OPTIMIZATION OF LADLE REFRACTORY LINING, GAP AND CRACK DETECTION, LINING SURFACE TEMPERATURE AND SAND-FILLING OF THE LADLE-TAPHOLE BY MEANS OF A 3D-LASERPROFILE-MEASUREMENT SYSTEM THAT IS IMMERSED INTO A HOT LADLE TO EVALUATE THE ENTIRE CONDITION

Rolf Lamm, Stefan Kirchhoff,
Minteq International GmbH - Ferrotron Division

Introduction

Laser profile measurement systems have been used in the steel industry since the 90s. Since the introduction of high speed laser scanners, they become more and more important for determination of the brick thickness of converter vessels, steel casting ladles and torpedo ladles. The laser measuring units are in operation as mobile measuring units or fixed installed systems globally. Besides the increased safety of the aggregates by avoiding of dangerous breakthroughs, economic aspects for the use of laserscanners, are important criterions too. The risk of a ladle breakthrough is always present in a steel plant. More important than the loss of production and costly consequences of damage is the potential risk of personnel injuries and risk of a fatality. Besides determination of the residual brick thickness, current lasermeasuring units enable the determination of the wear rate and wear speed of refractory. Additionally, information of the bath level, optimization of the tapping angle, evaluation of the bottom tuyeers, taphole inspection as well as the temperature profile of a vessel justify the increased use of laser scanners as process accompanying instruments.

Nowadays Laserscanner for the Steel Casting Ladle application are designed to measure the ladle refractory lining from outside the ladle by means of sending infrared laser pulses to the wall and bottom of the ladle. Fig. 1

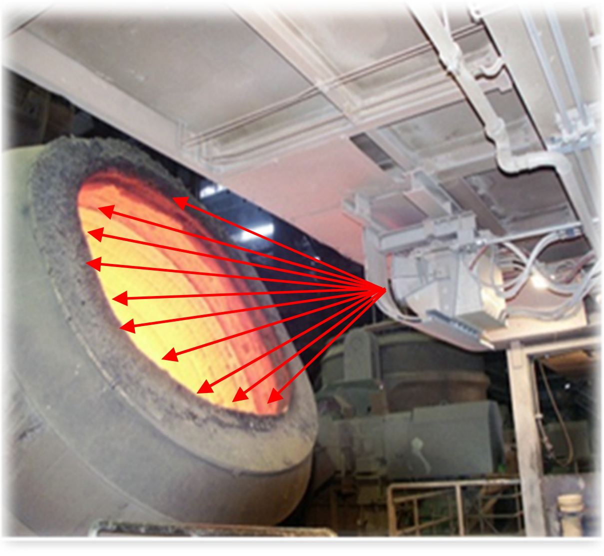


Fig. 1 Laserscanner measures from outside position

If the mouth of the ladle is “clean” and no skull is built up you can have good results from the entire ladle-refractory lining although the laserscanner is in front of the ladle mouth. However accuracy of the measurement is impacted by the spot size of the laserbeam which is depending on the laserbeam´s angle of incidence. Especially in the lower wall area of the ladle we have a flat dipping laserbeam by measuring from outside the ladle. Another issue is the shadowed area below the ladle mouth when skull could hinder the laserbeam to hit the wall area. This shadowed areas are not accessible for the laserbeam. This disadvantage has an impact on measurability of the slag zone which is a very important area in ladle lining relating to the risk of a breakthrough. To overcome the above mentioned drawback we introduced a newly developed laser measuring unit which for the first time enables the lasermeasurement of steel casting ladles from inside the ladle. Fig. 2

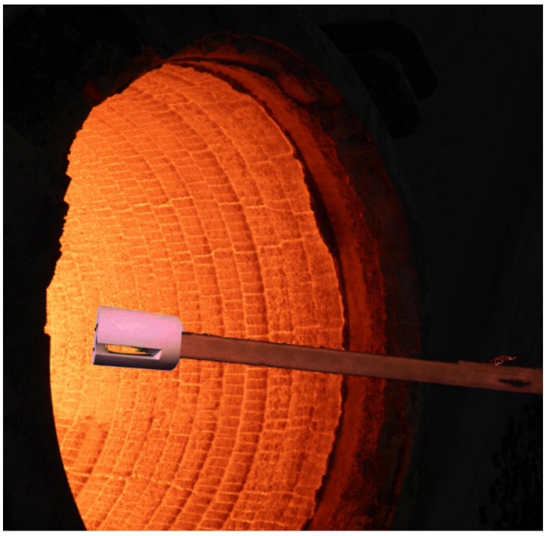


Fig. 2 New developed lasermeasurement system with immersed laserhead into a ladle

Proven Technology

The patented measurement method allows regular measurements of the refractory lining in a hot condition directly after the tapping. The method of immersing a laserscanner into a hot confined space was already introduced with our lasermeasuring system which measures torpedo ladles from inside the hot torpedo ladle.

The lasermeasuring system has been developed for non-contact measurement of hot refractory linings in metallurgical reaction and transport vessels. Rapid scanning with a laser-pulse-repetition rate up to 300 kHz or 125,000 measurement /sec.. "Echo-signal digitization" and "online waveform analysis" guarantees the best "real value readings" of the single measurement points.

This high measurement speed as well as the robust cooling system and consequent insulation of all components of the laser scanner allows measurements in high ambient temperatures up to 1100 °C and surface temperatures of 1700 °C. The measuring system has multiple sensors for temperature and cooling circulation to ensure that in case of any error, the laser scanner is automatically removed from the hot area. The entire measurement takes less than 3 minutes and more than 3.9 million points with accuracy better than 5 mm are created in the ladle scan.

Measurement Procedure (Fig. 3)

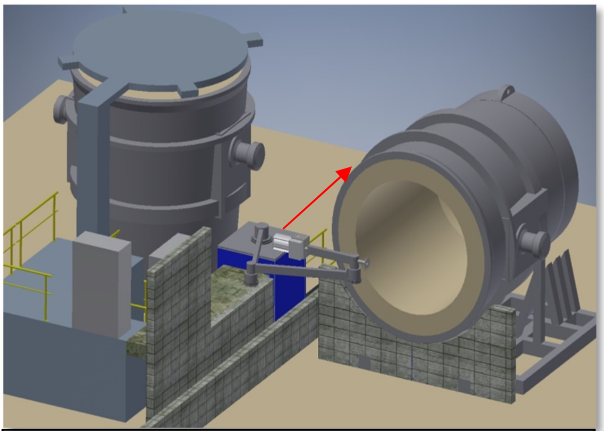
When the ladle is put in the ladle-stand the operator enters the ladle number (this can also be automatically detected or being received from Level 2 plant computer). The system selects the stored reference data of the particular ladle as a base for the evaluation. Then the operator start by just pushing one bottom the measurement procedure. The laserhead on the manipulator arm goes first in a position where the laserscanner sees the outer contour and a part of the mouth of the ladle in order to find the exact position of the ladle by using patented "3-D- structure finding" software (a) "Positioning-scan on shell").

A second scan in front the mouth area enables the measurement of the bottom area (b) "Bottom Scan"). Afterwards, the manipulator boom with a mounted scanner head moves completely through the mouth, inside the hot ladle where the entire ladle wall lining is measured with a 360° rotating laserscanner (c) "Center-Position-Scan 360°"). Each scan takes only 20 sec. After measurement the boom returns to the "park position". The collected data is processed by an industrial PC and measuring results are displayed on a monitor. The connection to intranet and level-2-system allow the direct use of the measuring results for further evaluation and reporting/documentation.

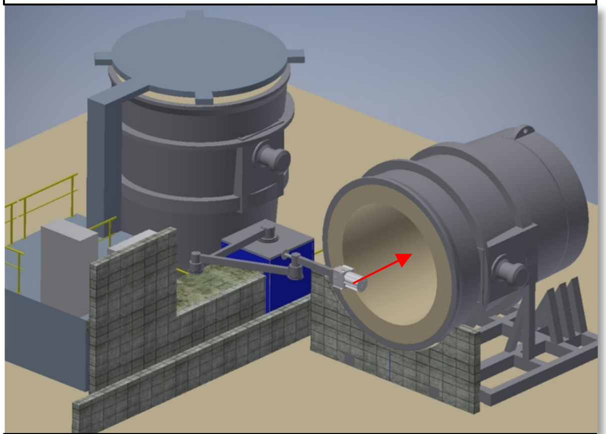
Evaluation and presentation of the results (Fig. 4)

The new developed evaluation possibilities allow a wide choice on presentation alternatives from tabular reports, horizontal and vertical "profile-cuts" in all angles and depth to virtual walk-throughs by means of configurable 3D-images. The measurement results are presented on a Graphical User Interface GUI and can be documented in various ways. Residual brick thickness, wear- rate/-speed, wear tendency and possibility of zooming into critical areas offers a very analytical way of refractory wear mechanism.

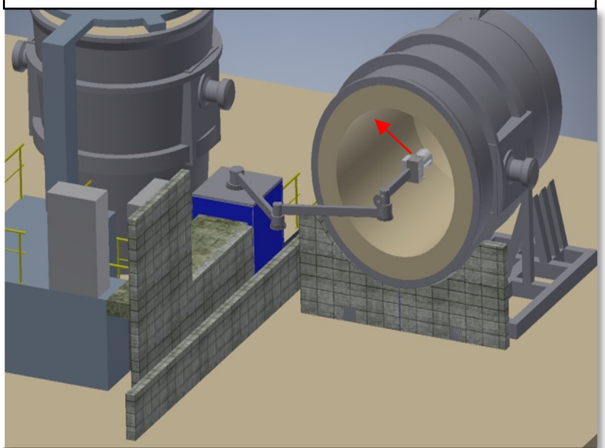
If the laserscanner is measuring from inside he can see shadowed areas below the ladle mouth when skull would hinder the laserbeam to hit the wall area with a conventional measurement from outside. (Fig. 5)



a) Position Scan on outer shell



b) Bottom-Scan from outside



c) Centerposition-Scan 360° inside ladle

Fig. 3 Measurement Procedure

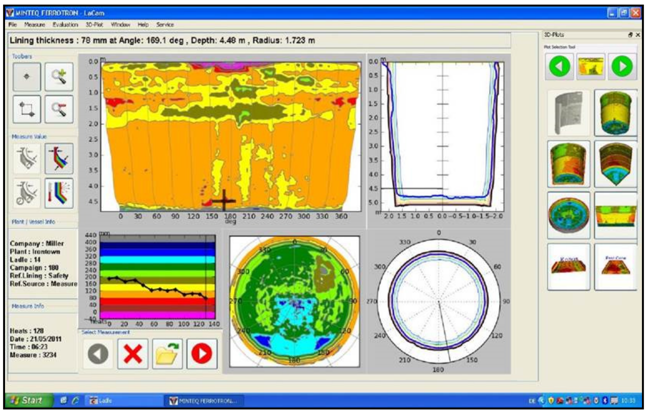


Fig. 4 Display which shows the measuring results at a glance and allows specific result presentation (section cuts, 3D, etc.)

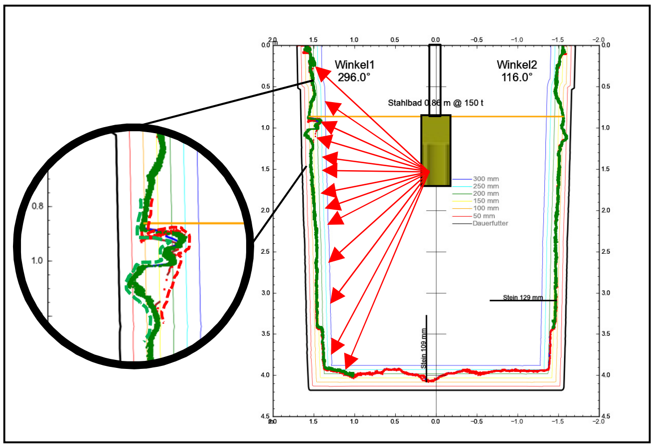
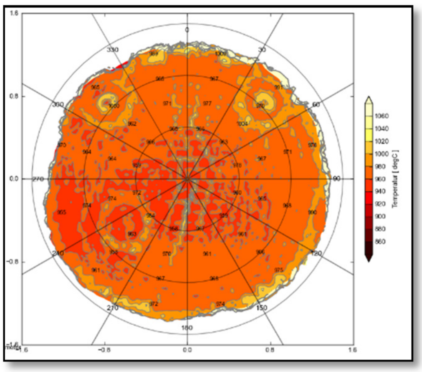


Fig. 5 Immersed laserhead can see dangerous areas which could not be seen from outside Laser-scan

Pyrometric Temperature Measurement (Fig.6)

Simultaneously to the lining thickness the system measures the surface temperature of the lining with a high density of data collection (one measure point per laser shot). Temperature profile is displayed in 2D-(a) and 3D graphics (b). With this additional information the system provides an improved confidence in refractory conditions and safety of ladles. Nonuniform temperature distribution of the ladle-lining and hot spots can be detected.

a)



b)

Fig. 6 Temperature Profile of ladle bottom and wall

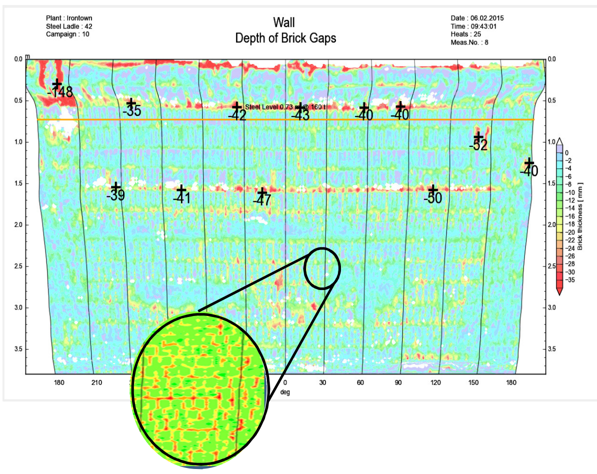
Gap and Crack Detection

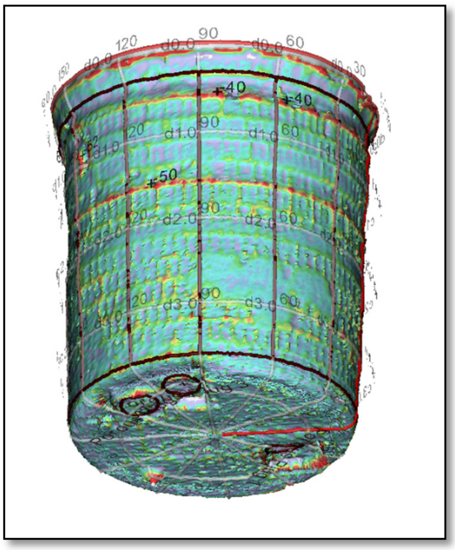
The laserhead has an increased resolution, high accuracy and a very small laserbeam which allows together with a better viewing angle (almost 90°) to the wall a much better detection of gaps and cracks in the wall. The critical areas of the slagline can be measured and dangerous areas can be detected now.

The data processing performed is a special 2D peak finding algorithm which has some similarities to image processing functions. In a combined evaluation of brick thickness-, surface temperature and laser echo amplitude a gap or crack in the lining can be determined.

The laserscanner provides high resolution thermographic images and due to thermal radiation physics, the gaps become visible as areas with higher temperature radiation compared to the surrounding. Another feature is the display of the laser-echo amplitude. This amplitude plotted on 2D or 3D gives a human-eye-like impression of the structure. Gaps become visible as highlighted structures due to the larger suppression of the back-scattered laser beam. All information, direct gap width and gap temperature respective laser echo amplitude, displayed either in 2D- (a) or 3D (b), allow the detection of critical gaps. (Fig. 7). The software can automatically output a warning if critical gap depth is exceeded.

a)





b)

Fig. 7 Superimposed Gap and Crack information

Taphole Condition and Sand Filling

By means of precise determination of the taphole-geometry an automated sand filling of the tap hole can be made. This leads to increased quality of sand filling will enhance ladle opening rate at continuous caster by detection of "Open slider", Debris above slider, optimum amount of sand mass, optimum sand filling by controlled x-y-position, optimum sand profile shape (Fig. 8)

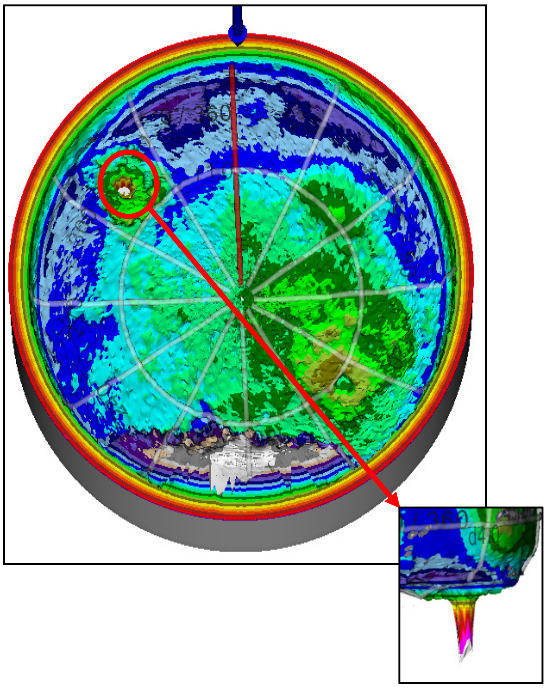


Fig. 8 Taphole condition before sandfilling

Bathlevel determination and Freeboard

The Lasermeasuring system is able to calculate exact bathlevel of the steel in a ladle by using the volume calculation considering the steel mass/slag equation. Not only for transport safety but also if the ladle will go to the vacuum degassing station the exact "freeboard" is of importance (Fig. 9)

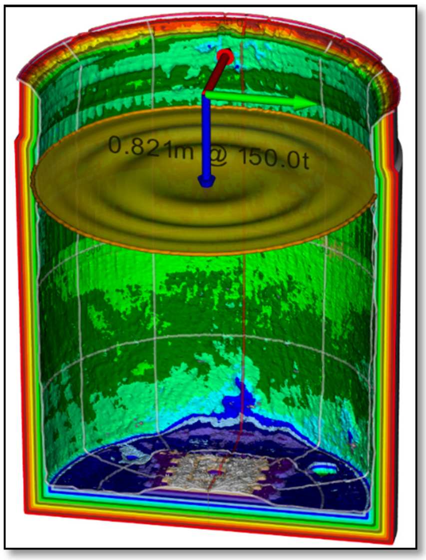


Fig. 9 Bathlevel and Freeboard determination

Summary

With this world premiere, we introduced a laser profile measurement system that makes a contactless measurement of the refractory lining inside of a hot ladle in less than three minutes. The versatile presentation of measuring results and the derived results enable steel producers to achieve cost savings in energy, material and maintenance while at the same time to increase safety, ladle availability and capacity as well as prolonging the refractory life span. This new measurement technology using a submerged laser-scanner can also be used in other confined spaces e.g. Torpedo Ladles. Further developments will follow.

Acknowledgements

The author wishes to thank the R&D team from Ferrotron Division especially Stefan Kirchhoff (Co-Author) and Niels Kyewski for their engaged work and passion during the project realization.

Literature references

Rolf Lamm, "Lasermeasurement for the Refractory lining of hot Torpedo ladles", Proceedings of the AIST 2012, Atlantic City,USA

Rolf Lamm, "New Lasertechnology for submerging a Laserhead into a confined space", Article in "Stahl und Eisen- Magazine", Sept. 2012