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VIBRATIONS AND TORQUE MONITORING PROCESSES FOR A COLD ROLLING MILL

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ABSTRACT

This paper presents researches made on a system of monitoring and other parallel systems for diagnose used in a cold rolling mill.

The first system (with specific measurement sensors) is an online vibration monitoring system for control (on-line) of the sheet quality and mill maintenance in relation with diagnostic in work for a cold rolling mill machine.

The second system is used for monitoring the torque measuring and mill parameters (force, mill speed, the gap between work roll etc.), part of the integrated process control.

KEYWORDS: cold rolling mill, torque, vibration, quality control, maintenance

1. Introduction

In the new globalizing economical system, the product of cold thin strip (in conditions of the total quality concept) is very important. For obtaining a low cost for the laminated strip it is necessary to increase the productivity of the cold rolling mill by in conditions of diminishing all the losses and using human and material resources at a maximum.

If we make a continuous monitoring of a working cold rolling mill machine we can reduce maintenance costs, increase productivity and improve product quality.

In the context of on-line monitoring for the cold rolling mill process we study the vibration for the most important parts of the cold rolling mill equipment. When in work, the rolling mill, causes severe damage for the mill machine and has a negative influence on the strip quality (Fig. 1).

When we talk about steel strip quality, we take into account the geometrical dimensions and the influences on the strip material due to the rolling mill chatter. Another imperfection or fault can be represented by the marks on the steel strip due to the marks possibly existing on the work rolls.

The integrated control process is undertaken to analyze the vibrations produced on the work roll chocks and backup roll chocks.

The noise and chatter signals are carried out in the time and frequency range. The noise has to be eliminated to obtain reliable strip quality in conformity with predicted dimensions.

In time, we can create a database used for comparison between an initially vibration signal and a vibration work signal for the cold rolling mill machine and finally to archive a quality standard for each laminated roll strip. We created a parallel system of comparison between the initial torque (when the strip is not between the work rolls) and the torque during the rolling process.

The purpose of this study is to find the cause of steel strip faults, to diagnose [1] the state of the mill machine, and to predict when some of its parts can encounter working problems.

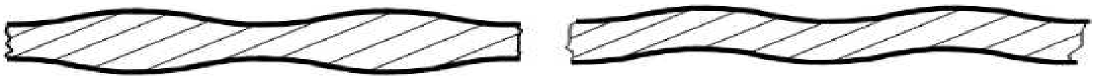

Fig. 1. *Faults of a laminated strip due to rolling mill vibration*

The accuracy of the sheet thickness (texture or surface roughness) is important for the beneficiary of this product.

In working conditions, vibrations or oscillations may occur, which again cause gauge chatter or chatter marks on the rolling sheet.

Gauge chatter are periodical faults in thickness or shape of the strip or regular shades on the surface of the strip transverse to the rolling direction.

Heavy vibrations of the roll stand may even cause ruptures of the strip. The amplitude and wave length of periodical strip faults depend on the vibration system and the vibration frequency.

2. Experimental procedure

2.1. Measurement of vibrations in a cold rolling mill machine

If we take into consideration the incitation system, free vibrations may occur when a single impulse (the rolling stand or parts of it oscillate with their own natural frequency) determines an oscillatory signal in the mill systems.

On the other hand there are excited vibrations in the rolling stands determined by damage that exist in parts of rolling mill machine.

In this context, vertical vibrations exist [2] from the roll stand (1- 16 Hz.), torsion chatter of the main drive (5- 20 Hz.), interspaces chatter or third-octave chatter (100 - 300 Hz.), roll vibration or fifth-octave chatters (500-700 Hz.).

In practice, the differentiations of interfering frequencies into those which are proportional to the speed and those which are not are the first step in describing the phenomenon of vibration and its manifestations. In Figure 1 we see the influence of vibration on the laminated strip on a 5-stand of cold rolling mill machine. The strip pattern is due to the rolls bearing eccentricity and damage of the drive system of the rolling mill machine. Another cause of strip geometry damage is due to displacement of shaft roll gap fluctuation and to excessive free motion.

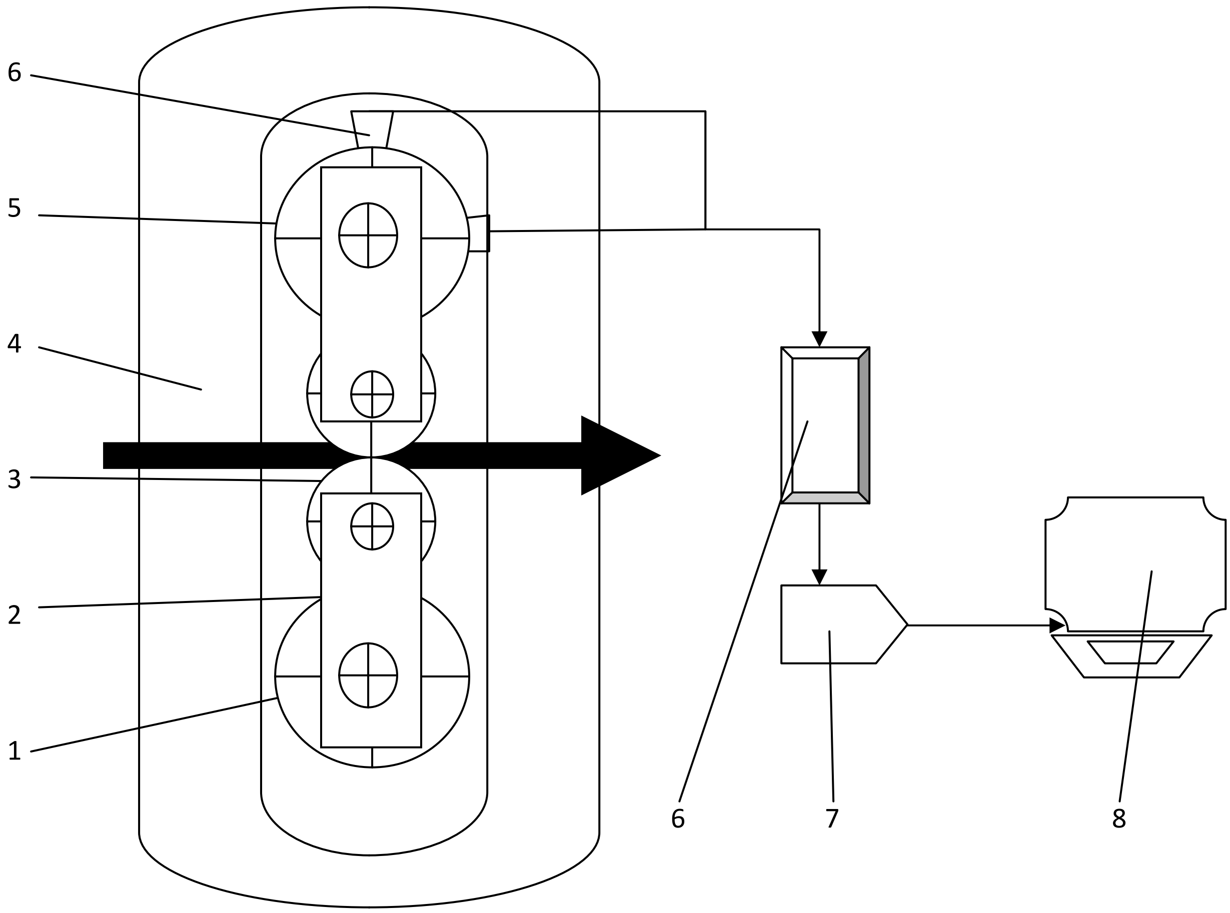

Fig. 2. *Schedule for parameters measured in the cold rolling mill machine: 1-work roll; 2-rolls support; 3-beckup roll; 4-mill stand (frame); 5-horizontal accelerometer; 6-vertical accelerometer; 7-signal preamplifier; 8-process computer*

Experiments were made on the 3, 4, 5 frames of the rolling mill (accelerometers are placed as in Figure 2) because on them there are the highest values of displacements, acceleration and frequency vibrations and that in fact, represents the latest stage in the achievement of the finished product. We use this schedule for automatic online diagnosis of the vibration in the working of a rolling mill machine.

The measurements were performed on 22 rolls, after which the change was made on the working cylinders of five stand of the rolling mill.

The frequency of the vibrations is directly influenced by the speed of rotation of the cylinders, the rolling force, the tension between frames, the emulsion used. The parameters of the vibrations were recorded over the period May - October 2012.

During the measurement campaign there has also been measuring and recording of the functional parameters for the five stand tandem (Table 1.a), the rolling forces, the tensions in the band and the rotation speed of the cylinders - for one of the rolling rolls.

Table 1.a

Frame	1	2	3	4	5
Rolling force, x10^{4}N	1260	1170	1120	1070	1025
Rotation speed of the working cylinders, rot/min	380	475	560	650	780
Tension between the frames, x10^4	1-2 48	2-3 37	3-4 21	4-5 14	

The rolled material was a strip of 12 Ust having [3]: 1.88 mm nominal thickness (entrance in tandem); 0.362-0.408 mm (output of tandem), chemical composition and mechanical characteristics as shown in Table 1.b.

Table 1.b

Chemical composition, [%]					
C	**Mn**	**P_{max}**	**Si_{max}**	**S_{max}**	**Al**
0.12	0.44	0.033	0.052	0.042	min 0.016
Mechanical properties					
R_m		**Flow’s limit $R_{p0.2}$**		**A_5**	
[N/mm^2]				[%]	
244		275-375		35%	

2.2. Type, location and recording of variables

In the following stage, we made another set of measurements regarding the vibration amplitude, accelerations, frequency spectrum in stands 3, 4 and 5 of the tandem rolling mill. The measurements were made on the support of lower and upper cylinders, on the operator side and on the drive system.

The measurements were made with transducers placed on cylinders bearings support of lower and upper work cylinders in horizontal and vertical position.

After the working parameters analysis we observed the greatest value for tension, force, speed, acceleration recorded at the 3, 4, 5 stands of the rolling mill (Table 1a)

For frame number 4, the measurement values recorded are presented in the subsections below:

a. Measurement of stand displacement

The maximum displacement measured on the cylinder back-up upper support (operator-action) was 355x10^{-6} m, 370x10^{-6}m.

The maximum displacement measured on the lower support of the cylinder (operator-action) emphasized lower values, meaning 36x10^{-6}m and 178x10^{-6}m.

By comparing these data, it will be noticed that the highest value of the movements was on the upper support of the cylinder (drive side). This is due, perhaps, to the existence of some vibrations coming from the chain of cinematic shareholders.

b. Measured and recorded of accelerations

The measured and recorded maximum of acceleration was about 4m/s^2, at the drive side, and about 3m/s^2, at the operator side.

c. Measured and Recorded Frequencies

The frequency spectrum (operator) is presented for the block of lower and upper cylinders, and the graphs of the frequency spectrum for the block of upper cylinders with values ranging 100-300Hz.

They made the same kind of measurements, namely: displacement, acceleration and frequency (on the upper and lower support of the cylinders - the side of shareholders and operator.

d. Accelerations measured in stand number 3

The maximum value was about 2m/s^2, which represents about 50% of the acceleration value in the stand number 4.

e. Accelerations measured in stand number 5

The maximum recorded acceleration was about 2.5m/s^2 so it is situated between maximum values from stand number three (1.6m/s$^{2)}$ and stand number four (4m/s^2).

3. Results and discussions

Monitoring of the vibration system may reduce the risk of gage or roll chatter and help to obtain quality products. Secondly, the torque monitoring is necessary for the optimization of the milling process and condition-based maintenance.

After measurements and records made, it resulted that:

-the highest vibration amplitude has been identified in the 4 rolling mill frame (action side), compared with frames 3 and 5;

-accelerations and frequencies had the greatest values at action sides, for all three frames (3, 4, 5);

-the vibrations caused the appearance of some wavy parts on the band surface (rolls 14 and 16; thickness output 0.37; width 1660mm), in the shape of cross stripe, with up to 20-40 mm;

-on the surface of the last 5 rolls strip, before the change of the working cylinders, there could be observed traces and printings belonging to these cylinders.

Analyzing the spectra frequency related to 3, 4, and 5 stands of the rolling mill machine, two maxima were noticed, respectively:

-frequency in range of 100-300 Hz **-** generally speaking, characteristics for spent camps and games of positioning system interspaces, for the quality of surface decks working cylinders, for lubricant but not the last for variations of cylinders rotation speed;

-frequency in range of 500-800 Hz - may generally show a wear stressed of decks of the cylinder support, of their camps (with games in the camps).

Areas of graphs frequency – related to the 500-800Hz range - in particular, the value of the vibration magnitude compared to the area relating to the range 100-300 Hz.

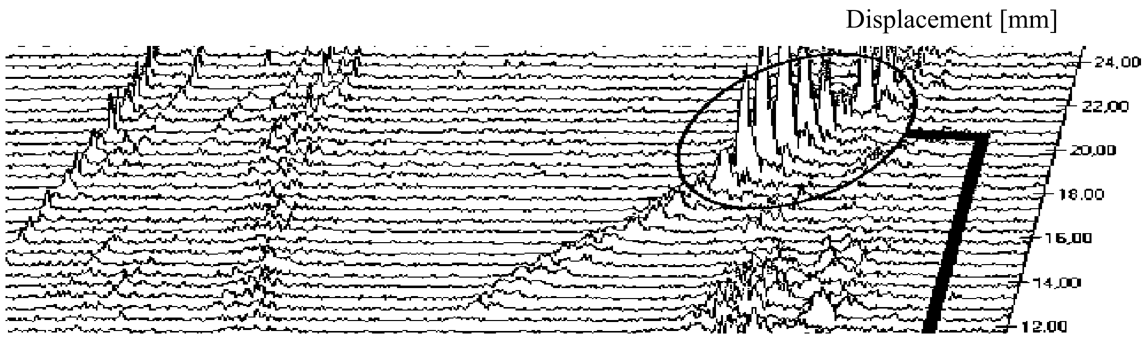

Fig. 3. *Vibration recorded at the drive side (marked with a black line) and at the operator side (left side) [4].*

We can conclude that surface defects occur due to some reasons presented up to a point but also in correlation with the state of wear of the rolling mill in general, the working cylinders, the camps etc.

During a temporary measurement the vibration initiating roll stand had to be identified. The results of the analysis showed that stand number 5 initially caused the gage chatter. The vibrations propagate via the strip to stand 4 and from there to stand 3 (identical constructions). The vibration showed a frequency of roughly 125Hz.

Finding the speed-proportional excitations is of crucial importance, as they allow the detection of the original, mechanical causes of the excitations.

However, the analysis of cumulative [4] spectrum is often time consuming as the excitation effects depend on many strip parameters (material, width, thickness etc.), and thus do not appear during each pass. It has been developed to simplify the evaluation of the spectra to compared to the cumulative spectrum, the benefits of the frequency-speed-collective are the greater time basis and a balanced distribution in the cinematic of the mill.

At rolling speeds between 600-1250m/min., and vibration frequencies not exceeding 450Hz, we have not registered print and sudden wave variations in the thickness of the rolling strip.

At vibration frequencies between 450 and 1150Hz, we noticed wave surface bands with 2-20mm step pronounced wear in the work and back-up rolls support.

Following the experiments carried out during 2011, for a number of rolls rolled over in 250 rolls strip, consisting mainly in measurement and analysis of the vibrations, the following range of common characteristics were established: vibrations in the range of frequencies 5-90Hz corresponding for gearing, gear box.

Vibrations with frequencies of 125-300Hz, corresponding to games in interspaces of positioning system, for wears in the work and support of rolls bearings and because of the lubricant used.

Vibration frequencies in the range of 500-980Hz related to wears in the drive system (work and back-up rolls support, motor-couplings bare-coupling, some types of wave on strip surface, emulsion used etc.). The vibrations are caused by the torsion occurring in the middle of the pass and determine a lot of marks on the strip surface and causing severe damage to the drive system.

A process work parameters optimization may be carried out if such events are recorded and analyzed. In this case, the lubrication system was improved. During the first pass the entering torque impact is very high.

The paper discussed two types of quality and maintenance-related monitoring systems for rolling mills [5].

Experiments in tandem operation revealed: the growing tendency in vibration amplitude at high speed lamination where the rolling speed is increased with about 50% per rolling mills, registered a magnitude vibrations that increased about 35% per frame of rolling mill.

On the other hand, the band widths with narrow and heavy sea manifest the same tendency of increasing amplitude vibrations, unlike bands with great width and thickness, where the effect of damping vibrations is considerably higher [7].

The torque sensors used in rolling mills must be very robust due to the rough ambient conditions.

Although this material represents only a small percentage of the yearly overall production at this mill stand, the arising torque loads damages components of the universal joint at a roughly ten times higher percentage in terms of residual lifetime.

The practical examples presented here on the monitoring systems confirm their efficiency.

For the cold rolling mill tandem - 1700 mm – after measurement of dynamic couples, we observed values exceeding the dynamic torque, when calculated with about 17% at stands I, II, and approx. 23.5% at stands III, IV and V. These differences are based on the following: the shock due to the clamp lane between rollers; games due to components usage chain training, inadequate emulsion; games related positioning system; the usage of the decks cylinders.

Of all the research results obtained, the current problem is to analyze the conditions for a scientific running of the rolling mills, the identification and quantification disturbing factors and, finally, the modern design, for increasing resistance, reliability, reduce consumption, ensure continuity processes and final quality products.

All this led to the development of a general concept for the establishment of dynamic influences on complex machinery and quantification of the dynamic forces [8].

The modern analysis of the tensions leads to the design with a minimum of approximation and uncertainty of sub-assemblies of equipment.

4. Conclusions

A major conclusion of the investigation on the basis of which some research contracts were concluded with ARCELOR MITTAL S.A. is a pressing need for reduction and possible elimination of vibrations in order to increase the reliability of all the rolling mills and the production of rolling strip in accordance with international standards.

If we do not take into account the effect of internal and external loaded (dynamic forces of inertia in starting and braking periods, games in components from inside the spaces of the cinematic drive system, wear subassemblies), severe repercussions will appear concerning the reliability and quality of the production process.

Under the action of variable loads (charging the forces and resistance on the mill parts), the materials of these parts suffer from damage and in time the phenomenon of fatigue is installing. This is the most frequent cause for the deterioration of equipment subassemblies.

Dynamic effects for the tandem studied permit to appreciate that the most important dynamic effects occur in the mill in tandem, in the positioning system, in drive system (motor-couplings bare-coupling, emulsions etc.)

We can take measures to reduce the load in the design stage of the rolling mill machine and the design of the cinematic and constructive schedules, correlated with the drive system. It is important to determine the size of dynamic moments that may occur during operations.

We must know the real physical processes that occur in the equipment, taking into consideration the parts mass distribution, the game inside of the drive system and electrical characteristics.

We use computer modeling to determine, simulation of cinematic and dynamic parameters and to optimization the drive system.

It is necessary to develop models that combine aspects of dynamic mechanical and electrical systems and through computer simulation to provide functionality and efficiency as well as deficiencies in work.

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