Automatic Control of Functional Parameters to an Stretch-Reducing Tube Mill

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Abstract: - This paper presents the drive solution, the requirements for dynamic behaviour of the speed regulated drives and the automation structure for a stretch-reducing mill for seamless having 28 rolling stands organised in three separate functional groups. The application have been designed, executed and putted into operation in a seamless tube mill modernised in the last years.

Key-Words: - Strench-reducing mill, automation control, hardware structure

1 Introduction
The steel pipes can be manufactured by two methods:
- obtaining a cylindrical body out of strip, then welding the body through various procedures;
- hot-perforating a solid body, after which, through successive rolling operations, the material is plastically deformed to the established finished product dimension [1,2].

With both manufacturing methods, the rolling tools and rollers - suitably accorded - give the pipe geometry. In practice, given the pipes’ extensive dimensions range, especially in the area of mid-sized and small pipes, obtaining a large range of dimensions only through the rolling line is difficult [4].

A modern manufacturing procedure was developed, which, starting from a limited number of blank dimensions on the rolling line, allows the obtaining of a large range of decreasing dimensions, using an operation that is particularly advanced from the technical, technology and production costs points of view. It consists of the successive reduction of the
external diameter of the pipe obtained on the rolling line, through a series of stands with tandem rollers, simultaneously with the material’s elongation between the stands, to reduce the pipe wall thickness [3].

Stretch-reducing mills are an important progress in pipe manufacturing, because they are used both for seamless pipes and for welded pipes. Since their apparition – the first reducing mill was built in 1920 – the stretch-reducing mills’ construction was improved successively, with remarkable consequences in terms of pipe quality and productivity.

Thus, modern stretch-reducing mills allow a pipe wall reduction of up to 35-40% (without any interior tool) and an outer diameter reduction of up to 85%, as a result of the material being subjected, during the reduction, to axial strains that exceed the hot metal’s flow limit.

The elongation is actually achieved by applying rotation speeds that are increased successively from stand to stand. In order to evidence more clearly the importance of the rollers’ speed, we will present in brief the basics of the calibration calculation method for stretch-reducing mills.

The blank pipe diameter and wall thickness that are optimal for the finished pipe will be determined first. Then there will be determined the number of rolling stands required, taking into account the maximum reduction per stand, which depends on the mill’s construction and the base speeds, respectively the rotation speeds that assure the constant wall thickness during the reduction. To the base speeds established by calculation there will be added, at each individual stand, the additional speed that provides the traction required for the wall thickness reduction and the reduction of the thicker pipe ends [5].

This paper shows the method of speeds determination and the basic automation of the stretch-rolling mill.

2 Problem Formulation

2.1 Speed control

The 4-motor drive consists of two drive groups which are mechanically separated from one another and, therefore, allow effective crop end control (CEC) even with close sequences of tubes. For this purpose, the entry mill stand group features exceptionally high gear ratios to obtain particularly large elongations (Figure 1).

The roll speeds for stand position \( i \) are calculated in the entry side drive group as:

\[
\text{Roll speed}(i) = \frac{IGRMD(i) \cdot ISMD1 + IGRMD(i) \cdot ISMD2}{IGRMD2 + IGRDD2} \\
\text{Roll speed}(i) = \frac{IGRMD(i) \cdot ISMD2 + IGRMD(i) \cdot ISMD1}{IGRMD1 + IGRDD1}
\]

(1)

(2)

The basis speed curve is characterized by high gear ratios in the entry drive group to enable positive differential gear action also in this area, i.e. identical direction of rotation of both basic and differential drives.

During the steady-state phase of the rolling process, the basic drives of this system run at identical speeds while the differential drive units operate at exactly synchronized speeds. The speeds are related by the following term:

\[
\frac{ISDD1}{IGRMD} = IKM \cdot \frac{ISMD2}{IGRMD2} + IKD \cdot \frac{ISDD2}{IGRDD2} \\
\frac{ISMD1}{IGRMD1} = ICF \cdot \frac{ISMD2}{IGRMD2}
\]

(3)

whereby \( IKM \) and \( IKD \) are constants. The motors are synchronized automatically in the basic automation system.

2.2 Stretch control

The motor speeds at changes in elongation are calculated with the rotational speed values resulting from the calculation of the changes in speed. This method ensures that the operator can effect a change in elongation by means of a change in speed, if necessary, if motor speed limits are reached with no change in speed. One input value is used for the change in elongation:

Input range: -100 ... +100%

Standard: 0 % (in rolling program)

Calculation: Conversion of the entered value P:

\[
PS = 1 + P/100 \cdot P_{\text{max}} / 100
\]

(4)

with \( P_{\text{max}} \) as internal limiting value, e.g. 20% in the actual project.
The following calculation results in a “pivoting” of the speed diagram with the pivot point IPSPP (Figure 2).

One stand position is defined as the pivot point: IPSPP = IPSI. This has the effect that the entry speed and thus the throughput of material remain more or less constant.

Each gearbox is assigned to one motor. A characteristic value which is determined together with the rolling program, determines the gear stage (0 or 1). The corresponding gear ratios are indicated in the Table 1.

Table 1

<table>
<thead>
<tr>
<th>Gear stage</th>
<th>Gear ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IGRMD1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Further calculation of new motor speeds: IGRMD 1 = 1 or gear ratio of the switching step chosen. The same is to be applied for IGRMD2, IGRDD1 and IGRDD2. For calculation reasons we define the variables X= IKM and Y = IKD.

If only the stand group on the inlet side is occupied by roll stands and the drives on the run-out side are not used to drive guide stands etc. the following applies:

\[ ISMD2 = \frac{ISMD1}{IGRMD1} \times IGRMD2 \]

and \( X=0 \) \( Y=1 \).

Final calculation of new motor speed:

\[ OSDD1 = \frac{UAV \times ISMD1}{IGRMD1} + \frac{ISDD1}{IGRDD1} + \frac{GRSDD1}{IGRSD1} \]

\[ OSMD1 = \frac{ISMD1}{IGRMD1} \times \left( \frac{ISDD1 - OSDD1}{IGRDD1} \right) + \frac{GRSDD1}{IGRSD1} \times IGRMD1 \]

\[ OSDD2 = \frac{YRAP \times ISMD1}{IGRDD1} - XY \times \frac{OSMD1}{IGRMD1} \]

\[ OSMD2 = \frac{OSMD1}{IGRMD1} \times IGRMD2 \]

The change in inlet and outlet speed can be calculated with the basic equation:

\[ IS = G \times AJ + IOS \]

with:

- IS - Inlet or outlet speed after change in elongation [m/s];
- G - Gradient relationship of inlet or outlet speed [(m/s)/%] (in Rolling program);
- AJ - Adjusted input value P [%];
- IOS - Inlet or outlet speed at default settings of the motors [m/s].

If only the stand group on the inlet side is occupied by roll stands and the drives on the run-out side are not used to drive guide stands, the following applies: \( OSDD2 = 0, OSMD2 = 0 \).

The Figure 3 shows the speed control diagram of the motors belonging to a stretch-reducing mill for seamless tubes with 4 motors, 2 main drives and 2 overlapping drives. The fifth motor corresponding to the last two shape forming stands for profiled tubes is not represented.

The figure 4 shows the results of experimental activities.

3 Solutions for Basic Automation

The modernization refers to the implementation of a process control system including new speed regulated DC drives and new basic automation (Figure 5).

The control of the rolling process is supported by a basic automation, setting independently and autarchic the basic rotating speeds for the stretch-reducing mill main drives. By means of a basic automation it might be possible to perform the rolling operation independently from the process control system. It offers the possibility to control the mill rotating speed by a reference value and an oscillating value.
The process control system based on PC hardware and software structures sets the additional rotating speeds, which are controlled in some moments. These two rotating speeds will be added in a current rectifier and we obtain a set value for the rotating speed. This activity proved to be adequate for a safe operation and for emergencies.

The basic automation functions are achieved by the PLC connected via PROFIBUS DP with two control and visualizing PC-s. The PLC has basically the following tasks:
- co-ordination, control and monitoring of the technologic process, of the actors and of the sensors;
- communication, bit and byte exchange with other systems;
- interlocking controls, connections with interlocking, development conditions and disconnection with disconnection conditions;
- monitoring of material flow: the material pieces are monitored from exit of reheating furnace to cooling bed; they are counted and distributed to the measure data belonging to the measuring points 1 and 2, being then processed further on (e.g.: data base function “Finished rolled batches”, and “Trend presentation for measuring techniques”).

For the connection to the periphery decentralized I/O stations have been foreseen, for the main drives controls, for the main pulps and for the larger valve blocks. The decentralized I/O stations as well as the rectifiers and the converters are connected by means of a field bus system.

The display in the local control places are connected by an interface RS-232.

4 Conclusion

A methodology has been worked out for the calculation of functional parameters of stretch-reduced tube mill. For performing the respective calculation we have used experimental data obtained by modeling the relevant reducing process. A new method for the control of parameters with PLC is presented.

Program Variable

IKM, IKD  Rolling mill constants. The values are determined when drawing up the rolling program.
ISMD1  Speed of the basic motor of the inlet side drive group
ISDD1  Speed of the differential drive motor of the inlet side drive group
ISMD2  Speed of the basic motor of the outlet side drive group
ISDD2  Speed of the differential drive motor of the outlet side drive group
IPSPP  Stand position number of the pivot point
IPS1  Stand position number of the initial pass stand
IPSF  Stand position number of the final stand
IGRMD(i)  Gear ratio at stand position “i” of the basic drive
IGRSSD(i)  Gear ratio at stand position “i” of the differential drive
ICF  Correction factor with unequal speed ranges of the basic motors
IGRMD1  Gear ratio of basic motor 1
IGRMD2  Gear ratio of basic motor 2
IGRDD1  Gear ratio of differential drive motor 1
IGRDD2  Gear ratio of differential drive motor 2
OSMD1  Speed of the basic motor of the inlet side drive group
OSDD1  Speed of the differential drive motor of the inlet side drive group
OSMD2  Speed of the basic motor of the outlet side drive group
OSDD2  Speed of the differential drive motor of the outlet side drive group
References:

Fig. 5. Speed control diagram of the DC motors of the two main groups of stands