CHARACTERISTICS AND POSSIBILITIES OF THE ROLLING LINE OF THE INSTITUTE OF METAL FORMING AND SAFETY ENGINEERING

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Abstract

The paper presents the characteristics and possibilities of a mill line based on a Duo D-300 mill located at the Institute of Metal Forming and Safety Engineering at the Czestochowa University of Technology. In 2012 year has been started new laboratory semi-industrial rolling mill. Through the years, basic 2-hi rolling mill with independent drives of each roll has been successive expanded of the innovative elements and equipment as fully mechanized and automated roller tables with regulation of the position or active heat shields of the rolled feed. In parallel, measurement and control system integrating all elements has been developed, based on programmable logic controllers. A full technical characteristic and research ability of this rolling mill system have been presented in this paper. With using it a lot of advanced experimental works and scientific researches in area of plastic working processes of metals has been conducted. The characteristic of a few most interesting works were described e.g. asymmetrical rolling of the plates, rolling with heat treatment of special steel grade for pipeline installations, rolling of preliminary explosively welded bimetals, including light weighted bimetal and tri-metals based on magnesium and aluminum.

Keywords: Rolling mill system, plastic working processes, asymmetrical rolling, bimetals

1. INTRODUCTION

In Faculty of Production Engineering and Materials Technology of Czestochowa University of Technology the semi-industrial rolling mill was built. Main element of mill is rolling stand duo 300 and air-water cooling device. A plan of laboratory mill arrangement is shown in **Figure 1**. The main equipment of this rolling system is 300x300 two-high reversing mill (1). Each roll has independent drive consists of electric motor (2), clutch (3), main gear (4) and shaft (5) horizontally symmetrical placed. On both sides of cage mill, two sections of roller bed are located (6). Over the each roller table, two section head shields (7) are placed. On extension of one conveyor, the cooling bed (8) with active zone of water air spray (9) is located. It is supply from compressed air and water pump station (10). An addition of cooling equipment is the quench bath (11). Drives of main motors and other control elements of the cage are integrated in main cabinet (12). Oil supply for hydraulic systems of rolling mill and conveyors is realized by hydraulic stations (13). Steering the working of the whole system is done from the control panel (14). Electrical equipment of roller tables heat shields and cooling bed are placed in steel cases (15,16) located next to them. The batch for rolling is heated in the electrical furnace (17). Operation of rolls exchange or other heavy services with help of the 2 Mg gantry is done (18). Total length of whole laboratory rolling system is over 14 meters. In the future, in the gap between roller table and cooling bed conveyor, the saw for hot strip cutting will be mounted.

During the process, the main parameters, as the rolling force and torque were measured and recorded. The force was measured directly by two 250 kN sensors (CL21 type, manufactured by ZEPWN Czerwinscy), placed between housings of bearings of upper roll and the set screws. Signal from each load cell was gained and conditioned by independent industrial instrumentation amplifier, CL100 type, to the voltage within 0-10V range. The rolling torque, separately for upper and down roll, was measured indirectly with using of feature of the main motors drives, ACS 800 type. On the analog output of RMIO boards installed on both frequency converters, the results of internal DSP calculation of motor torque as a function of angular speed and actual power was available as the current signal in standard 0-20 mA with 24 ms updating interval.

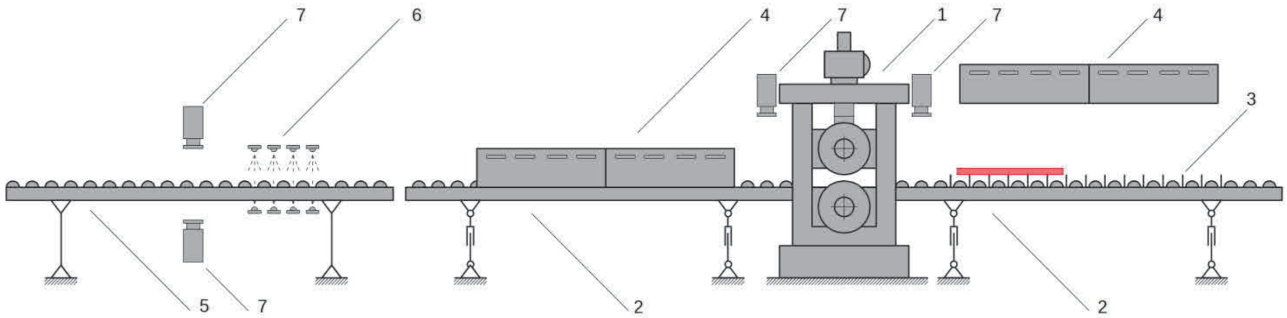

Figure1 Scheme of laboratory rolling mill arrangement

These all standardized signals were transferred to the analog inputs module of Vision V1210 programmable logic controller, to further processing, displaying and storing. In special subroutine, on the base of calibration function for each load sensors, the real value of rolling force has been calculated, Similarly, taking into consideration ratio of main gear (1:40) the rolling torque on the rolls was computed. Theses values on the PLC's screen were displayed and visualized as well as saved to the file with 100 ms interval.

Also the key issue from the point of view of new rolling processes development is monitoring of temperature of rolled strip. For technological reasons, continuous measurement can only provide non-contact methods [4]. Because it is important to also know the temperature profile across the width of the band's surface, applied on-line monitoring using infrared cameras, capable of measuring the temperature distribution in any of the selected line in the image. The four cameras, OPTRIS P160 (6) with heat shield and water proof (IP67) were used. Two of them were located over the inputs to the rolling mill, next two, were placed over and under the cooling bed.

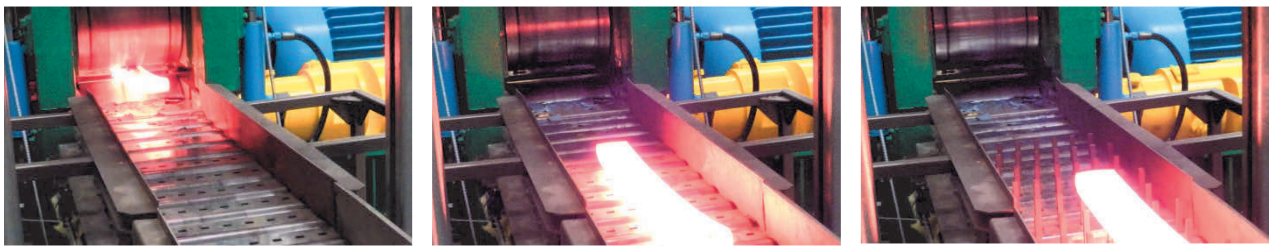

Figure 2 Sequence of rolling process with strip lifting between passes

2. PREVIOUS RESEARCH

2.1. Research on the asymmetrical rolling mill process

As a result of experimental research, the technology of asymmetric hot rolling of thick plates, which enables the control of the shape of the strand at the exit from the rolling mill, and thus obtaining the product with better geometrical parameters, was successfully verified based on numerical and physical modeling. The research work was carried out using the DUO300 reversing mill, maintaining the scale of the experiment and for the conditions of the initial and finishing cage with a roller diameter of 3600mm, for steel grades S690QL and S355J2G3, **Figures 2 and 3**. During the research, the effect of asymmetry of peripheral speed of rollers as well as the angle of application of the strand on its curvature as well as energetic and power parameters of the rolling process were analyzed.

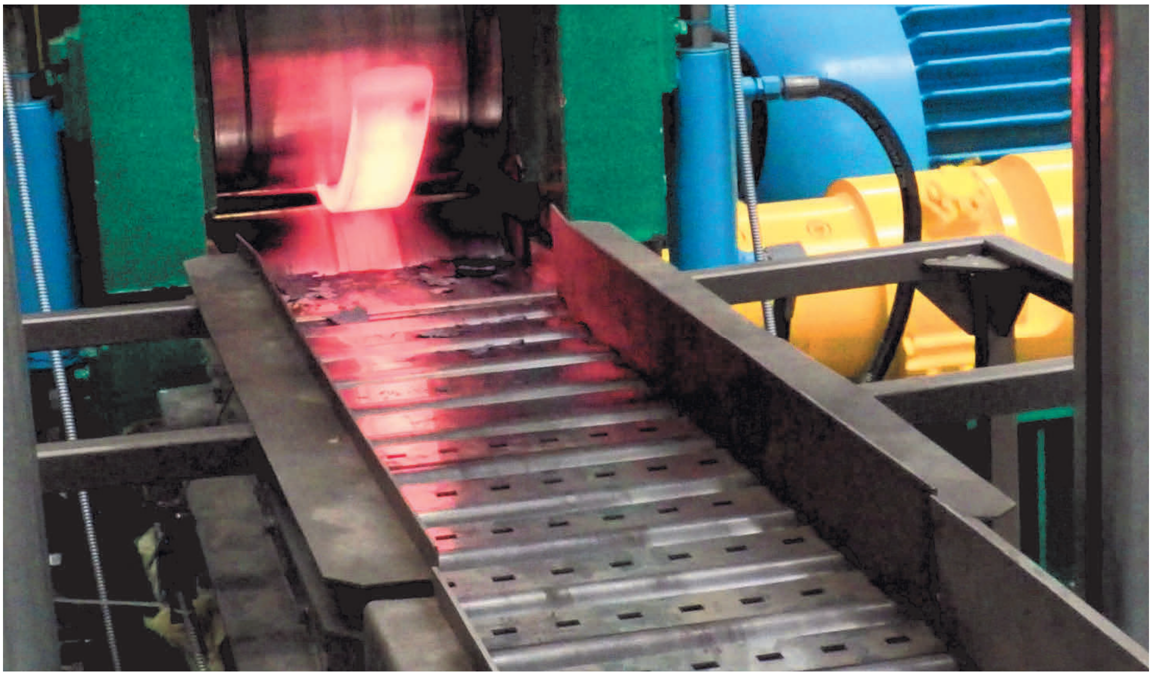

Figure 3 Example of rolling with critical asymmetry

2.2. Verification of assumptions for controlled rolling technology with accelerated cooling after sheet rolling according to API5L standards

The experimental verification of the developed assumptions concerning the technology of rolling rolling with accelerated cooling after rolling of sheets meeting the strength requirements for X80 and X100 pipe grades according to API5L standards (rolling and cooling schemes) confirmed their correctness, **Figure 4**. The obtained results, in terms of the microstructure or mechanical properties of the samples taken after the rolling process using the DUO300 rolling mill, coincide with the results obtained for the samples obtained in the physical modeling process using the Gleeble 3800 simulator.

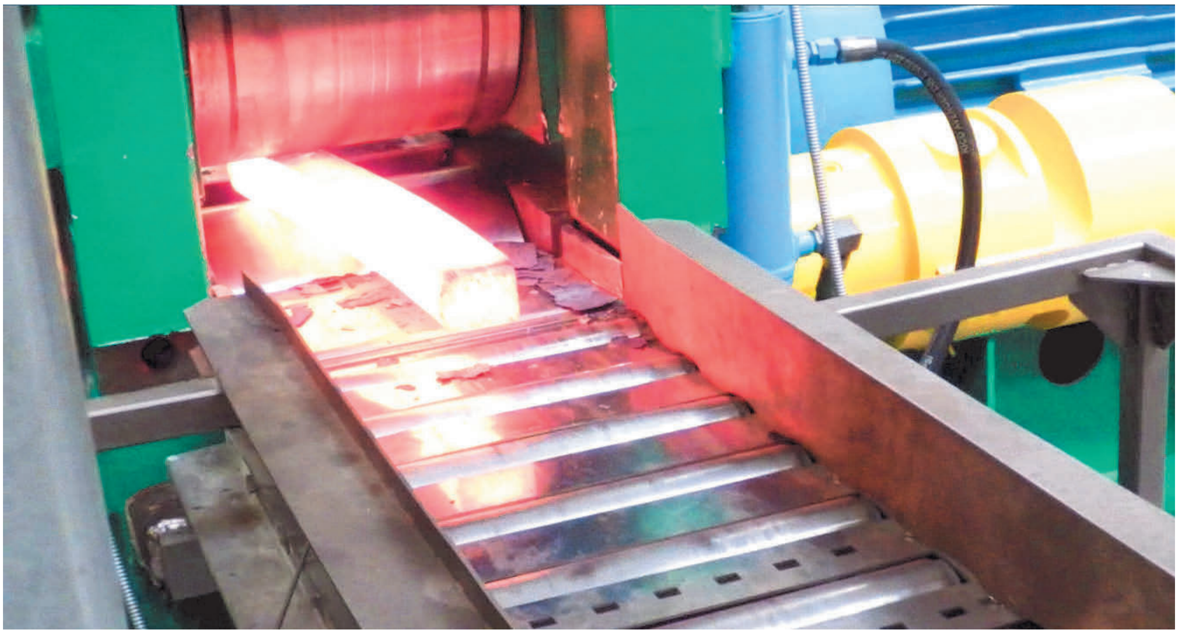

Figure 4 Example of rolling X80

2.3. Experimental tests of rolling magnesium alloy

Various variants of the AZ31 aluminum magnesium ingot, 50 mm high, blank in the form of sheet metal with a thickness of 3.5 mm were tested. The above works, aimed at determining optimal process conditions, included rolling on the DUO300 rolling mill, ingots with different deformation patterns and additional heating between the culverts. During these tests, the energy-force parameters of the process and the quality of the rolled charge were analyzed (delamination, appearance of cracks) after subsequent culverts

2.4. Investigations of the experimental Al-Mg-Al tri-metal rolling process pre-connected by an explosion

The starting material for experimental research was an experimental three-layer batch material consisting of two layers of aluminum alloy Al 1050 with a height of 3 mm separated by a layer of 20 mm magnesium alloy AZ 31, pre-connected with the energy of explosion. The research work was carried out using the DUO300 reversing mill. The scope of research included hot rolling (at an initial temperature of 420□C) for various deformation patterns in subsequent culverts and reheating between operations. As a result of the work carried out, semi-finished semi-finished products in the range of 9 - 10 mm were obtained for selected deformation patterns without delamination and cracks.

2.5. Research on the rolling process of magnesium sheets for components of bimetal products manufactured in ARB processes

As part of the experimental research, a hot plate rolling process was carried out with a thickness in the range of 3-4 mm from the AZ31 alloy with an initial height of 7.5 mm, for two batch patterns and additional heating between the gaps. These tests were aimed at selecting the optimal variant of the process conditions in terms of the quality of the final product enabling its further processing in the ARB process. During this research, the energy and power parameters of the process were also analyzed. As the most advantageous, the rolling variant was chosen in three passes ($7.5 \rightarrow 5.7 \rightarrow 4.6 \rightarrow 3.5$) with reheating (400° C) after the first culvert.

2.6. Research on the rolling process of three-layer thick plates made of magnesium alloy, aluminum plated on both sides

As part of the work, a hot rolling process was carried out on AZ31 magnesium alloy plates clad on both sides with an aluminum alloy series 1000 which were carried out on a load with a percentage share of the layers: AZ31 76% and 2 × (Al 12%). As a result of the tests, a positive verification of the assumptions about the possibility of rolling flat products from this type of trimetal, which could be used in the aviation and automotive industries, was made. During the laboratory tests, optimal conditions and a scheme for conducting the rolling process were determined, allowing to obtain a sheet with a final thickness of 10 mm without tears or cracks in the joint area. The process was also evaluated in terms of energy and strength parameters.

2.7. Research on the process of rolling trimetal sheets from aluminum alloys pre-connected with an explosion.

The starting material for experimental research was an experimental three-layer batch material for thin sheet metal production for the automotive industry, consisting of three layers of 5000, 1000 and 2000 aluminum alloys with a percentage of 52%, 13% and 35% respectively, pre-connected with energy explosion. The scope of the research included hot rolling of the 69 mm height (at an initial temperature of 500□C) for different deformation patterns in subsequent culverts and reheating between operational ones. As a result of the work carried out, for the selected deformation patterns, the semi-finished product was obtained for further processing, four times reduced, characterized by the absence of delamination and cracks in the joint zones. The tests carried out thus showed the possibility of deformation of this type of materials. At the same time, it was found necessary to introduce asymmetry in the peripheral speed of the rollers in the rolling process in order to obtain a straight band.

2.8. Research on the process of rolling bimetal plates resistant to corrosion for applications in geothermal installations

As part of the work, preliminary tests were carried out, necessary to carry out the commissioned research work entitled "Numerical, physical modeling and rolling of bimetallic corrosion-resistant plates produced by the explosive method for applications in geothermal installations" during which initial experimental verification of the assumptions of puters, number of bushings or asymmetry ratios in which the rolling process should be carried out correct geometry and final thickness of 4mm. The research concerned the rolling of bimetal bits of 13mm thickness pre-connected with an explosion consisting of a base layer made of P355NH steel and plating layers of high-strength alloys based on nickel, molybdenum and chromium, corrosion-resistant austenitic steels, including high-alloy and austenitic-ferritic super-high alloys duplex. As a result of the work, semi-finished products in the form of sheets with correct geometry and assumed thickness from 4mm to 5mm were obtained.

2.9. Experimental verification of numerical control modeling results in the bimetal sheet rolling process with their shape and mechanical properties

As a result of experimental research, the asymmetric rolling technology, based on numerical modeling, has been positively verified, allowing the shape and mechanical properties of bimetallic plates to be controlled. The tests were carried out on a bimetal batch of which the 10 mm thick base layer was 10CrMo9-10 steel and the 2 mm thick cladding layer made of X2CrNiMo17-12-2 steel. During the rolling of the starting material in a symmetrical process, highly bent samples were obtained as a result of uneven plastic flow of individual bimetal layers. However, in the asymmetric rolling process, with the parameters determined in the analysis of the numerical modeling results, i.e. with the velocity asymmetry av = 0.75 and σ = 18%, the desired straight strip was obtained at the exit from the roll gap. Based on the metallographic examinations of the processed samples, it was found that after asymmetric rolling, finer grain with an average size of 22μm was obtained rather than after symmetrical rolling, after which the average grain size was 33μm; which is a predictor of improving the mechanical properties of sheets rolled in this way. During the tests, energy and power parameters of the process were also recorded, on the basis of which a nearly 20% decrease in the rolling force in the asymmetrical process was found.

2.10. Research on the experimental asymmetric rolling process

During the research carried out as part of international cooperation, an experimental hot-asymmetrical rolling process was carried out (at 1000 ° C) of ferritic-pearlite steel sheets with high velocity asymmetries of the upper and lower roll av below 0.8. As a result, bands characterized by rolling with a significant radius of curvature were obtained. Based on the analysis of the experimental data, it was found that the desired asymmetry ratio 0.75, in real conditions, is reduced to 0.85, due to the mutual interaction between each other through the rolled band of independent drive systems of the upper and lower rollers. The obtained test results are the starting point for further research in the real control area as the asymmetry factor during the process. As part of the research carried out at this point, a comparative process of symmetrical rolling was also carried out. During it, in further passages, rolling was carried out with large crushes, for which the rolling force was at the level of maximum parameters.

3. CONCLUSION

The mill line presented at the Institute of Metal Forming and Safety Engineering at the Czestochowa University of Technology is a unique set of devices enabling the verification of newly designed rolling technologies for flat products in a wide range. A number of works carried out with the use of the presented rolling mill confirm its wide application. Roller duo reversible with independent drives of each roller is successively extended with innovative elements such as fully mechanized and automated loading and receiving receipts with position regulation and active thermal shields allows for controlled rolling along with heat treatment. The integrated measurement and control system integrating all elements, based on programmable logic controllers, enables precise process control.

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