ALGORYTHMS FOR SPEED AND STRECH CONTROL OF THE MAIN DRIVES OF AN STRECH-REDUCING TUBE MILL

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Abstract. This paper shows the drive solution, the speed references calculation and the automatic control of all speeds range for the assembly of the 24 stands belonging to a stretch-reducing mill for seamless pipes. The correlation between the speed control and the stretching control of the rolled pipe is also shown. The experimental results are real data associated to the most recent project that has been executed at a seamless pipe plant in China.

1 Introduction

The concept of common drives of the stands using distribution and differential gear-boxes represents a flexibility limitation of the performances of the mill but using it we can sensibly reduce the costs of the drives [1], [2]. Therefore, when we are designing rolling mills of this type, we have to study carefully the necessity and the utility of choosing individual drives for each stand or common drives [3].

If we are using a common reducer driven using main and overlapping drives the rotating speed ratios are changing simultaneously at all stands by control of the rotating speed at both (or one of the two) motors and maintaining the ratios for the rotating speeds of the rolling stands as been established by designing of the gears. Thus, in this drive system we can change only the speed average or the stretching average, but not the distribution of the deformation values in the individual sequence of the stands [4], [5].

If we may give up the advantages of the individual speed control on the pipe deformation and if we except a larger slipping between the rolls and the rolled material (a current status at easier rolling programs) we could accept a common drive with distribution and differential gears [6], [7].

2 Electromechanical drive solution

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 as,

In the entry side drive group:

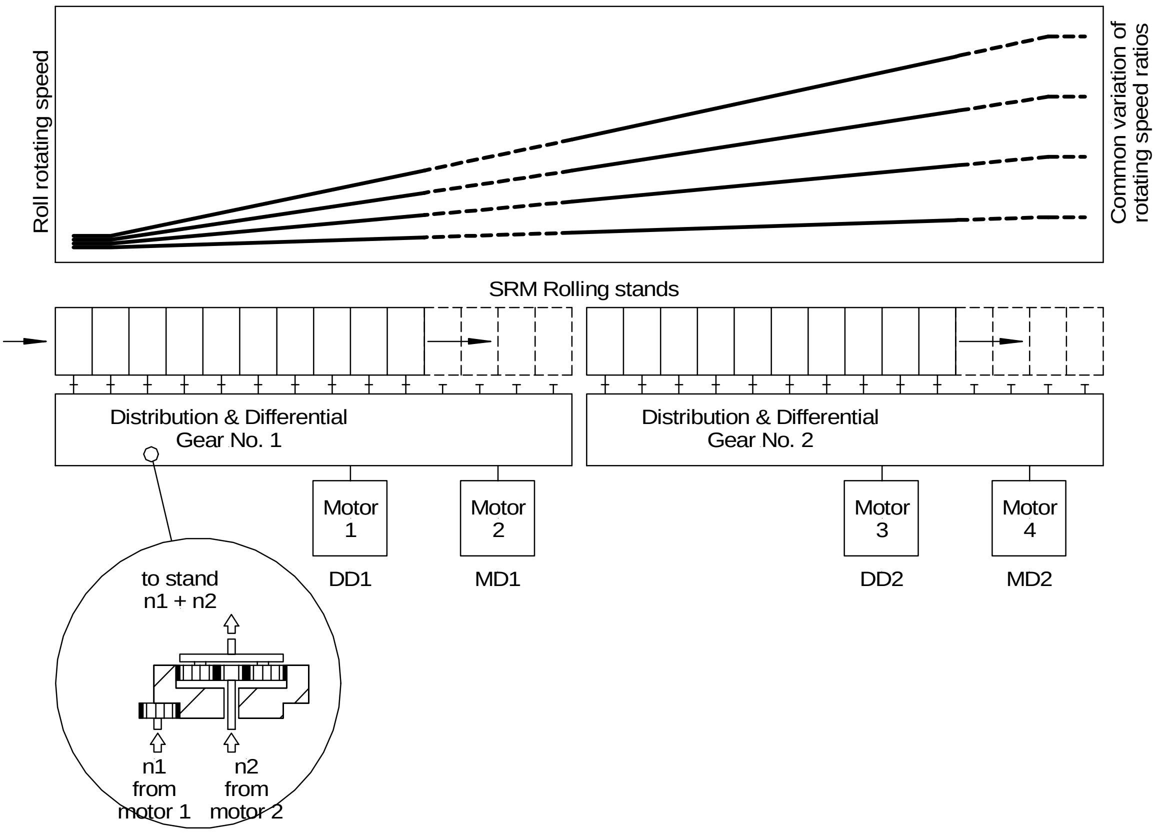

Figure 1: Schematic for SRM with Common Drive with Distribution and Differential Gears

$$Roll\ speed(i) = \frac{IGRSMD(i) * ISMD1}{IGRMD2} + \frac{IGRSDD(i) * ISDD1}{IGRDD1} \quad (1)$$

With respect to the drive group on the run-out side:

$$Roll\ speed(i) = \frac{IGRSMD(i) * ISMD2}{IGRMD2} + \frac{IGRSDD(i) * ISDD2}{IGRDD2} \quad (2)$$

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:

$$\frac{ISDD1}{IGRMD} = IKM * \frac{ISMD2}{IGRMD2} + IKD * \frac{ISDD2}{IGRDD2} \quad (3)$$

$$\frac{ISMD1}{IGRMD1} = ICF * \frac{ISMD2}{IGRMD2} \quad (4)$$

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

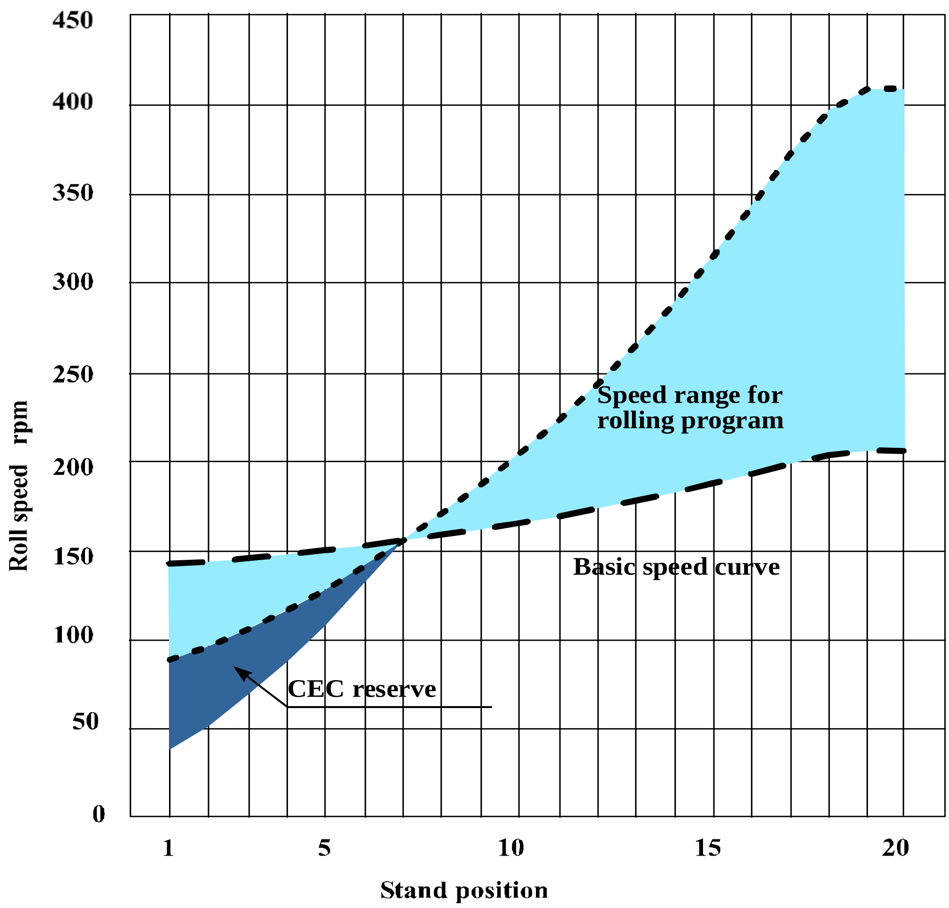

Figure 2 : Speed diagrams of the tandem differential drive

2.2 Strech 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:

$$PS = 1 + P/100 * P_{max}/100 \quad (5)$$

with P_{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.

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*.

Table 1

		Gear ratio			
		IGRMD1	*IGRDD1*	*IGRMD2*	*IGRDD2*
Gear stage	0	1	1	1	1
	1	1	1	1	1

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:

$$ISMD2 = \frac{ISMD1}{IGRMD1} * IGRMD2 \quad \text{and} \quad X=0 \quad Y=1 \tag{6}$$

Final calculation of new motor speed:

$$OSDD1 = \frac{UAV * \left(\frac{ISMD1}{IGRMD1} + \frac{ISDD1}{IGRDD1} * IGRSDIGRSMD \right)}{IGSRSDDIGRSMD * UAV + ZMW * ICF * IGRSSDD(IPSI)} - \\ - YRAP * ICF * IGRSDD(IPSF) * IGRDD1 \tag{7}$$

$$OSMD1 = \frac{\frac{ISMD1}{IGRMD1} + (ISDD1 - OSDD1)}{(IGRDD1 * IGRSDDIGRSMD)} * IGRMD1 \tag{8}$$

$$OSDD2 = \frac{YRAP * \left(\frac{ISDD1}{IGRDD1} \right) - XY * \left(\frac{OSMD1}{IGRMD1} \right)}{(ICF * IGRDD2)} \tag{9}$$

$$OSMD2 = \frac{\left(\frac{OSMD1}{IGRMD1} \right)}{ICF} * IGRMD2 \tag{10}$$

After every calculation of a motor speed, limit values are checked and corrected accordingly.

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

$$IS = G * AJ + IOS \tag{11}$$

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: *OSDD*2 = 0, *OSMD*2 = 0.

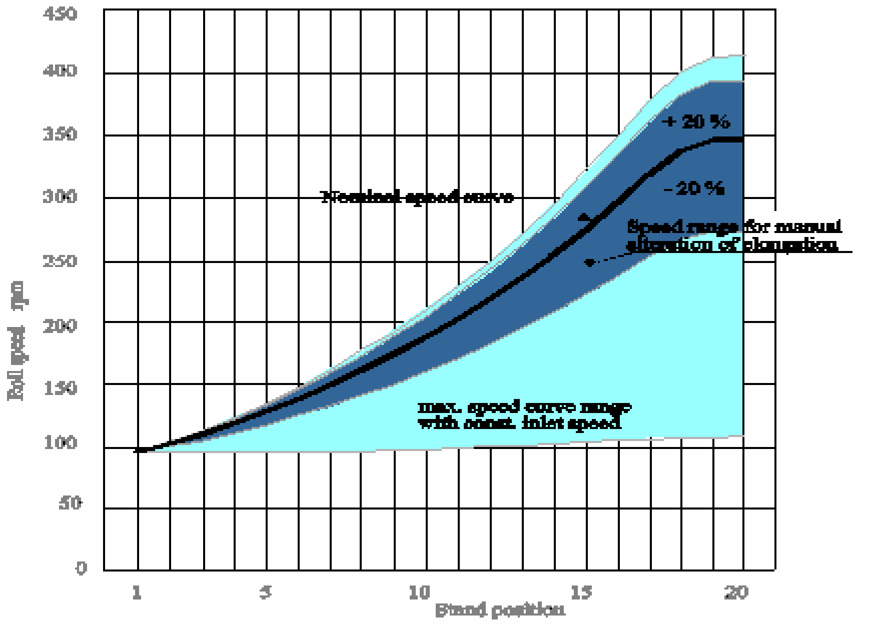

Figure 3: Speed diagram ranges.

3 Experimental results

Table 2

Motor speeds:

	MD1	OD1	MD2	OD2
Nominal	970.74	503.42	970.74	913.10
P = 100%	1076.64	473.76	1076.64	1142.83
P = - 100%	864.83	533.07	864.83	683.37
	ve[m/s]	**va [m/s]**		
Nominal	1.13	7.35		
P = 100%	1.16	8.81		
P = - 100%	1.10	5.89		

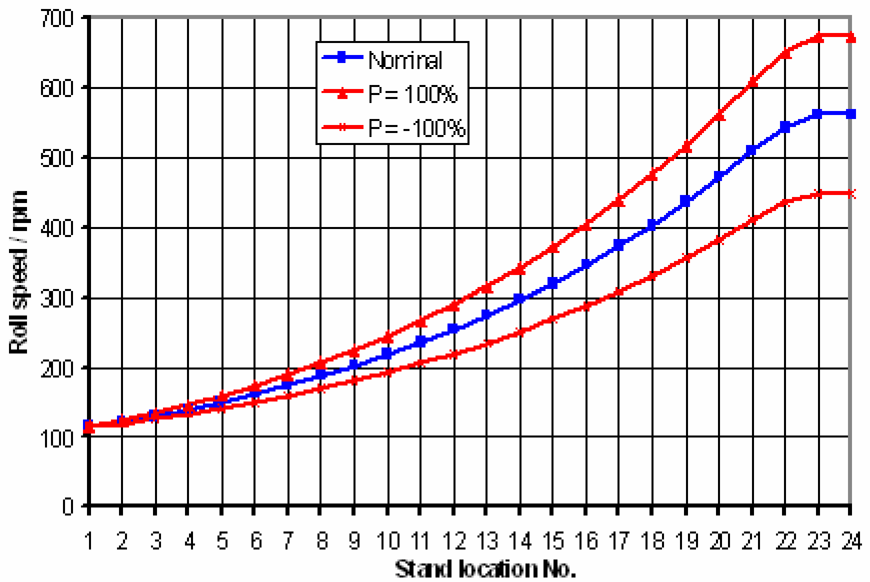

Figure 4: Experimental speed diagram

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PROGRAM VARIABLES

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
IPSI Stand position number of the initial pass stand
IPSF Stand position number of the final stand
IGRSMD(i) Gear ratio at stand position "*i*" of the basic drive
IGRSDD(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