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An Innovative Automated Surface Inspection of DC Cast Billets

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Abstract

The visual surface inspection of a billet is mainly qualitative due to human interpretation. To reach higher quality standards and to reduce the overall operating cost, an automated surface inspection system developed by NYX Dimensions Inc. was selected. In 2013, a pilot of this innovative technology was integrated into the existing billet conveyor system at the Rio Tinto Alcan Arvida Works.

The surface of each billet is scanned by four lasers while they are conveyed at normal speed prior to ultrasonic inspection. Two additional lasers measure the position of the defects as well as the billet length. Up to 26 million measurements are logged per billet. Dimensional analysis is used to categorize surface defects based on the topography of the surface and on the average billet diameter.

The use of this innovative automated inspection system ensures to eliminate human decision errors and maintain customer satisfaction. In addition, the acquired data provides valuable information to improve process control.

Introduction

When Rio Tinto Alcan (RTA) Arvida Works approached the company NYX Dimensions Inc., they had two needs in mind. The first one was to reduce process variations and eliminate errors related to difficult human decisions in order to decrease operating cost. The second need was to increase the inspection quality level to reduce unnecessary rejects of billets and eliminate customer complaints.

NYX Dimensions Inc, founded in 2006, is the result of complementary expertise and a novel vision of the development of new 3D acquisition systems. Located in Saguenay, Québec, Canada, NYX Dimensions Inc. designs, develops, builds, and commercializes contactless 3D acquisition systems, mainly for industrial application. The expertise of the company lies in the grouping of ultra-specialized competencies in industrial metrology and mechatronics. NYX Dimensions Inc. has already acquired a wide experience in designing various systems with customers such as Rio Tinto Alcan, Elkem Metal, Canada General Cable, Rio Tinto Fer et Titane, and Alouette.

The project goal with Rio Tinto Alcan Arvida Works was to build a new automated inspection system integrated to the existing plant conveyor systems. The best location for the laser scans identified for the project is on the first rolling conveyor, in front of the ultrasonic inspection system, which is located before the rejection conveyors and homogenizing furnaces.

Figure 1 – Layout of the system installed at Arvida Works

In addition to rejecting scrap billets, this system has to be able to classify the types of defects, keep and improve the feedback loop to the DC casting pit crew, and thus help them take necessary actions on specific defects. Furthermore, the system should also be able to provide to the technical team the key performance indicators needed to monitor and improve the process performance.

To keep up the production rate, the automated inspection has to maintain or improve the current visual inspection time. Finally, the new system needs to communicate with the plant automate to meet a complete integration.

Development

Equipment
This technology allows quantitative measurement and recognition of the surface characteristics of cylindrical billets. The surface measurement is contactless, using only lasers and scanners to collect information. All this information is acquired in real time and quickly treated. The system can measure length, diameter, and bows. With the topography records of the billet and criteria such as width, depth, length, slope, etc., it is possible to find and

characterize the defects. Once done, the system communicates the information of the defects (position and type).

Machine
The machine characteristics are dictated by the billet speed on the conveying system and by the expected defect resolution. The constraints for Rio Tinto Alcan Arvida are the following:

- conveyor speed: 1.2 m/s,
- area of defect: 2 mm x 2 mm,
- depth of defect: 0.5 mm,
- height of defect: 0.5 mm,
- precision of diameter measurement: 0.1 mm.

Laser position
The billet length and the defect position are measured using two infrared lasers. Their response time must be very fast (15,000 Hz). These lasers should have a precision of less than 2 mm over a 20-m distance and have a great repeatability. They must be reliable and able to sustain an industrial environment, including hits, high temperatures, artificial lighting, and electromagnetic noise.

Scan lasers
The lasers used for scanning were chosen for their high scan frequency (up to 6000 Hz). They have three different measurement zones. The measurement resolution is in function of the field depth, the nearer the laser is from the target, the finer is the resolution. At the opposite, the farther the laser is from the target, the coarser is the resolution. The scanner has two measurement axes: the “X” axe, which is materialized by the laser line projected on the target, and the “Z” axe, which is the distance between the laser and the line seen on the target. The “X” resolution is directly related to the focal distance. The distance between the laser and the billet is chosen in order to accommodate the different diameters to be scanned (178 mm to 254 mm for this installation).

In order to build the topography of the billet, the scanners are preset to work at 1000 Hz. The data collected with this setting are sufficient to build a very detailed model of the billet surface.

To build the topography of the billet, the scanner needs to use a differential method. This method can treat the lateral movements of the billet while it is moving on the conveyor. In doing so, the stabilisation of the billet is simulated. To do this, the laser works in pairs, and all scanning results are expressed as: Z Laser 1 – Z Laser 2. In this way, it is easier to know the diameter of reference work and, at the same time, a readjustment of the scans can be done even with the parasite movement of the object.

The two laser scan pairs are configured for the topography and are assisted by a pair of linear lasers, which give the measurement in the « y » axel (lengthwise). Those lasers reposition each scan while modelling the billet. The final modelling will allow finding the defects as well as calculating the billet diameter, bow and length. The measurement will also be used to mark the billet defects location with paint, if needed.

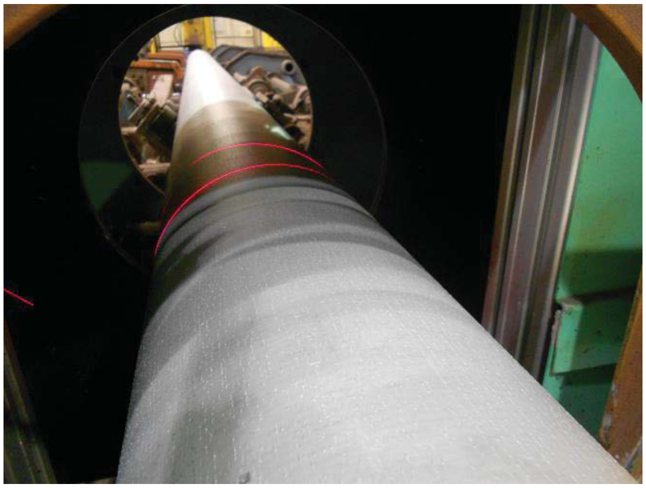

Figure 2 - Scanning laser on the billet

Program
Characterisation of a billet requires processing more than 25 million xyz coordinates. The acquisition is done via Serial and Ethernet ports. In a first step, the program eliminates erratic data and statistically increases the quality of the position measurement. This filtration is important as it helps stabilizing the measures and reducing the complexity of the data treatment algorithm. In a second step, the program collects the data linked to a circumference, and gathers all the circles in a matrix, which allows a real-time visualisation display of the topography. A plant metallurgist can see the image of a billet and visually recognize a defect. Different types of defects can be detected by the system depending on the defect characteristics such as length, depth, width, length to width ratios, etc.

The system analyses the billet surface using given rules to find existing defect position and type. The plant metallurgist can adjust parameters in order to increase or decrease the machine sensibility. After each billet, the system communicates the defect type, position, diameter, length, and bow to the plant management system.

Computer
A rapid computational power is needed to give results in the time allowed by the inspection process (a few seconds).

The computer configuration used for this project is as follows:

- Linux OS
- 2 CPU 2.5 GHz 8 cores
- 32 Gig ram
- 500 Gig SSD
- 3 Ethernet port 1G
- 2 RS485 ports
- 8 ports 1 GHz switch

The optimization of the program is important in order to fully use the multitasking capability of the computer.

Prototype
In 2012, a first test version was built in the workshop of NYX Dimensions Inc. to run performance tests on the equipment. Due to a lack of precision of the position laser, it was decided to average multiple readings rather than choosing only one value.

Regarding the scan laser, due to the processing capacity of the system, it was decided to decrease the amount of the scan frequency per second from 6000 to 1000 Hz without losing too much accuracy. A stationary billet was used to confirm the feasibility of the instrument.

Many assumptions were validated when using the experimental version, which was composed of one position laser and two scanning lasers located one in front of the other. First, the use of a common referential for all four lasers in production was confirmed. Some lacks were noted in the initial differential measurement algorithm, which was due to the angular scan and to the interference between scanners. Secondly, while slowly pushing the billet, it was noted that the chosen differential approached did not compensate for all the vibration movements. Thirdly, from the experimental results, it was possible to differentiate the good from the erratic values coming from the scanning lasers. Fourthly, from the data acquired, it was also possible to validate the algorithm and calculate the necessary computational needs.

Implementation

Integration with the automate

A technical team, including people from Rio Tinto Alcan Arvida, Rio Tinto Alcan IT, and NYX Dimensions Inc. was created to implement this system.

First of all, the cast number, coming from the plant management system, must be sent to the automate, which signals the beginning of the inspection to the laser inspection system.

For each ingot, a smart camera, used as an optical character recognition (OCR) system, recognizes the billet ID (see Figure 3).

Figure 3 - Ingot ID on the billet foot

The billet passes through the laser and ultrasonic inspection systems. Both systems send the inspection results to the automate, which, depending on the production to be prepared, logs or cut billets, decides to either scrap the ingot or use the automated painting unit to mark the defect so it is sawn later. At this time, the ingot information (ID, length, diameter, bow, and defects) is sent to the cast house management system. At the end of the cast, the rest of the information, total number of ingots, etc. is also sent to the management system. All this information is used for traceability and to help the management of the sawing system.

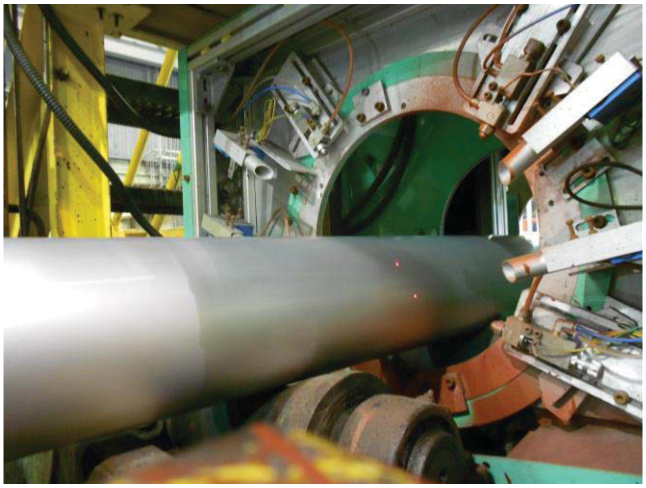

Figure 4 - Painting unit with a paint detection system

Installation

At the end of 2012, an engineering project was started. The existing rolling conveyor was modified to make room for the automated inspection and the marking system. The conveyor was adjusted and revamped to reduce ingot lateral movement, which increases inspection difficulties. The scanning laser and the marking system were inserted in front of the existing ultrasonic inspection equipment conveyor. An OCR camera was installed in front of the entrance conveyor, and finally, a pair of linear lasers, for the billet position, was installed at the beginning and the end of the conveyor.

Commissioning

Once in line, the system was modified to compensate for ingot lateral movement and any other operational issues such as vibration, hits, etc. A sampling campaign was carried out to choose as many ingots as needed to adjust the system parameters. A billet viewer was developed to observe the image of the billet scanned and analyzed. This viewer is not only useful but necessary for the commissioning of the system. The first data collected showed some irregularities that had to be covered by the plant. For example, excessive ingot movement has to be reduced via mechanical modifications rather than via filters in the software. The viewer also allows adjusting the parameters and completing the debugging of the software.

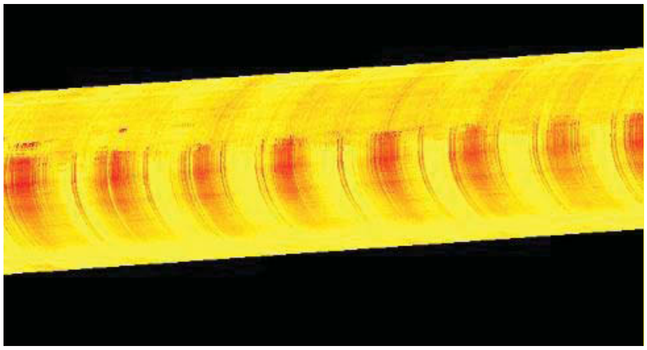

Figure 5 - Effect of the lateral movement on the conveyor without correction

Results

Once the parameters are set, it is possible to identify defects such as horizontal tear, vertical tear or rough surface. Combined with the ultrasonic inspection system, it is now possible to fully inspect the ingots without human decision.

Figure 6 – Example of an inspected defect (vertical tear)

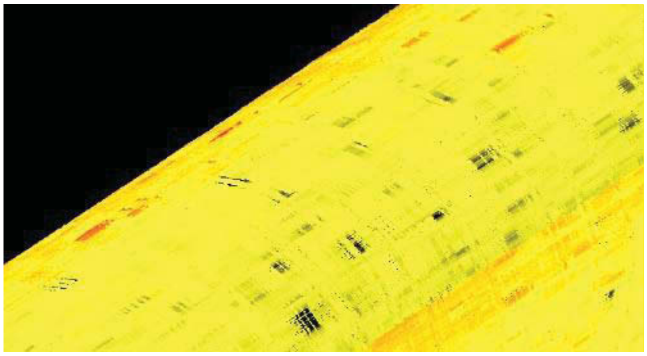

Figure 7 – Example of a rough surface billet scan

Control

A control tube was designed in order to follow the system performance to ensure stability in time. This tube is made of titanium, which is selected for its lightness and robustness. This tube has machined references and will be used to verify the bias and drift of the machine as well as fulfill ISO 9001 requirements.

The signature of the reading of this control tube is then compared periodically to check any deviation or drift over time.

Figure 8 – Control tube with machined reference

Conclusion

The implementation of the automated scanning system allows an excellent ingot surface measurement. With the appropriate settings, ingots with minor cosmetic defects are not discarded any more, and ingots with more important defects such as vertical tears and cold shuts are removed from the production line. The defects are analyzed with quantitative data rather than with the usual qualitative visual inspection, which can be subjective. The implementation of the system allows eliminating the inspection task, thus reducing the operating costs.

Partnership

The development and implementation of this system by NYX Dimensions Inc. and Rio Tinto Alcan Arvida Works would not have been possible without the collaboration of many partners such as Cegertec-Worlsey-Parson and the Rio Tinto Alcan Arvida Research and Development Centre, who provided solutions and technical skills, as well as CQRDA and the Rio Tinto Alcan Regional Development, who provided financial support.

New generation

With the experience acquired when designing the system, a second version of the machine is already on the drawing board. This new version will keep the same elements but will be improved with new tools for the optimisation of the measurement.

In the current version, lasers are fixed. Therefore, depending on the diameter, the resolution in “Z” varies. In order to counter this phenomenon, the machine will be equipped with linear actuators used to position the lasers at a better distance from the billet, thus allowing the best resolution available anytime.

Presently, the lasers are located at 45, 135, 225 and 315 degrees from the vertical line. Those angles are dictated by the plant production line. In a future version, angles will be set at 0, 90, 180 and 270 degrees, reducing unnecessary calculations. Furthermore, an inclinometer will ensure the exactitude of the angles.

New faster scanning lasers are now arriving on the market. Those scanners will allow a better measurement precision. New scanners will multiply by four the acquisition rate and divide by five the measure uncertainty. Rather than emitting a red light, those new laser scanners will emit in blue, thus allowing a better filtration of the data.

Since its installation, the system has been affected by plant environment such as dust, water, foreign bodies, etc. These elements can be detected on the billet by the scanner, and the billet can be falsely rejected. To reduce those pollutants, the measurement chamber will be equipped with a high efficiency dust collector.

To facilitate maintenance, panels shall be easier to remove giving fast access to vital components. Furthermore, a modular conception will allow a fast replacement of a defective module.

Regarding external communications, the future version will be equipped with different communication modes: Ethernet, USB, Serial, and optionally Profibus.

The hardware and software will be modified in order to simplify the structure design and improve the time consuming calculations. More than 100 million points will be treated, four times more than what is presently done. This of course forces to reconsider the current calculation methodologies. The final objective is to deliver results within two seconds after the billet passage.

The new system will be more compact, more shock resistant, easier to transport and easier to implement.

Automation

In the future, reports of defective billets coming from the automated inspection system could be used to optimize saw performance. With new investments and by using an additional smart camera at the saw, the sawing system could be fully automated.