METABK 55(1) 79-82 (2016)
UDC – UDK 621.41.1:539.416:669.5:531.78:6=111

A METHOD FOR THE SELECTION OF CERTAIN FORCE AND ENERGY PARAMETERS OF AUTOMATIC SHEET METAL COILING MACHINES

Received – Primljeno: 2015-03-03
Accepted – Prihvaćeno: 2015-07-10
Preliminary Note – Prethodno priopćenje

The paper concerns issues related to the sheet coiling process on processing lines. The industry's needs and requirements for semi-finished products in the form of coil sheets are presented. The paper also discusses the results of the calculations of selected force and energy parameters of devices for coiling sheets made of a zinc-titanium alloy. The presented results were obtained based on calculations and a practical verification of the adopted assumptions using newly-designed devices introduced into operation.

Key words: coil sheet, Zn-Ti alloy, sheet coiling machines, force, energy

INTRODUCTION

The technological development and progress of the automation of processing necessitates the use of stock supplied on a massive scale. Currently, a majority of production in the automotive, construction, power engineering, home appliance, agricultural and food industries, as well as related industries, is based on stock in the form of cold-rolled sheets. Working on this type of stock increases the efficiency of the process. Furthermore, the use of systems, such as coil accumulators and assemblies for joining strip ends, ensures the uninterrupted operation of a processing line.

In the current market situation industry needs high-performance devices with low energy consumption. Every design error entails losses in the future caused by breakdowns, equipment downtime and excessive power consumption, etc. For this reason it is important to carefully review the design solutions and correctly analyse the force and energy parameters of the devices, while taking into account the material, especially its properties.

The wide range of machines and devices operating in the industry generates various needs and requirements concerning coil stock [1-5]. An important issue during coiling is the correct arrangement of coils, ensuring flat lateral surfaces of a coil and the correct level of friction between coils, which influences the stability of the their shape (Figure 1).

The paper presents a method of selecting basic engineering parameters of automatic sheet coiling devices, along with a thorough analysis of force and energy parameters. This method, verified in industrial conditions, is a basis for a good engineering design of a device which ensures the high quality of a coil to be manufactured.

M. Stańczyk, T. Figlus, The Silesian University of Technology, Faculty of Transport Katowice, Poland

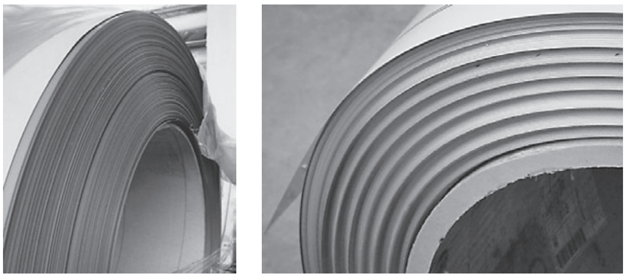


Figure 1 Coil winding errors

SHEET COILING DEVICES

Sheet coiling machines almost always work on a processing line. Most often they can be found on automatic sheet cutting lines. Standard systems of this type are built of modules consisting of: decoiler with a coil loading system, feeding system, leveling machine, slitting shear, cross shear, stress relief system (loop pit), brake, coiler with a coil unloading system.

Comprehensive processing lines can be further expanded by adding modules which increase their versatility and processing capabilities. Figure 2 shows an example of a sheet cutting line with a coiler, while Figure 3 shows an example of a coiler design solution.

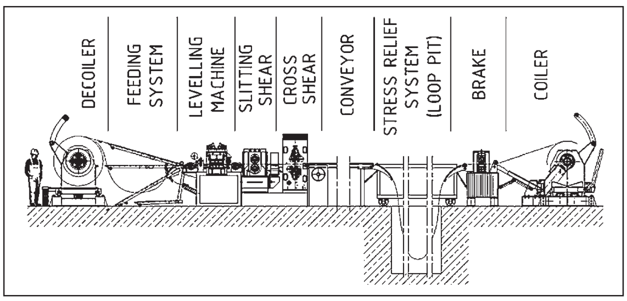


Figure 2 Coiled sheet metal cutting line [6, 7]

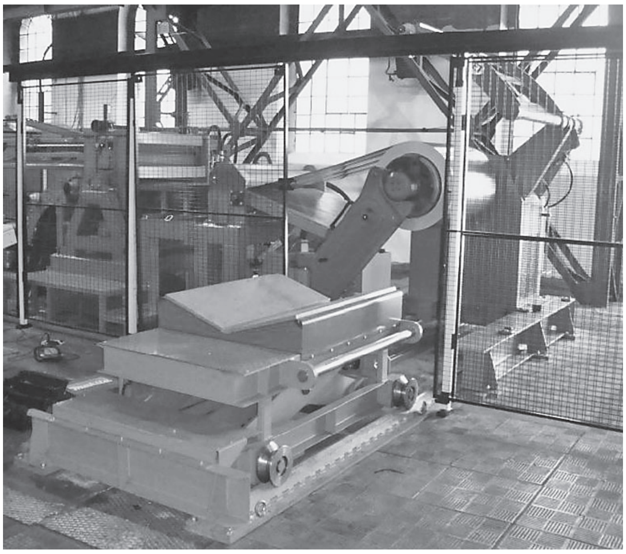


Figure 3 General view of a coiling machine made by the Inmet company [7]

Sheet coiling devices may have a number of different design solutions, including: drum stress-relieving and strip-locking systems, drive transmission, etc. Generally, it should be assumed that sheet coiling machines ensure:

- the locking of the beginning of a strip on a drum or an intermediate element;
- the winding of strips, while taking into account: speed, acceleration (during the start-up of empty and preliminarily loaded drums), tension, shape quality (lateral edge and interior opening),
- removal of a wound coil from the device.

FORCE AND ENERGY PARAMETERS OF SHEET METAL COILING MACHINES

Accurately determined power and energy parameters ensure the correct selection of the device's drive unit, optimum energy consumption, smooth operation, and compatibility with other devices on a processing line. The following factors should be taken into account when specifying the main parameters of sheet coiling systems, such as power and torque:

- coil parameters (geometry, mass, required internal and external diameters, material type and its properties…);
- speed and acceleration values in the system (linear and centripetal acceleration values, as well as acceleration resulting from acceleration times);
- system resistance (which includes variable drum load, resistance in bearings and tension resistance, etc.);
- required level of strip tension (which includes strip width and thickness, as well as material properties);
- required drive parameters (which include the possibility to accelerate the system to the target speed within a specified time at full load, motion resistance and the required tension force for the max. stock geometry).

Based on an analysis of literature data, it can be concluded that there are no detailed guidelines concerning the selection of the listed parameters of the sheet coiling line.

In the further part of the paper, a method (which was verified in practice) is presented of selecting the above-mentioned basic engineering parameters of sheet coiling devices, along with an analysis of force and energy parameters.

DESIGN ASSUMPTIONS AND CALCULATION RESULTS

The design assumptions included in Table 1 were adopted in the study.

Table 1 **Design assumptions**

Coil parameters	
D – coil external diameter	1 300 mm
d – coil internal diameter	500 mm
b – coil (strip) width, min. / max.	180 / 1 000 mm
h – stock strip thickness, min. / max.	0,5 / 1,5 mm
Stock material properties [8,9]	
Stock type	sheet Zn - Ti
$R_{0,2}$ wg EN-988	min. 100 N/mm^2
R_m wg EN-988	min. 150 N/mm^2
A_{50} wg EN-988	min. 35 %
g – alloy density	7,20 g/cm^3
Processing line parameters	
v – max. (target) linear velocity	70 m/min
t_{ms} – time of acceleration to the max. speed	5 s
max. permitted strip tension	5 % $R_{0,2}$

Based on the adopted assumptions, the further part of the paper presents a method of selecting basic parameters of sheet coiling devices, along with calculation results.

Coil mass is determined by taking into account basic geometric parameters and alloy density. This value directly affects the selection of the parameters of a drive system, and the durability of the structure. Figure 4 shows the described dependence.

Coiling speed and acceleration values constitute an important aspect from the point of view of the selec-

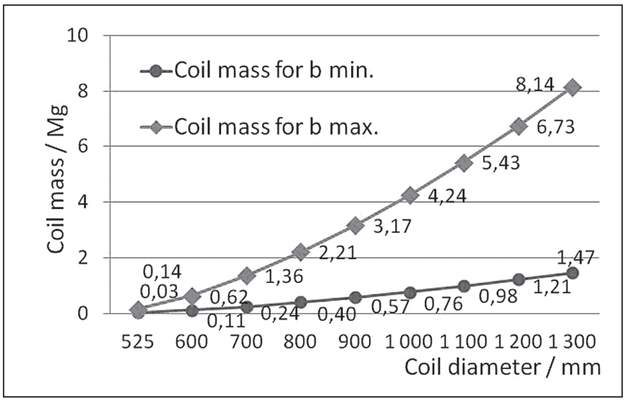


Figure 4 Dependence of the coil mass on the external diameter

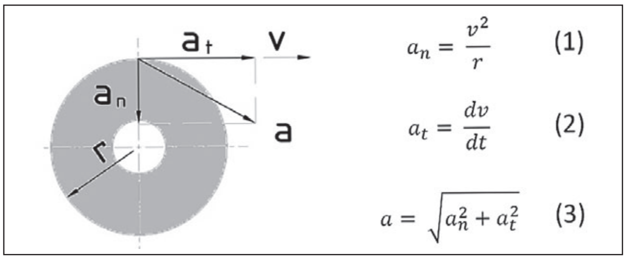


Figure 5 Acceleration values prevalent in a coiling system

tion of the drive of a device. In order to determine the above-mentioned values, among others time interval dt should be adopted during which the device will reach target speed $v_2 = v$ from the start-up time ($v_1 = 0$). The drive should make it possible to accelerate the system within the assumed time regardless of the initial mass of a coil already wound on a drum (conditions resulting from planned and unplanned down times of the device). When acceleration times, target speed, temporary geometry and mass of the coil are known, acceleration constituents are determined based on dependences (1÷3) described in Figure 5.

For the adopted main performance parameters linear acceleration a_t is at a steady level of 0,23 m/s^2. The two other constituents are at a similar level, as shown in Figure 6. It should be noted that the presented dependence describes acceleration values in a braked and accelerated system at a selected point in time during coil winding. Due to the fact that maximum acceleration values are the most important ones in the system, centripetal acceleration a_n is determined for the target speed. The value of linear acceleration a_t depends to a large degree on the adopted acceleration time.

Motion resistance and strip tension are affected, inter alia, by:

- friction forces in bearing systems,
- forces resulting from the required strip tension,
- forces caused by the acceleration of the system.

In view of the diversity of bearing systems of sheet coiling devices and the negligible role of friction forces in bearings compared to other constituents, these values can be omitted at the initial calculation phase. These forces are included in Figure 9 in order to illustrate their role in the selection of the drive. The most important value, which directly affects the geometric quality and stability of a coil, is the strip tension force. Tension is the result of the correlated cooperation of two assemblies, i.e. the brake and winding units. Brake systems have varied designs and use different methods of generating the braking torque. Regardless of the type of the used brake, selecting the braking force in such a manner that the system operates in optimum force and energy conditions is problematic. Excessive tension results in increased power consumption, overheating of drive subassemblies and, in extreme cases, damage to devices or the stock material. The problem intensifies as the geometry of the coiled sheet decreases. Generally, in the case of strongly elongated plastic materials and narrow strips, stock may stretch or break. The method of determining tension in this paper is based on constant stress induced in the coiled strip. This assumption makes it possible to wind a coil at an identical level of stress induced in the material, regardless of the temporary diameter of a coil.

Currently there are no studies based on which the stress level can be selected which ensures the correct strip tension when coiling sheets. This parameter is determined experimentally; the maximum level of 5 % $R_{0,2}$ was adopted for the analysed case. It can be assumed that a production line operator can adjust the tension which induces stress in the wound sheet from 0 to 5 % $R_{0,2}$. Figure 7 illustrates the dependence of the tension force on strip thickness. The characteristics cover extreme widths of the wound strip as well as intermediate ones: 500 and 750 mm.

The device drive, and therefore the need for power and torque of the drive, determine the constituents of all motion resistance in a system. The device must reach the target operating speed within a specified time. Furthermore, one of the most important pieces of data is the braking torque generated by the tensioning system. In view of this, determination of the required driving torque on the shaft of the coiling machine is justified. The paper is limited to the presentation of the results of the calcula-

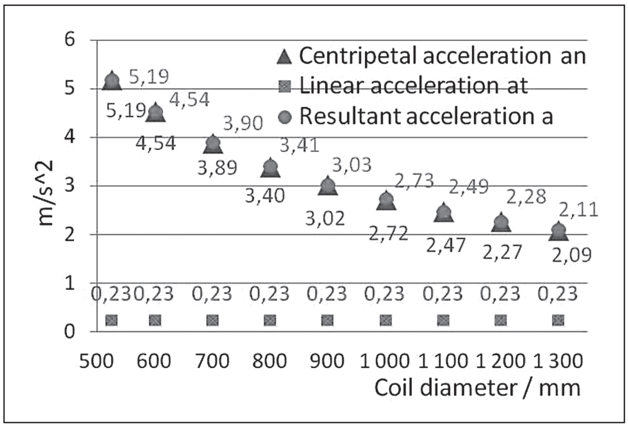


Figure 6 Dependence of acceleration values prevalent in the system on the external diameter of a coil for a system accelerated at any point in time

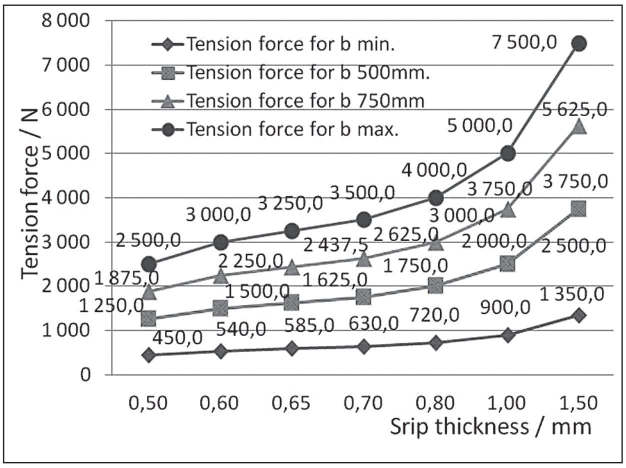


Figure 7 Dependence of tension on strip thickness 180, 500, 750, 1 000 mm

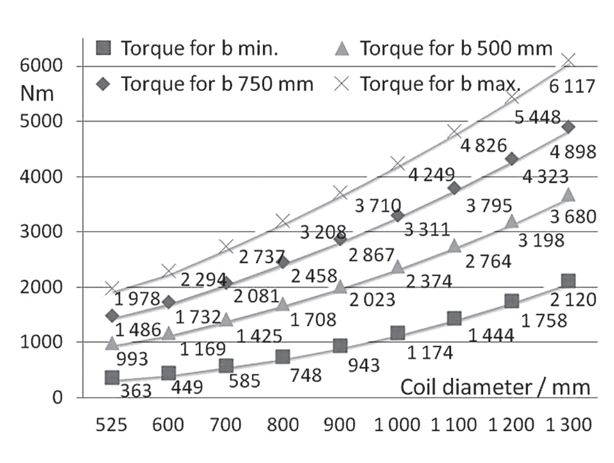
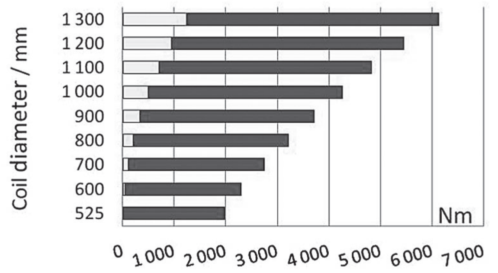


Figure 8 The dependence of the required torque at the shaft of the coiling machine on the external coil diameter for various strip widths



	525	600	700	800	900	1000	1100	1200	1300
braking torque from acceleration	9	44	111	206	333	495	697	942	1235
braking torque of the bearing system	0,2	0,6	1,2	2,0	2,8	3,7	4,7	5,8	7,1
braking torque from strip tension	1969	2250	2625	3000	3375	3750	4125	4500	4875

Figure 9 Share of the main braking torque values depending on the external coil diameter for the maximum strip thickness and width

tion process of force and energy parameters of the device. Figure 8 shows the dependence of the required torque at the shaft of the coiling machine on the external coil diameter.

It was assumed that regardless of the temporary coil diameter the device could be stopped and accelerated to the target speed. The characteristics were determined for the maximum thickness of the coiled sheet as well as the assumed target speed and the time until it is reached. Basic braking torque values resulting from the acceleration of the device were taken into account, as well as braking torques in the bearing system and the required strip tension. Figure 9 also shows characteristics in which individual motion resistance values are singled out. The characteristics were prepared for the maximum thickness and width of the coiled sheet.

CONCLUSIONS

When analysing the presented force and energy parameters of devices for coiling sheets into coils it is relatively easy to determine the basic energy parameters of a device. Naturally, every discussed case should be treated individually and needs to be subjected to a detailed calculation analysis, which takes into account a number of factors, including: type, dimensions and properties of the stock sheet, operation speed in the production line system, and many others. Assuming that tension is an important parameter from the point of view of sheet coiling quality, a very broad range of the operation of a device can be clearly read from Figure 7. The required tension for the narrowest and widest strips ranges from 450 to 2 500 N for thin sheets (circa 0,5 mm) and 1 350 ÷ 7 500 N for 1,5 mm thick sheets. The required torque on the shaft of a device can be determined based on Figure 8. For 1.5 mm thick sheets the value of the required torque ranges from 363 to 6 117 Nm. The paper presents selected force and energy parameters, while taking into account the principal values which affect their levels. It should be noted that the quality of the finished product is to varying degrees affected by numerous other factors, which need to be analysed and subjected to industrial verification. Due to the fact that there are no detailed design or parameter guidelines for machines of this type, it should be assumed that the discussed subject is evolving, and further research, as well as process analyses, should be conducted.

REFERENCES

[1] N. Wellmann: New trends in research on sheet metal working, Technologies to Maximise Productivity in Sheet Metal Working / BLECHbuisness 2007 Conference 27-29 November 2007 in Warsaw; 9-21.

[2] K. Stahl: Stamping and forming machines for new steel grades, Technologies to Maximise Productivity in Sheet Metal Working / BLECHbuisness 2007 Conference 27-29 November 2007, Warsaw; 103-117.

[3] B. Gajdzik: World class manufacturing in metallurgical enterprise, Metalurgija 52 (2013) 1, 131-134.

[4] M. Boldys, M. Stańczyk: The influence of the steel chemical composition onto the possibilities of using it in the process of cold shaping, Transport Problems 2 (2007) 3, 81-91.

[5] G. T. Halmos: Roll Forming Handbook, CRC Taylor & Francis Group 2006.

[6] Technical documentation Inmet Company, www.inmet.com.pl.

[7] Technical documentation Matio Company, www.matio.pl.

[8] EN988 Zinc and zinc alloys. Specification for rolled flat products for building.

[9] EN1179 Zinc and zinc alloys. Primary zinc.

Note: The responsible translator for English language is A. Nowak, Chorzow, Poland