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# Quality Issue Classification by Using Dedicated Data Analysis Software Created in Phyton Language

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**Abstract**: Quality issues enroll as one of the most important aspects which needs to be avoided in a factory. When a product has quality issues always the economic losses for the company are experienced. The paper approaches manufacturing steel sector and presents the methodology used to classify the quality issues detected to coils in hot strip mill (HSM) factory. The algorithm was developed in python software language and tested on data sets from the plant site. The method used proves the efficacity of the algorithm through the quality issues classification identified on HSM. rnAlso, the HSM represents one of the most important components from a steel factory. Any kind of issues that may occur on HSM production line has direct impact on finished products, which may conduct to big economic losses to the company. In this paper, a method for coils issues classification is described. The dedicated software was created in phyton language and after months of tests was installed to the operators computers for a quick quality issues identification.

**Keywords:** Telescopicity, Hot strip mill, Coils, Data analysis, Algorithms, Distance lasers sensor

## Introduction

Metallurgical plants contain mixed and quite complex processes that extended along the flow of production lines to the finished product. All these processes have a great impact on final quality of the products in higher or lower ratios. In a hot strip mill, slabs are heated and passed through a series of rough stands, are transformed in a plate with proper thickness and width. The finishing train – a tandem with 7 stands – transform this plate in a continuous strip. After exit of finishing train, the strip passes through the run-out table where is cooled at a proper temperature to be coiled (Figure 1). Coils are the most efficient manner to storage, manipulate and deliver strips, without needs to cut or fold.

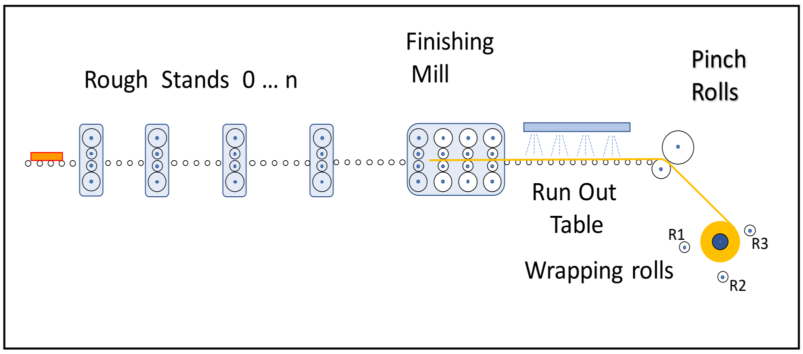



Figure 1. Hot strip mill layout.

In a hot strip mill, the coiling process is totally different from other lines, where the first layers are performed at low speed with or without help of a belt wrapper. Here the coiler is a special device which consists of a mandrel and a few wrappers rolls and with the aid of two pinch rolls is capable to "catch" and roll the strip head at very high speed.

## Quality Issue That May Occur in Hot Strip Mill

The European Standard EN 10051 for coils results from hot strip mills contains information to be supplied by the purchaser at the time of enquiry and order and tolerances for the main characteristics (European Standard EN 10051, 1991): thickness, length, width, flatness, out of squareness and edge camber. All these quality issues may occur in different stages of manufacturing process. Hot strip mill has a great impact on final product and the continuous adjustment is needed to be performed. To achieve the tolerances for the main features, the laminating and coiling processes must be very well performed by high-speed modern controllers, the mill maintenance must be excellent, the mechanical and hydraulic parts must be in good conditions.

A supplementary requirement for coil is in general asked by the customers, regarding the coil shape. The coil aspect at hot strip mill exit not only indicates the ability of manufacturer to manage the process. A coil with uneven laps can provoke supplementary defects when transporting by bending of out triggered edges or in the further manipulating of coils – in pickling, skin pass, galvanizing lines or cold strip mills.

## Telescopeness

The misalignment of coil wraps is called telescopeness (Ostroverhov, et al., 1992) . Even if the telescopeness is not an issue described in European standard for coils, the winding quality is more and more important for clients, which introduce in contracts special requirements in this direction, because of further problems that can appear. Most coil deliverers define their own internal standards regarding the telescopeness. So, in company's products catalogues, we can meet values like 50mm, 60mm or, in worst case 70 mm for this feature. An example of the telescopennes quality issue can be seen in Figure 2, here below.

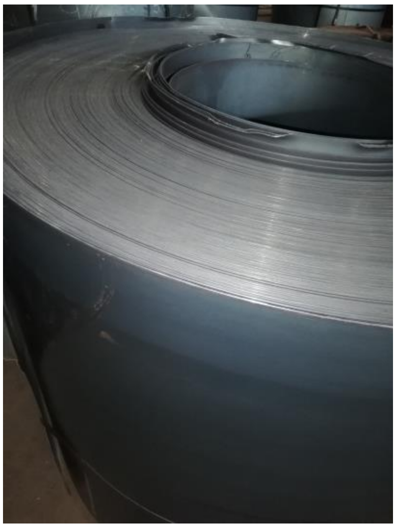


Figure 2. Example of telescopeness quality issue

The customers and the manufacturer are interested by the telescopeness issue and the cause that produce this need to be investigated, because can appear in different locations on the coil and has different causes. Generally, the coil defects depend on the process variables. At the coiling beginning, the first laps are performed with a low tension in the strip. The expansion of the mandrel and the disturbance in strip tension can provoke a misalignment of the first laps – the so called internal telescopeness. In the middle of the process, an incorrect tension in strip between finishing mill and mandrel, can also generate an alternate coiling. At the end of the process, after the tail of strip leaves the finishing mill, the uncontrolled movement of the strip on running table can generate the so called external telescopeness.

Similar study was presented in different science papers, and the methods applied to measure the distance with the laser sensor were different. For example, in Tonnon et al. (1998, pp. 801-808) and in Degner et al. (1999, pp. 87-89), motorized laser distance sensor was used to trace a half of coil profile, directly on the mandrel or near the mandrel.

Another publication, Lima Junior et al. (2007, pp. 7-11)**,** propose a hydraulic device to correct the telescopeness of coil, for horizontal and vertical position. For online correction, (Popovich et al., 1994), a device with two variable frequency drives and two linear induction motors corrects the aluminum strip position by manipulating the tension across the strip and the same problem is solved by applying two different forces on the upper pinch roll shaft (Zhang & Ren Lianeli, 2018). In literature we can find the description of an offline simulator, (Choi & Lee, 2009, pp. 53-61), and the influence of temperature is studied to reduce the coiling telescope.

## Installation Description

The coils are transported by a chain conveyor to the expedition sector. Over the chain, a distance laser sensor, using triangulation method is placed in a protective case (Figure 3). The distance between the hot coil and laser sensor must be enough to avoid the sensor damage, even in case of conveyor stoppage.

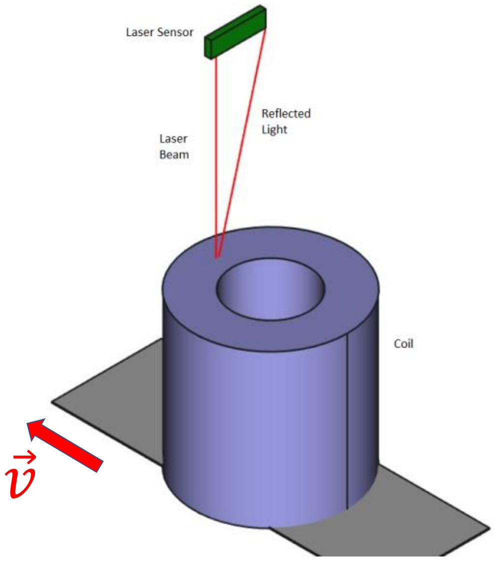



Figure 3. Principle of coil telescopeness measuring.

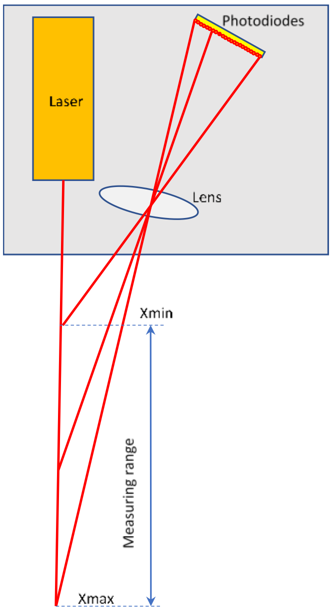



Figure 4. Triangulation principle.

The triangulation method was used because of the advantage of continuous energy radiated. In this method, a laser beam is projected on the side of coil and created a spot on the wraps and the reflected light is analyzed by a receiver placed at a known distance from the laser. The light passes the receiver window and is concentrated on a photodetector with 2000 cell arranged in line with a lens. Knowing the angle of received light, the distance can be measured with a precision 1/2000 of the measuring range. With the help of DSP (Digital Signal Processor) the resolution can be improved to 1/32000 of measuring range. The principle is sketched in Figure 4 where Xmin and Xmax represents the minimum and maximum distance of the laser sensor.

In Figure 5, a simplified diagram of quality classification system is presented. Laser sensor (LIMAB, PreciCura) includes an electronic part capable to filter itself the signals and to deliver a proportional signal with the distance to the obstacle. The laser sensor is used at maximum sample speed (2 kHz) provided by the internal synchronizing bloc (Sinc In.). The Detector CCD is the light sensor with 2000 photodiodes. With the COG (Center of Gravity) bloc, the distance is measured with an improved precision, up to 1/32000 of measuring range. The results are divided and filtered (not in this case because we have our own algorithm to process the signals) and delivered to some interfaces. The interface is RS232 with a baud rate 38400 bit/s. The serial interface baud rate and data format for information about distance (6 bytes) permit to transmit the distance in samples in less than 2 ms. With help of an IOT (Internet of Things) device, data in serial format are transferred through Enterprise Ethernet Network to a server. For every coil, a. csv (Comma Separated Variable) file is generated containing the successive results of measuring. There are hundreds of files every day.

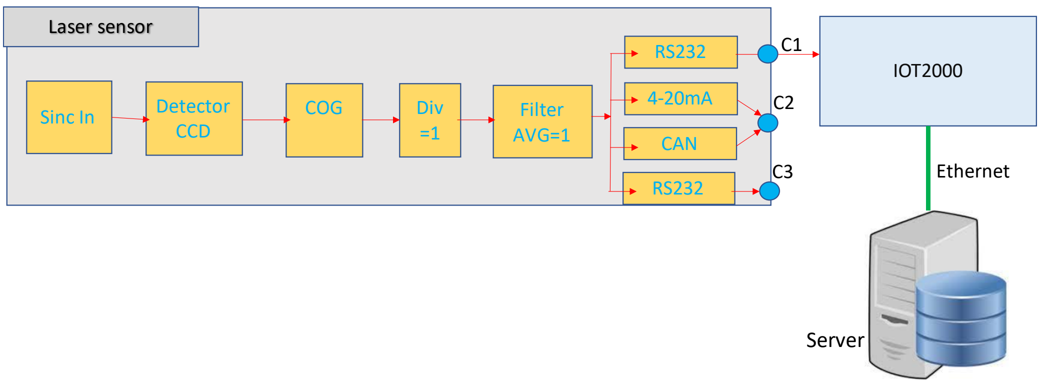



Figure 5. Quality classification system simplified diagram.

The sampling time must be small enough to avoid missing wraps. For continuous - time signals of finite bandwidth, the Shannon-Nyquist theorem (Shanon, 1998) establish a sufficient condition for the sample period to capture the entire information contained in it. The formulation of the theorem is:

“If a function x(t) contains no frequencies higher than B hertz, it is completely determined by giving its ordinates at a series of points spaced 1/2B seconds apart” (Shanon, 1998).

In other words, the sampling must accomplish the Nyquist criteria (Nyquist, 1928, p. 617):

$$T = 1 / 2B \qquad (1)$$

where:

- $T$ – the sample time or sampling period
- the bandwidth of the signal – there are not frequencies higher in the continuous time signal

In our case, for the smallest thickness of the strip with at least 2 samples for every wrap, we can reconstruct “the envelope” of the coil.

The criteria become:

$$T = b_{min} / 2v \qquad (2)$$

where:

- T – the sample time required for DSP

- bmin – minimum strip thickness
- v – the chain conveyor speed (constant)

By replacing variables in (2) with mill characteristics, T is equal to 4.3ms. The installation, that means the laser sensor, the IOT system and the server must be able to process the samples in this time or faster.

## Methodology Used for Classification

For daily reports, the .csv files are opened one by one, and the workflow of the algorithm is indicated in Figure 6, here below.

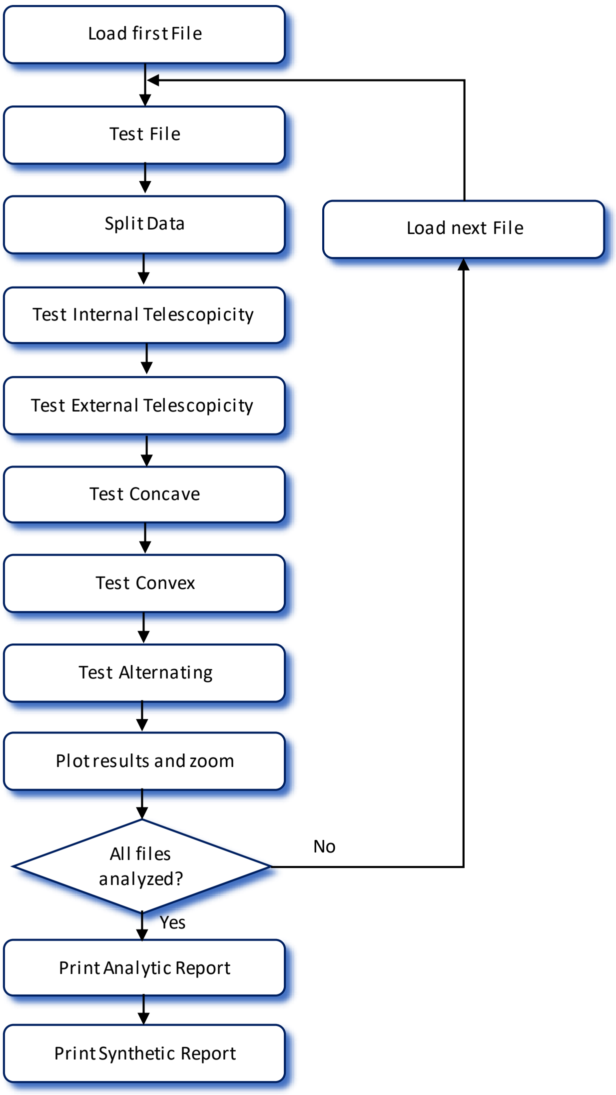
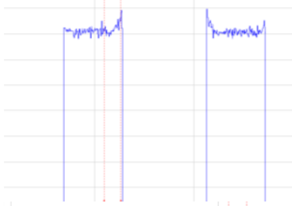
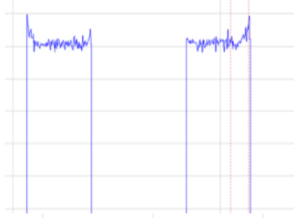



Figure 6. The classification algorithm workflow.

First, the opened file is tested if data are ok. That means the number of rows must be equal with the declared value in the first row of the file, the measured distance must be in the width range of the mill products, the calculated hole diameter must be equal with the mandrel diameter, the coil must be symmetric, etc. If the chain conveyor is stopped when the coil is passing under the laser beam, this test will generate an alarm. In the next step, the recorded data are split in six groups to test for internal telescopeness, external telescopeness, for concave and convex test, alternating test.

Examples of telescopeness issues, observed with the actual PDA (Process Data Acquisition) system before implementation of the algorithm in server are shown in the Table 1.

Table 1. Telescopeness issues -data visualization in actual PDA system

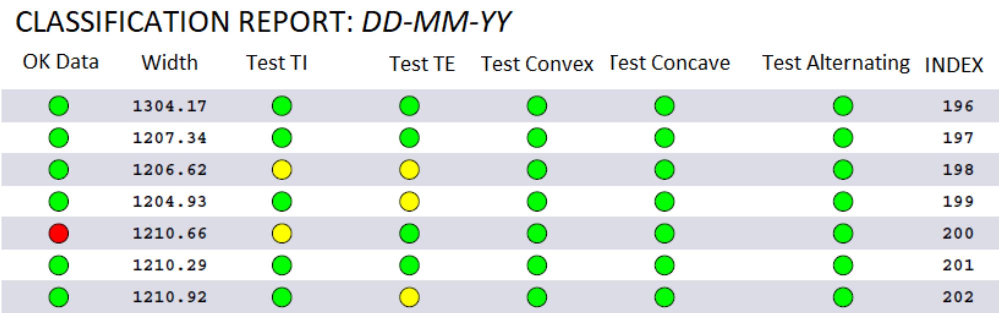
| PDA image | Type of quality issues |
|---|---|
|  | Internal telescopeness |
|  | External telescopeness |
|  | Convex telescopeness |
|  | Concave telescopeness |
|  | Alternate wrapping |

Mixed telecopeness issue may also occur but the tests are more complex to identify all of them.

## Results and Reports

For an easy interpretation, data are plotted. Three graphs are plotted for every coil – an overall graph, a zoom graph, and a graph with sample times. At the same time, a row in a file with test results is recorded. After all files are tested, two reports are printed in pdf format, classification, and analytic reports.

In the classification report, for every coil, that means for every file, a row with test results is added. In Figure 7, a facsimile from a daily report, with coils with indexes from 196-202 is shown. We can observe that data are not OK for coil with index 200, the coils with indexes 198 and 200 have internal telescopicity (TI) marked with yellow filled circle (Test TI – deviation between 30 mm and 60 mm), coils with indexes 198, 199 and 202 are marked with yellow filled circle for external telescopicity (TE) (Test TE – between 30 mm and 60 mm) while all the other tests are marked with green filled circle (between 0 and 30 mm).


CLASSIFICATION REPORT: *DD-MM-YY*

| OK Data | Width | Test TI | Test TE | Test Convex | Test Concave | Test Alternating | INDEX |
|---|---|---|---|---|---|---|---|
| ● | 1304.17 | ● | ● | ● | ● | ● | 196 |
| ● | 1207.34 | ● | ● | ● | ● | ● | 197 |
| ● | 1206.62 | ● | ● | ● | ● | ● | 198 |
| ● | 1204.93 | ● | ● | ● | ● | ● | 199 |
| ● | 1210.66 | ● | ● | ● | ● | ● | 200 |
| ● | 1210.29 | ● | ● | ● | ● | ● | 201 |
| ● | 1210.92 | ● | ● | ● | ● | ● | 202 |

Figure 7. The classification report – facsimile.

In the analytic report, one page for every coil is added. At page 197 we find all the information about the coil with index 196 marked with green circles at all tests. Green circles mean deviation between 0 and 30 mm. We can observe a value for telescopeness equal to 29 mm and a standard deviation equal to 2.84 mm. Knowing the chain conveyor speed and measuring the passing time, also the approximate coil diameter is calculated. This value is also checked in algorithm to accomplish the mill feature.

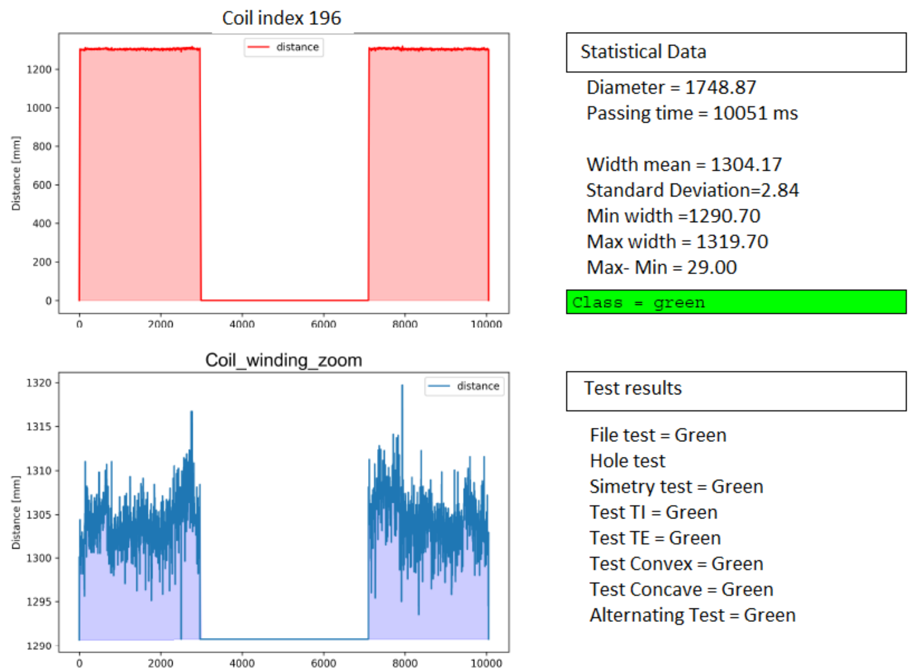


Figure 8. The analytic report – facsimile from page 197.

An example of external telescopeness identification (yellow class) is shown in Figure 9, hele below, where, the telescopeness has the value 52.80 mm and the standard deviation is 4.33 mm.

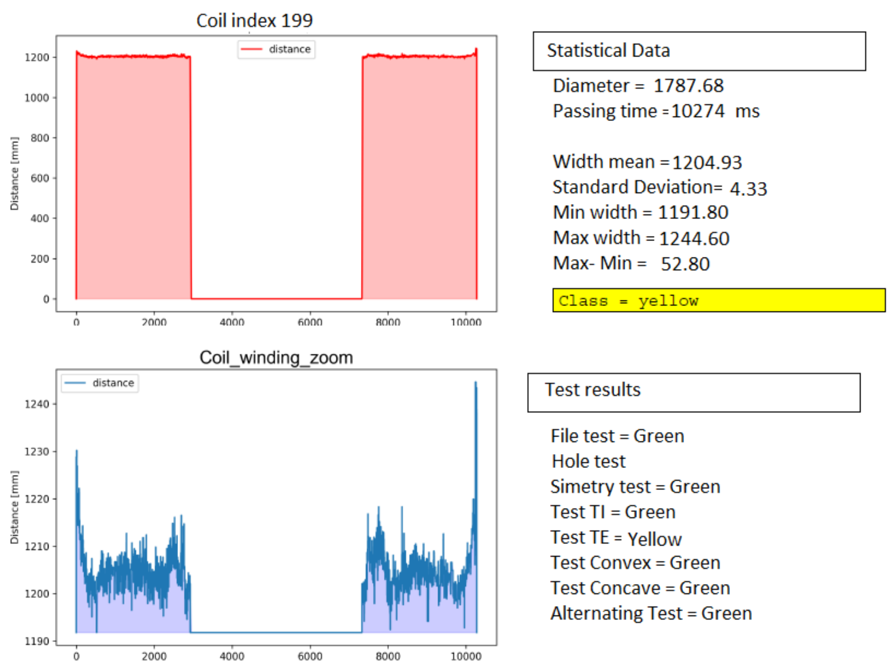


Figure 9. The analytic report – facsimile from page 200.

For index 200, as shown in Figure 7 (extraction from the classification report), in analytical report at page 201, the cause for the red circle was identified – the coil was stopped under the laser beam. An example of a combination of internal and external telescopeness identification (yellow class – both) is shown in Figure 11 and the overall telescopeness has the value of 40.50 mm and the standard deviation is of 3.86 mm.

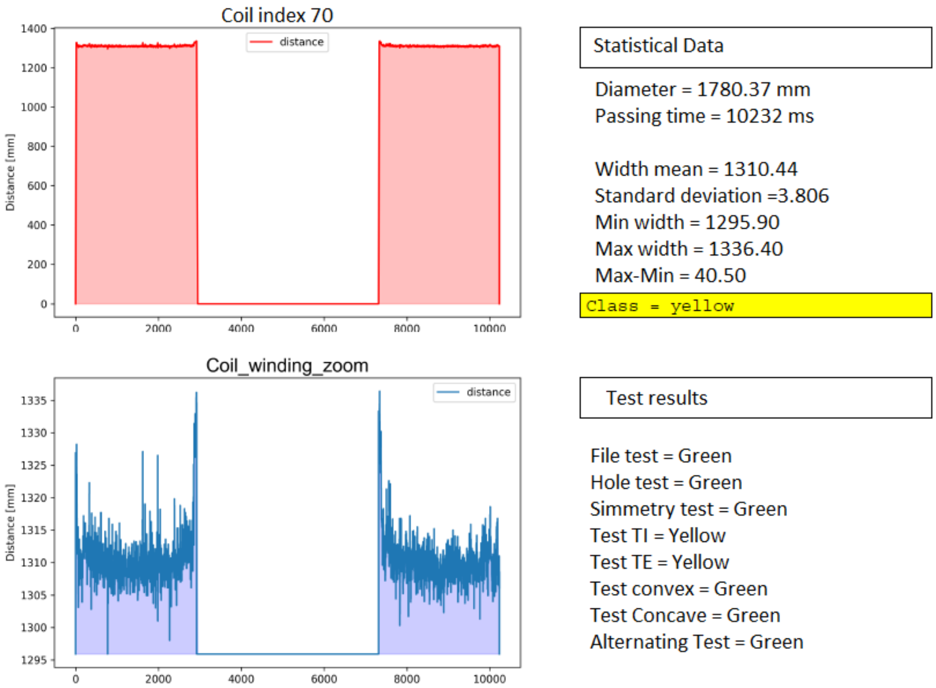



Figure 10. The analytic report – facsimile from page 71.

A bad coil with a combination of three issues - internal telescopeness – red class, external telescopeness – yellow class, and concave issue – yellow class is shown in Figure 12. The overall telescopeness has the value 103.30 mm and the standard deviation is 10.646 mm. But the coil is easy to repair. The internal telescopeness can be easy decrease to yellow class by applying a force with a special device and the coil can be delivered further.

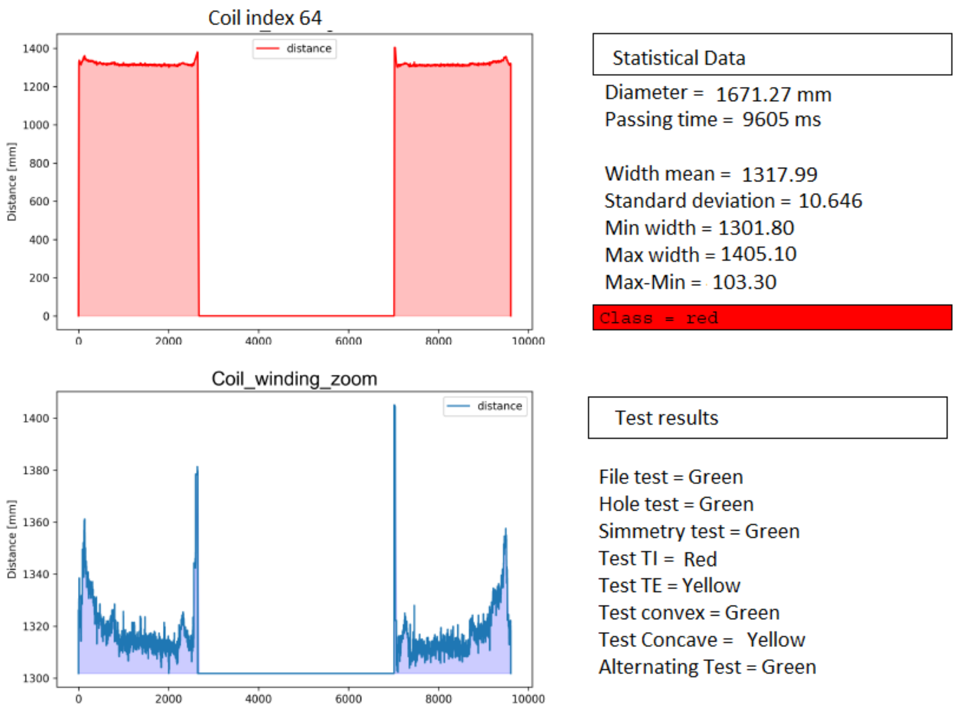



Figure 11. The analytic report – facsimile from page 65.

Another analysis, made for each coil is about the data quality. In the same analytical report, for every coil is generated a graph about the sensor performances. Due to harsh conditions and because the reflected light from moving strip edges has a very unregulated pattern, the laser can vary the sample time to achieve stability of a certain measurement. In next figure the mean for sample time is 2.15 ms and represent a good value in order to analyze the coil.

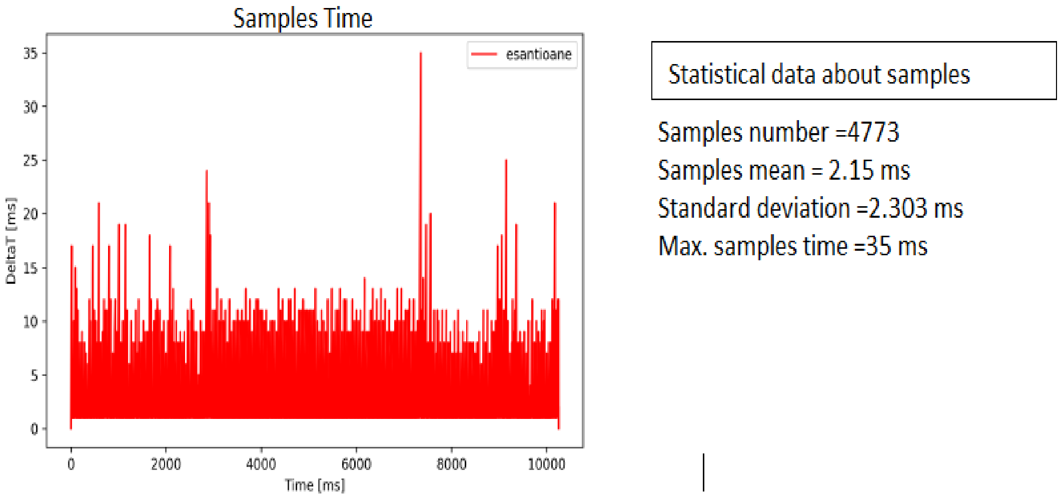



Figure 12. The analytic report – facsimile about sample time.

An automatic schedule service is folding the files and generates the two reports at the end of the day.

## The Online Interface

An on-line interface was also developed to be used by operators to analyze the quality of coiling process, and to signalize to engineers any issue. In this way, small adjustment can be made from coil to coil. In Figure 14, here below, can be seen a photo with the interface.

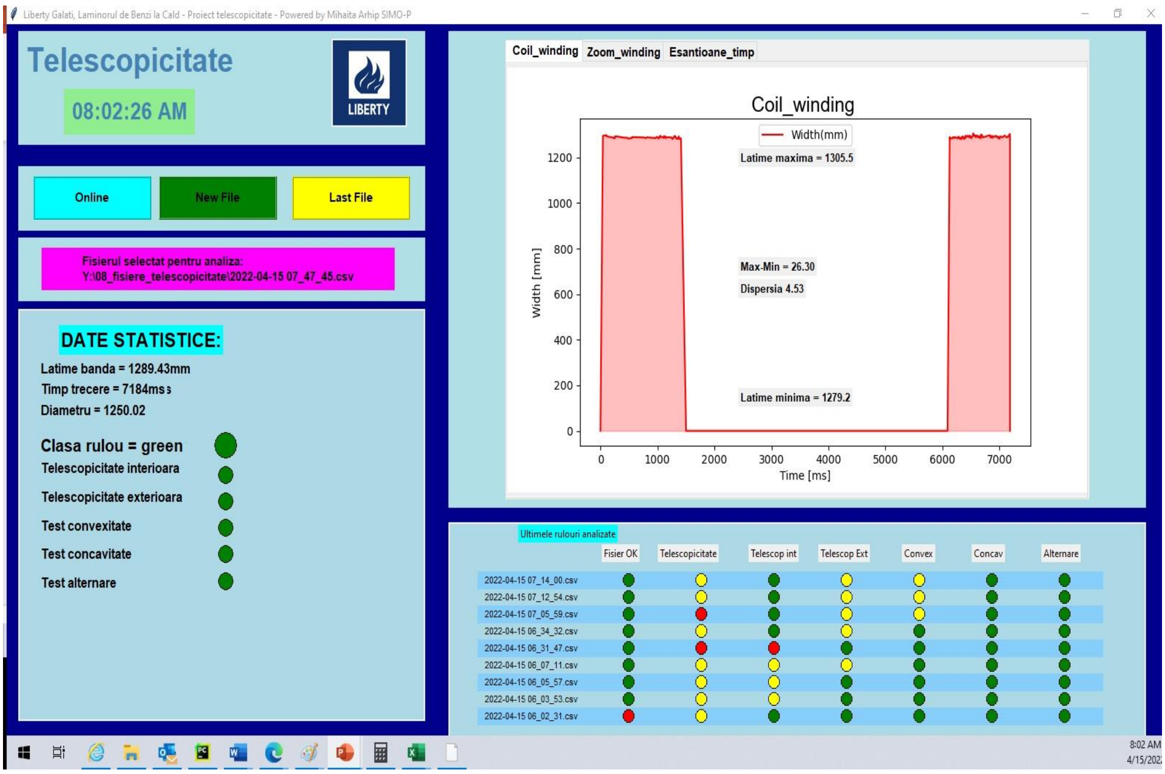



Figure 13. The on-line operator interface.

The same results of tests presented in the „Results amd reports" are displayed for the last coil immediately it passed under the laser beam (the left part of the monitor). In the right-upper part part of the monitor, a notebook with 3 pages shows the results of laser measurement, without and with zoom and the statistical about samples. In the right-lower part of the monitor, the results for the last 9 coils are shown.

## Conclusions

A more and more important issue in hot strip mills is the coiling quality or telescopeness. In this paper, a method and an algorithm for coils classification was described. A distance sensor using laser triangulation was used to measure the position of every lap of coil, during the passing of coils under the sensor. For every coil, a data file was created and send to the server. An algorithm, implemented in Python programming language classified the coils and delivers online reports and daily analytic and classification reports. This system is exploited today and together with process parameters recorded by data acquisition system (like torque from mandrel, pinch rolls, wrapper rolls, strip temperature, steel grades, etc.) is very useful in improving coiling quality.

The on-line interface detects anomalies immediately and permits to make small adjustments from coil to coil. The classification reports are very useful to identify at a glance the coils with problems and in the analytic reports at indicated pages a lot of details about the coil cand be found. The environment is harsh, the strip edges are not the best reflectors for laser beam so some signal missing can appear, but the results are encouragers.

## Scientific Ethics Declaration

The author declares that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the author.

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