A Possible Method for Measuring Some Technological Parameters

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Abstract: - The resulted cold laminated aluminum foil is rolled in bales; the foil is then unrolled and rewound in rolls with some imposed parameters: the exterior diameter of the roll, the length and mass of the rewound foil. These parameters must be measured with imposed precision and during the technological process. The paper presents a measurement method that solves this practical problem in the aluminum processing industry; the method is based on the pulses generated by two rotary incremental encoders and an IBM-PC compatible computer displays the measured values, enables the parameter prescribing and assures a simple dialog with the user. An error analysis is also presented; it enables the estimation of the maximum probable absolute error for each parameter.

Key-Words: - encoder, parameter, measurement, precision, error analysis.

1 Introduction

It is well known that in the aluminum processing industry, the resulted cold laminated foil is rolled in bales with certain foil thickness (rigorously controlled during the technological process). The aluminum foil is then unrolled and rewound in rolls with some imposed parameters, such as exterior diameter of the roll, width, thickness, length or mass of the foil. These parameters must be measured with imposed precision, during the technological process.

The machine for adjusting aluminum foil [2] contains one tambour that draws the foil from the bale. The foil is then rewound on the roll lap arbor. Two free reels stretch the foil and establish its path between the bale and the tambour. A special device, placed between the ball and the first free reel, cuts the foil to the assigned width (with imposed precision). If the bale contains a double foil, two identical rolls will result at the end of this process.

The machine for adjusting aluminum foil assures the achievement of following conditions:

a) linear velocity of the foil is equal to the tangential velocity of the tambour;
b) aluminum foil doesn't slip on the tambour;
c) foil is perfectly stretched (it doesn't wave) during the rewinding process;
d) tambour circumference (C_T[mm]) is known and rigorously constant;
e) successive aluminum sheets are in perfect contact on each roll.

During the finishing process of the aluminum foil, three parameters must be measured and displayed:

- L – the length of the rewound foil;
- M – the mass of the rewound foil;
- D – the exterior diameter of the roll.

The requirements to the measurement system are the following:

- each parameter must be measured with imposed precision;
- the foil width and thickness must be assigned before each measurement process;
- all parameters must be measured and displayed quasi-continuously during the finishing process.

Table 1 shows the measurement ranges and tolerances for the parameters L, M and D.

Table 1. Value domains and tolerances for the measured parameters

Parameter	Minimum value	Maximum value	Tolerance
L[m]	10	10000	±5%
M[kg]	1	600	±5%
D[mm]	40	600	±5mm

A measurement system, organized around a microprocessor Z-80 and presented in [2], was initially used. The prescribing block for the foil width and thickness and the displaying block for the measured parameters L, M and D are presented in [4]. This system assures the dynamic measuring and displaying of the parameters L, M, D, but it supposes a complicated structure, push buttons for the prescribed values and many 7-segment LED displays for the measured and prescribed parameters.

This paper presents a method for measuring the parameters L, M, D, with imposed precision, based on the pulses generated by two rotary incremental encoders, and an IBM-PC compatible computer displays the measured values, enables the parameter prescribing and assures a simple dialog with the user. The paper also presents an error analysis and error estimation for the measured parameters.

2 Method for Measuring the Roll Parameters

The measuring method supposes two rotary incremental encoders:

- RIE_1 – attached on the tambour shaft,
- RIE_2 – attached on the roll shaft.

The rotary incremental encoder is an electro-mechanic device, converting angular displacement of its shaft into a digital electric signal [1,3,5]. During a complete rotation of its shaft, the encoder RIE_i generates P_{Amax} pulses A_i (or B_i), and a pulse N_i appears after each complete rotation.

2.1 Measurement Principle

The measurement method, presented in this paper, supposes that the conditions a, b, c, d, e (specified in Introduction) are all satisfied. The measuring of the parameters L, M, D is based on the pulses A_1 (from RIE_1) and N_2 (from RIE_2) and this method imposes $P_{Amax} \geq C_T$[mm].

All rewound foil is carried by tambour because the aluminum foil doesn't slip on the tambour. During its complete rotation, the length of the rewound foil is C_T[mm] and the rotary incremental encoder RIE_1 generates P_{Amax} pulses A_1. When the rewinding starts, we consider the moment t=0. If P_1 pulses A_1 are counted until the moment t, the foil rewound until this moment is

$$L[mm] = \frac{P_1}{P_{A\max}} C_T[mm] \tag{1}$$

The mass of the aluminum foil rewound until the moment t is computed based on its length L[mm], width l[mm] and thickness g[μm]:

$$M[kg] = L[mm] \cdot l[mm] \cdot g[\mu m] \cdot \rho_{Al}[kg/m^3] \cdot 10^{-12} \tag{2}$$

where $\rho_{Al} = 2674[kg/m^3]$.

Between two consecutive pulses N_2, generated by RIE_2, at the moments t' and t" ($t'' > t'$), P_D pulses A_1 (generated by RIE_1) are counted:

$$P_D = P_1(t'') - P_1(t'). \tag{3}$$

Because the foil is perfectly stretched (it doesn't wave) during the rewinding process, the exterior diameter of the roll can be computed based on the number P_D:

$$D[mm] = \frac{P_D}{\pi P_{A\max}} C_T[mm]. \tag{4}$$

So, the exterior diameter D of the roll, the length L and mass M of the rewound foil can be computed based on the pulses A_1 (from the encoder RIE_1) and N_2 (from the encoder RIE_2), if the tambour circumference (C_T[mm]), the width (l[mm]) and thickness (g[μm]) of the foil are known.

2.2 Error Analysis

In the following error analysis, we denote Δx the maximum probable absolute error of the parameter x.

The absolute errors ΔL, ΔM and ΔD, of the measured parameters L, M, D, are computed using the derivatives' method [1], based on the absolute errors ΔP_1, ΔC_T, Δl, Δg, ΔP_D of the independent variables P_1, C_T, l, g, P_D; $\Delta P_1 = \Delta P_D = 1$ for the numbers P_1 and P_D.

a) ΔL error analysis

$$L = \frac{P_1}{P_{A\max}} C_T \quad , \tag{5}$$

$$\Delta L = \frac{\partial L}{\partial P_1} \Delta P_1 + \frac{\partial L}{\partial C_T} \Delta C_T, \tag{6}$$

$$\Delta L = \frac{C_T}{P_{A\max}} + \frac{P_1}{P_{A\max}} \Delta C_T. \tag{7}$$

b) ΔM error analysis

$$M = L \cdot l \cdot g \cdot \rho_{Al} \cdot 10^{-12}, \tag{8}$$

$$\Delta M = \frac{\partial M}{\partial L} \Delta L + \frac{\partial M}{\partial l} \Delta l + \frac{\partial M}{\partial g} \Delta g, \tag{9}$$

$$\Delta M = l \cdot g \cdot \rho_{Al} \cdot 10^{-12} \cdot \Delta L + L \cdot g \cdot \rho_{Al} \cdot 10^{-12} \cdot \Delta l + L \cdot l \cdot \rho_{Al} \cdot 10^{-12} \cdot \Delta g. \tag{10}$$

The units of measurement for M, L, l, g, ρ_{Al} are those specified in (2).

c) ΔD error analysis

$$D = \frac{P_D}{\pi P_{A\max}} C_T , \quad (11)$$

$$\Delta D = \frac{\partial D}{\partial P_D}\Delta P_D + \frac{\partial D}{\partial C_T}\Delta C_T , \quad (12)$$

$$\Delta D = \frac{C_T}{\pi P_{A\max}} + \frac{P_D}{\pi P_{A\max}}\Delta C_T . \quad (13)$$

Observations

- ΔL depends on L, and ΔD depends on D when $\Delta C_T>0$.
- For great values of L ($L>10^5$mm), $P_l >> P_{Amax}$ and ΔL can touch important values if $\Delta C_T \neq 0$.

2.3 Error Estimation

The maximum probable absolute errors of the parameters L, M, D can be computed for some real values and maximum probable errors of width and thickness foil, shown in Table 2. The real value of the tambour circumference is C_T=1000mm.

Table 2. Value domains and maximum probable errors for the parameters l and g

Parameter	Minimum value	Maximum value	Tolerance
g[μm]	6	300	±4%
l[mm]	30	100	±(0.2…0.4)
	100	1000	±(0.5…0.9)
	1000	1200	±1

Table 3. The maximum probable absolute error of the foil length (L)

L[m]	Conditions		**ΔL[m]**	T[m]
10	$P_{Amax}=10^3$	ΔC_T=1mm	**0.011**	±0.5
		ΔC_T=0	**0.001**	
	$P_{Amax}=4\cdot10^3$	ΔC_T=1mm	**0.01025**	
		ΔC_T=0	**0.00025**	
10^4	$P_{Amax}=10^3$	ΔC_T=1mm	**10.001**	±500
		ΔC_T=0	**0.001**	
	$P_{Amax}=4\cdot10^3$	ΔC_T=1mm	**10.0002**	
		ΔC_T=0	**0.00025**	

Many possible situations will be studied:

a) P_{Amax}=1000 and ΔC_T=1mm;
b) P_{Amax}=1000 and ΔC_T=0;
c) P_{Amax}=4000 and ΔC_T=1mm;
d) P_{Amax}=4000 and ΔC_T=0.

The maximum probable absolute errors ΔL, ΔM and ΔD, obtained for specified conditions, and the imposed tolerances T are presented in Tables 3, 4 and 5, for different values of the parameters L, M, D.

Table 4. The maximum probable absolute error of the foil mass (M)

M[kg]	Conditions		**ΔM[kg]**	T[kg]
1.069	L=10m l=10^3 mm g=40μm	ΔC_T=1mm	**0.0449**	±0.05
		ΔC_T=0	**0.0416**	
	L=10m l=125mm g=300μm	ΔC_T=1mm	**0.0483**	
		ΔC_T=0	**0.0473**	
588.3	L=10^7m l=10^3 mm g=22μm	ΔC_T=1mm	**24.72**	±29.4
		ΔC_T=0	**24.12**	
	L=10^7m l=74mm g=300μm	ΔC_T=1mm	**27.53**	
		ΔC_T=0	**26.94**	

Table 5. The maximum probable absolute error of the roll diameter (D)

D [mm]	Conditions		**ΔD [mm]**	T [mm]
40.18	$P_{Amax}=10^3$	ΔC_T=1mm	**0.358**	±5
		ΔC_T=0	**0.318**	
	$P_{Amax}=4\cdot10^3$	ΔC_T=1mm	**0.119**	
		ΔC_T=0	**0.079**	
600	$P_{Amax}=10^3$	ΔC_T=1mm	**0.918**	
		ΔC_T=0	**0.318**	
	$P_{Amax}=4\cdot10^3$	ΔC_T=1mm	**0.679**	
		ΔC_T=0	**0.079**	

The following conclusions result after a comparative study of these experimental results.

a) All estimated errors depend on ΔC_T.
   - ΔL is strongly dependent on ΔC_T: for great values of L, ΔL drastically increases with ΔC_T and depends on L; when ΔC_T=0, ΔL becomes very small and doesn't depend on L.
   - ΔM is almost insensible to ΔC_T.
   - When the diameter value increases, the sensibility of ΔD with ΔC_T increases too; if ΔC_T=0, ΔD doesn't depend on D.

b) When P_{Amax} increases four times,
   - ΔL and ΔD decrease four times if ΔC_T=0, for any value of L, and D respectively;
   - ΔL is almost insensible to P_{Amax}, if $\Delta C_T>0$;

- an important decrease of ΔD occurs, depending on D, if $\Delta C_T>0$;
- ΔM is almost insensible to P_{Amax}.

c) The last term of sum (10) is the most important when ΔM is evaluated based on the real values of L, l and g. So, an important decrease of ΔM is possible only if the tolerance Δg decreases.

3 Overview of the Measurement System

An intelligent system enable the precise measuring and displaying of the roll parameters L, M, D, based on the measurement method presented in this paper, and it also enables the assignment of width and thickness for the rewound foil. This measurement system consists in two rotary incremental encoders, a signal conditioning electronic module, an intelligent interface and an IBM-PC compatible computer.

The intelligent interface is similar with that presented in [8] and it is organised around a microcontroller from the 80C552 family (Philips Semiconductors), that is very flexible and versatile, with excellent control possibilities in various industrial applications. Hardware resources of the interface enable the engendering of some digital or analogue commands and the acquisition of many digital or analogue signals. The intelligent interface is serial connected to an IBM-PC compatible computer and between interface and computer there is a soft interaction. The computer assures the final data processing, it displays the measured and assigned parameters, and it also assures a simple dialogue with the user.

Program modules to the intelligent interface level and computer level implements many elementary functions [6,7]: serial dialogue with the computer, acquisition of the analogue and digital signals etc.

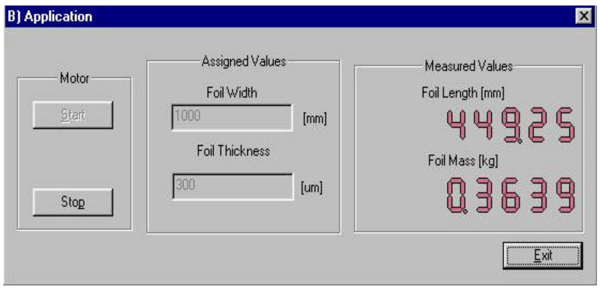

Fig.1. The dialog window

The measurement method, presented in this paper, was verified using an experimental system, with the above-presented structure. The rotary incremental encoder under test is of SUMTAK origin, the LBL-007-1000 type; $\Delta\phi = 0.36\deg$ for this encoder. Using a soft method [6], the resolution of the displacement measurement becomes 0.09deg. This experimental system imposes the assignment of the foil width and thickness, before each measurement process; all assigned and measured parameters are displayed. Because the technological process cannot be perfectly simulated, only two parameters (L and M) are measured. The dialog window, shown in Fig. 1, displays the assigned values (width and thickness) and the measured parameters (length and mass).

4 Conclusions

The paper presents a measurement method that solves a practical problem in the aluminum processing industry. This method enables the precise measuring of three parameters of the rolls with aluminum foil (the exterior diameter of the roll, the length and mass of the rewound foil), during the technological process. The measurement method is based on the working conditions of the machine for adjusting aluminum foil and the parameters are computed using the pulses generated by two rotary incremental encoders. The error analysis and estimation enable the computation of maximum probable absolute error of each measured parameter and the experimental results confirm that this method satisfies the requirements concerning the precision.

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