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Garstka T.
Dyja H.
Laber K.
Koczurkiewicz B.

EXPERIMENTAL STUDY OF THE POWER PARAMETERS IN ROLLING PROCESS OF HIGH CARBON STEEL WIRE ROD

The increase in demand and requirements for quality of steel wire rods over several decades were a factor in stimulating the continuous works on development of its manufacturing at stages of steelmaking & casting and rolling as well as process monitoring and control [1, 2, 3]. Contemporary rolling mills of steel wire rod are characterized by capacity of production on one strand over 100 Mg per hour and finish rolling speed exceeding 100 m/s (360 km/h) with very good dimensional tolerances and surface characteristics. This high performance was achieved with using advanced No-Twist Mill® (NTM) and Reduce Sizing Mill® (RSM) equipment machinery (Fig.1) originally produced by Morgan Company [4].

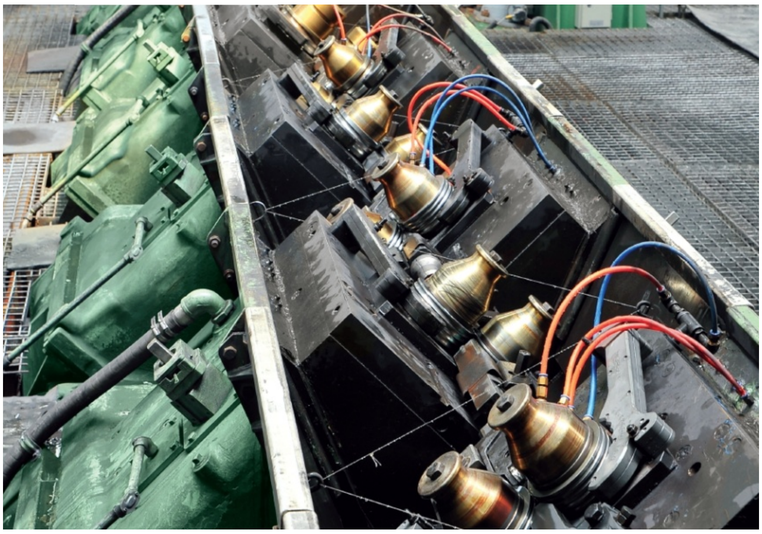

Fig. 1. A view of NTM Morgan rolling mill block [4]

In the last years, further development is determined also by the request of minimizing post-production additional operation as annealing or drawing by secondary manufacturers producing final products. It let to reduce and optimize costs as well as contribute to natural environmental protection [5]. In conditions of modern, high-speed wire rod mills offering wide range of possibilities of control of production process and its parameters, it is achieved by modifying existing and developing new technologies. That trend fits research project carried out at Faculty of Production Engineering and Materials Technology of Częstochowa University of Technology, aimed at development of new, proecological production technology of high carbon steel wire rod which let to obtain desirable microstructure without of patenting treatment and thereby to provide good conditions for further plastic working in drawing process [6, 7].

One of the stages of these investigations are measurements and analysis of power and force factors of rolling process in industrial conditions, providing information to characterize and comparison of modernized production technologies as well as to obtain data input for mathematical modeling and simulation of steel wire rod rolling and their verification

A flowchart layout of relevant high-speed rolling mill was shown in Fig.2 Whole rolling process can be divided into two stages: conventional rolling in medium section H/V system mill and finishing rolling in specialized Morgan blocks.

Continuous rolling line is divided into 3 sections:

- roughing mill with group of seven roll stands;
- intermediate mill with group of six roll stands;
- pre-finishing mill with group of four roll stands.

Between each group of stands are installed shears in purpose to emergency cutting as well as cutting off endings of rolled band. Rolling in stands no. 2 – 10 is realized with tension, in other stands with loop.

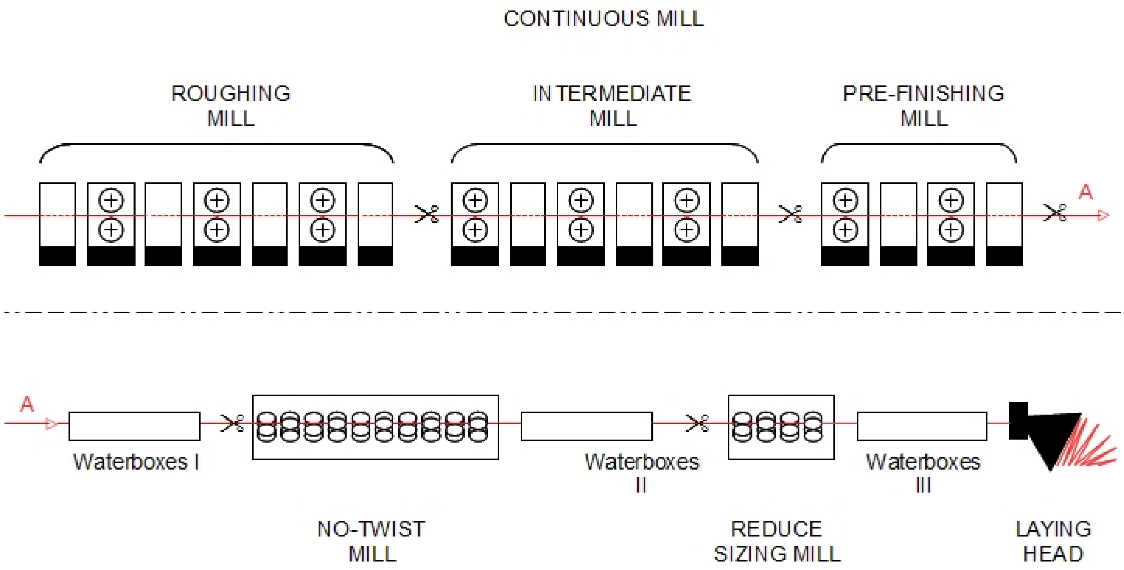

Fig. 2. Layout of analyzed wire rod mill

During the rolling of high carbon steel wire rods with final diameter 5,5 mm, after last seventeenth stand, rolled band with speed about 7 m/s is fed up trough the set of water boxes to the two integrated Morgan rolling block. The NTM consists of one strand system of small diameter ring rolls mounted on endings of the shafts, alternately at angle ±45º to the horizon level (Fig.1).As a result they create arrangements like known H/V configuration of roll stands and eliminates necessity of twisting the rolling band between oval – round passes. Single main motor drives the rolls trough the two main shafts and a lot of gearboxes enclosed in a compact housing. In this rolling block the band is under high deformations rates in succeeding ten passes and the output speed of the band is about 70 m/s. Due to high increase of temperature in this block, the rolled band must be cooled in the second sections of water boxes.

Next in rolling line is four stands RSM block. It has similar idea of construction with single drive and rolls arrangement. The two first passes are responsible for the reduction for controlled rolling and the next two, adjustable during process are used for small reduction for precise sizing. The final linear speed of the band on the output of RSM is above 100 m/s [6].

Finally, after the cooling in third set of water boxes, the band is passed to the laying head of the ring former and further heat treatment on STELMOR conveyor [6].

Each stand in continuous mill as well as NTM and RSM rolling blocks are driven by independent electrical AC motors powered by modern frequency converters to flexible control of rolling speed. The high accuracy of control and quick response on load of motors drivers let to be at the present time a source of reliable information about momentary parameters of motor, e.g. torque and can be propagated indirectly on some parameters of rolling process, too. In heavy, industrial conditions, it is very often only way to estimate the rolling torque.

Momentary values of motor parameters calculated by the processors in the frequency converters are distributed on standard outputs or via industrial network. In analyzed rolling mill plant two independent systems of data acquistion has been established. One is dedicated for continuous rolling mill line (sampling rate 20 ms) and the second for NTM and RSM blocks monitoring (sampling rate 50 ms). Both capture not only data of drives but also information about temperatures, speeds, flows and pressure of cooling medium as well as other parameters of the rolling process. For high speed measurement e.g. of entry of the band to the rolls dedicated service software may be used with 1 or 2 ms accuracy [8].

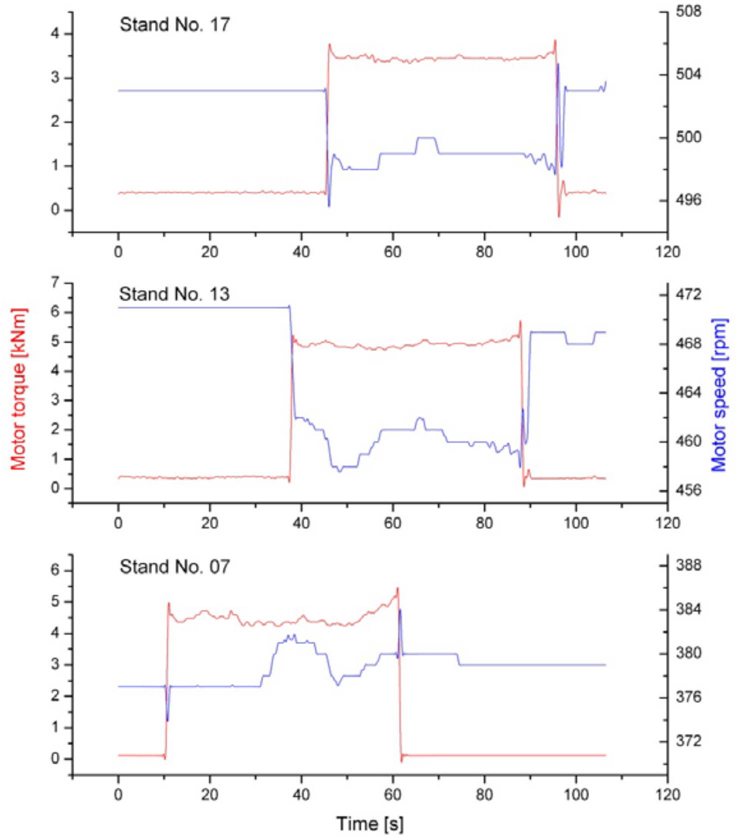

Fig. 3. Example of torque and rotation speed of motors in selected stands

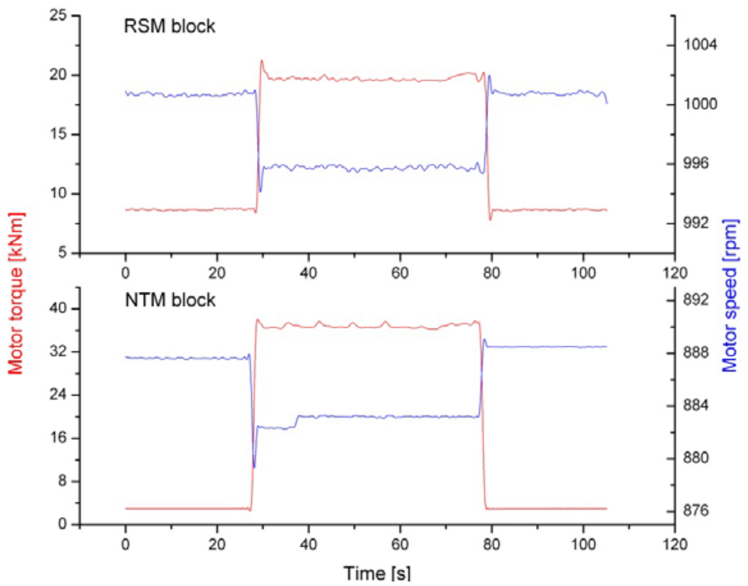

Fig. 4. Example of torque and rotation speed of motors in NTM I RSM block

During the presented study, the four feed stocks with 7meters length were rolled. They were made from C70 steel grade [6], the same as used during normal production of steel wire rod. Example of collected experimental data of motor in chosen roll stands, in each of sections of continuous mill were presented in Figure 3. On these plots changes of rotation speed and torque were shown as essential for further calculations. Their courses are typical, with good visible moments of entry and output of the band and also changes connected with the changes of its temperature. Taking into consideration ratio of gearboxes between motors and rolls, torque of rolling in each stand was calculated. It should be understand although idle torque was subtracted, these values are still affected by additional torque in bearings during rolling pass. Obtained results were shown in bar diagrams in Figure 5 with added rolling speed profile. The highest torque – 147,7 kNm occurred in fourth stand and then diminishes in the next while the speed increasing. These results are in good correlation with preliminary study [7].

Analogical courses of torque and rotational speed for NTM and RSM drives were shown in Figure 4. In these rolling blocks, from the point of view of the drive motor, coupled stands are as visible as one stand. Due to being still recognized torque distribution between particularly stands, depended of a lot of factors, value in their passes were not presented in this paper.

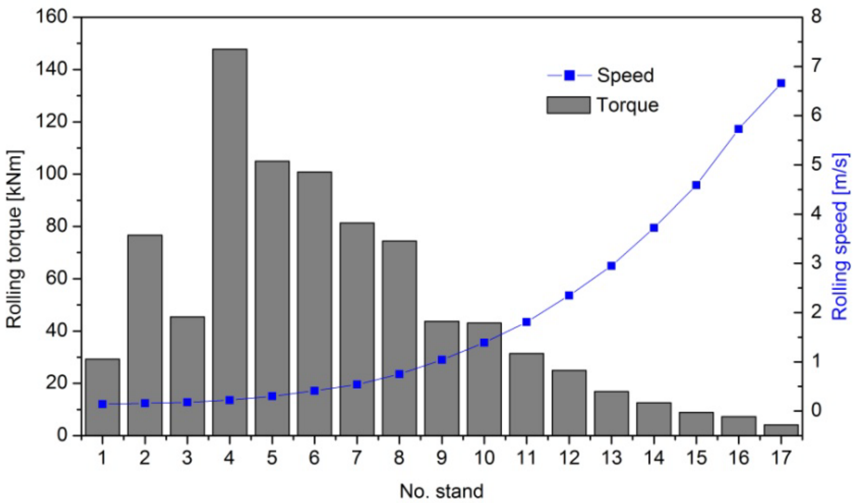

Fig. 5. Rolling torque in particularly stands with rolling speed profile

Based on the collected data of torque and rotational speed, value of momentary power of rolling for each sample was calculated from formula:

$$P_r = (T_r - T_i) \cdot \frac{2\pi \cdot n}{60},$$

where P_r – power of rolling; T_r – torque during rolling; T_i – torque during idle time; n – motor speed in [rpm].

From these values, averaged power in each passes was determined, presented in the Figure 6. In stands No. 4 – 17, mean power was 207 kW

Summarized results of power calculation for continuous mill and NTM and RSM block were collected in Table 1. In relation to the main motor power of these rolling blocks it is respectively 48% and 33%.

Table 1

Summarized rolling power

	Continuous mill	No-Twisted Mill	Reduce-Sizing Mill
Power	2,98 MW	3,15 MW	1,20 MW

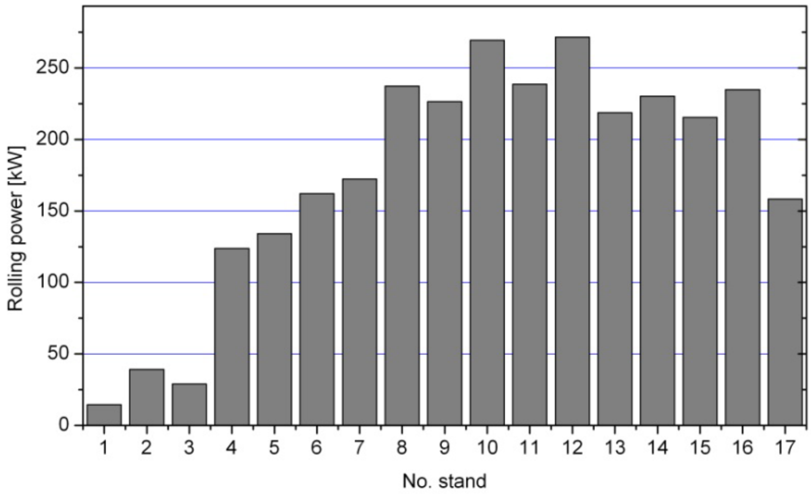

Fig. 6. Rolling power in particularly stands

During the investigations also the influence of temperature of rolled band on NTM motor torque was analyzed. Quick response of frequency converter on torque load changes (about 3ms) [8] let to analyze fluctuation of torque with quick changes of temperature. In Figure 7 comparison of temperature profile of the rolled band measured before entry to the NTM and of motor torque was presented. For better visibility the temperature scale was inverted. As can be observed, changes in torque very good related to temperature variations [9].

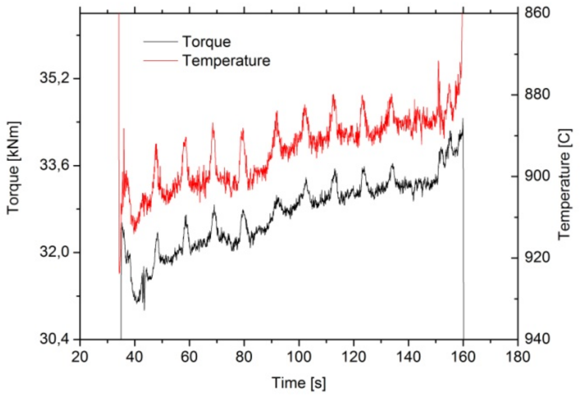

Fig. 6. Changes of NTM motor torque and band temperature during rolling

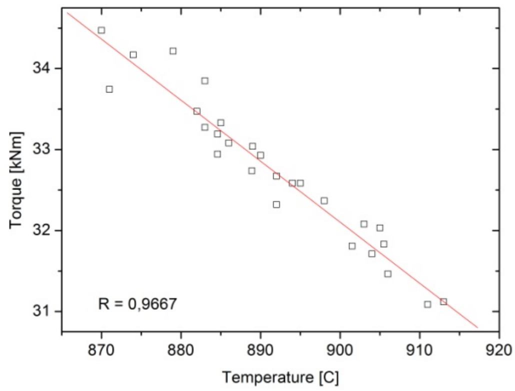

Fig. 7. NTM motor torque *vs* temperature of the rolled band

In Figure 7, dependence of NTM motor torque with temperature of the rolled band for some captured samples was presented. Torque was found to increase about 10% with decreasing of temperature from 910 °C to 870 °C. These changes can be approximated with good accuracy (R = 0,9667) by equation:

$$Torque = -0{,}07536 \times Temperature + 99{,}92$$

SUMMARY

An industrial investigation of the power parameters during rolling of high carbon steel wire rod 5,5 mm diameter was carried out. As the effect of this study torque and power of rolling were determined. On this base, rolling force can be calculated in the future. The influence of the rolled band temperature on summarized rolling torque in NTM, reduced to shaft motor was studied too and the relationship between them was found. This dependence will be used for better materials characterization at high rate of deformation. All received results, beside of production processes characterization and comparison under e.g. energy consumption will be also used as input data for mathematical modeling and simulation of high carbon steel wire rod rolling and their verification.

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Garstka T. – Częstochowa University of Technology, Faculty of Production Engineering and Materials Technology, Institute of Plastic Working and Safety Engineering Częstochowa, Poland;

Dyja H. – professor, Czestochowa University of Technology, Faculty of Production Engineering and Materials Technology, Institute of Metal Forming and Safety Engineering, Czestochowa, Poland;

Laber K. – doctor, Czestochowa University of Technology, Faculty of Production Engineering and Materials Technology, Institute of Metal Forming and Safety Engineering, Czestochowa, Poland;

Koczurkiewicz B. – doctor, Czestochowa University of Technology, Faculty of Production Engineering and Materials Technology, Institute of Metal Forming and Safety Engineering, Czestochowa, Poland.

E-mail: tomasz.garstka@wip.pcz.pl

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