolled product in engagement and during releasing). For this reason it was suggested that lower speed of rolls under 100 rpm be used for further rolling. Formation of central cavity was not seen with this plain material; moreover the input material was made of formed material that had been formed homogeneously within its whole section.
4. PARTIAL CONCLUSIONS

Reading of work parameters was performed at a frequency of 1 second, which is insufficient with regard to the time of rolling (see fig. 6 to 8). Therefore the reading frequency was adjusted to 0.1 sec. Individual trends (relations of particular monitored parameters depending on time) showed values of the given parameter in % instead of the corresponding units - therefore subsequent calibration of all values was implemented. By comparing the speed of rolls and the final elongation of rolled products it is clear that the higher the rolling speed the greater the elongation of the rolled product (sample No. 1 was not included in the comparison as the position of the mandrel was changed for it).

Fig. 6 The course of torque values on the left and right work roll, sample 2

Fig. 7 The course of electric current values on the left and right work roll, sample 2.
5. CONCLUSIONS

As a part of solution of RMSTC project, an investment was realized called "Laboratory equipment for research of technological processes of seamless tube rolling". The laboratory workstation is equipped with a unique plant, the so-called universal rolling mill. This is unique equipment and there is not anything like that in the Czech Republic now. A similar plant for modelling in Central Europe is e.g. in the VFUP Institute (a society for promoting forming and production technology) in Riesa (Germany) [9]. It is assumed that the laboratory plant will be used for the processes of physical modelling of piercing or elongation for cross-rolling of seamless tubes. However, a successful completion of the whole investment project will require a number of adjustments of equipment and development of methodology, i.e. technology of testing on this equipment. The ascertained results will be subsequently verified in operational conditions of actual production.

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BIBLIOGRAPHY