Laser Measurement System for the Refractory Lining of Hot Torpedo Ladles

This paper introduces the world's first laser profile measurement system for the refractory lining of hot torpedo ladles, the LaCam®. The torpedo measuring system allows immersion of a laser head into a hot torpedo ladle with surrounding temperatures of more than 1,000°C. Benefits include improved safety, increased ladle availability and capacity, extended refractory life, and cost savings in energy, material and maintenance.

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Since their introduction, high-speed laser scanners have become more and more important in the determination of brick thickness of converter vessels and steel ladles. The laser measuring units are used as mobile measuring units or fixed installed systems worldwide. Besides determination of the residual brick thickness, current laser measuring units enable the determination of the wear rate and wear speed of refractory. Additionally, information on the bath level, optimization of the tapping angle, evaluation of the bottom tuyeres, as well as the temperature profile of a vessel justify the increased use of laser scanners as process-accompanying instruments.

Besides economic aspects for the use of laser scanners, the increased safety of the aggregates in avoiding dangerous breakthroughs is an important criterion, as they have high significance in the transport of pig iron from the blast furnace to the steelmaking plant. Worldwide, torpedo ladles transport liquid iron on railways, partly on public railway tracks. Especially here, breakthroughs would have serious effects.

Torpedo ladles are becoming increasingly important, as steel plants without a pig iron mixer often need 90% of the torpedo fleet for its standard operation and as a buffer between the blast furnace and converter shop. An outage on one torpedo ladle already results in a severe disturbance of the production process.

Ferrotron, a division of Minteq International GmbH, introduced the laser measuring unit, LaCam® Torpedo, which for the first time enables the laser measurement of hot torpedo ladles from inside the torpedo ladle.

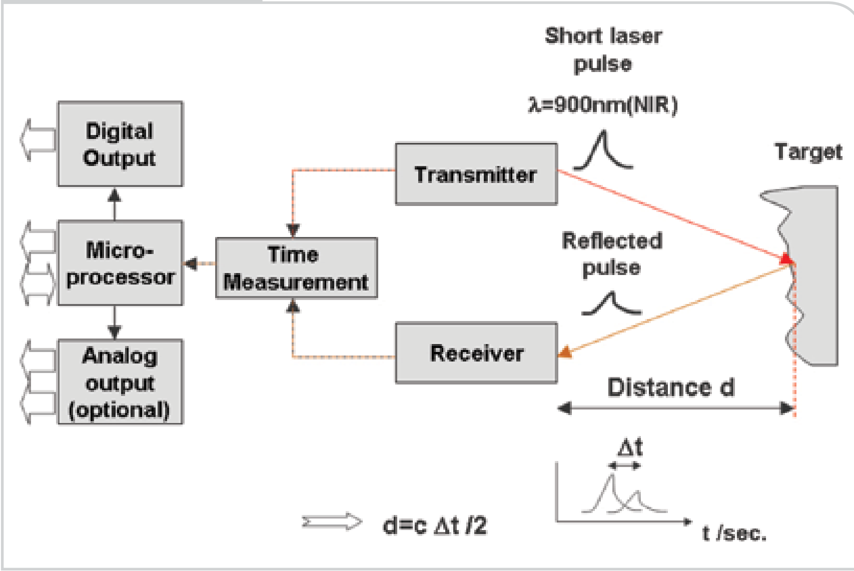
The patented measurement method allows for the regular measurements of the refractory lining in a hot condition directly after the tapping. A reliable evaluation of the actual condition is possible and the refractory lining life can be maximized.

LaCam Laserscan Technology

The LaCam profile measuring system has been developed for non-contact measurement of hot refractory linings in metallurgical reaction and transport vessels.

Rapid scanning of the object is possible via a pulsed laser beam (time of flight (TOF) measurement with a near-infrared (NIR) laser diode), which is deflected by a rotating mirror system (Figure 1). Thus, a three-dimensional frame of the vessel's inner surface is created within a few seconds. To ensure reproducible measuring accuracy in combination with high-speed scanning, the laser pulse repetition rate is up to 300 kHz,

Figure 1



Principle of time of flight measurement for determining distance.

Figure 2

Setup of LaCam Torpedo during laser measurement.

or 125,000 measurements/second, in combination with "echo-signal digitization" and "on-line waveform analysis." To use the LaCam technology without special safety measures, a laser of safety class 1 (eye safe) is used.

Today's Practice

Today, most steel plants are conducting a "cold inspection" of their torpedo ladles. That means after a certain lifetime or number of heats, the torpedo ladle will go to an inspection stand where it cools for up to three days. An inspector will climb into the cold torpedo ladle and break off refractory bricks at a location that looks noticeably weak. After the brick thickness is measured with a ruler, it will be decided if it is necessary to repair the torpedo ladle, replace the entire lining of the torpedo ladle or put the torpedo ladle back into the production cycle. The repairs require two days before the torpedo ladle will be preheated for another two days. After this break, which can take up to seven days, the torpedo ladle is again ready for further transport of pig iron.

New Method

When taking regular measurements in hot conditions, methodical cold inspections can be reduced to a period of only four to five days. Furthermore, energy costs can be saved and emissions reduced. This measurement during hot condition was the goal of the introduction of the new LaCam Torpedo technology.

Operational Applications

The first test setup was installed in a European steel plant with an annual production of pig iron of around 11 million tons. The plant uses 73 torpedo ladles, where 60 ladles are needed for daily operation. The average charging weight of the torpedo ladle is 270 tons. The system was constructed in such a way that the torpedo ladle cars stop to be cleaned (Figure 2).

The system consists of a 3D laser profile measurement head mounted on top of a cooled movable boom, a cooling system, automated mechanical manipulator and industrial PC station (Figures 3 and 4). The special cooling system and application of specialized heat protection material, the easy yet sturdy construction, and the fast measurement time enable the laser head to be immersed into the hot torpedo ladle with ambient temperatures of more than 1,000°C without being damaged. The whole measurement sequence runs automatically and takes less than three minutes.

Figure 3

System consisting of laser head, manipulator, platform, container with equipment and operator terminal.

Measurement Procedure

When the torpedo ladle car enters the inspection stand area, it has to be placed by means of position markings next to railway tracks. The torpedo ladle must stop in order for the LaCam boom to be directly in front of and central to the torpedo mouth for scanning (Figure 5).

After placing the torpedo ladle in front of the measuring unit and a 90° turn into the direction of the measuring system, the operator is asked for some information of the ladle (e.g., ladle number, etc.). This information — if available — can be read automatically from the level 2 system using an identification system (e.g., RFID) or can be entered manually to the evaluation system. The reference profile (taken by a predetermined laser scan of the shell or permanent safety lining of the torpedo ladle) is uploaded to compare it with the actual measurement.

The first step of a LaCam Torpedo measurement is the scan of the outer shell of the torpedo ladle (Parking-Position Scan[1]). By using patented 3D structure-finding software, the exact position of the torpedo ladle is recognized and the impact area is measured (approx. 20 seconds, 180° grade measuring area). A second scan in the mouth area enables the measurement of the tapping area below the mouth (Mouth-Position Scan[2]). Afterward, a boom with a mounted scanner head moves completely through the mouth, inside the hot torpedo ladle, where the entire torpedo lining is measured (Center-Position Scan[3]).

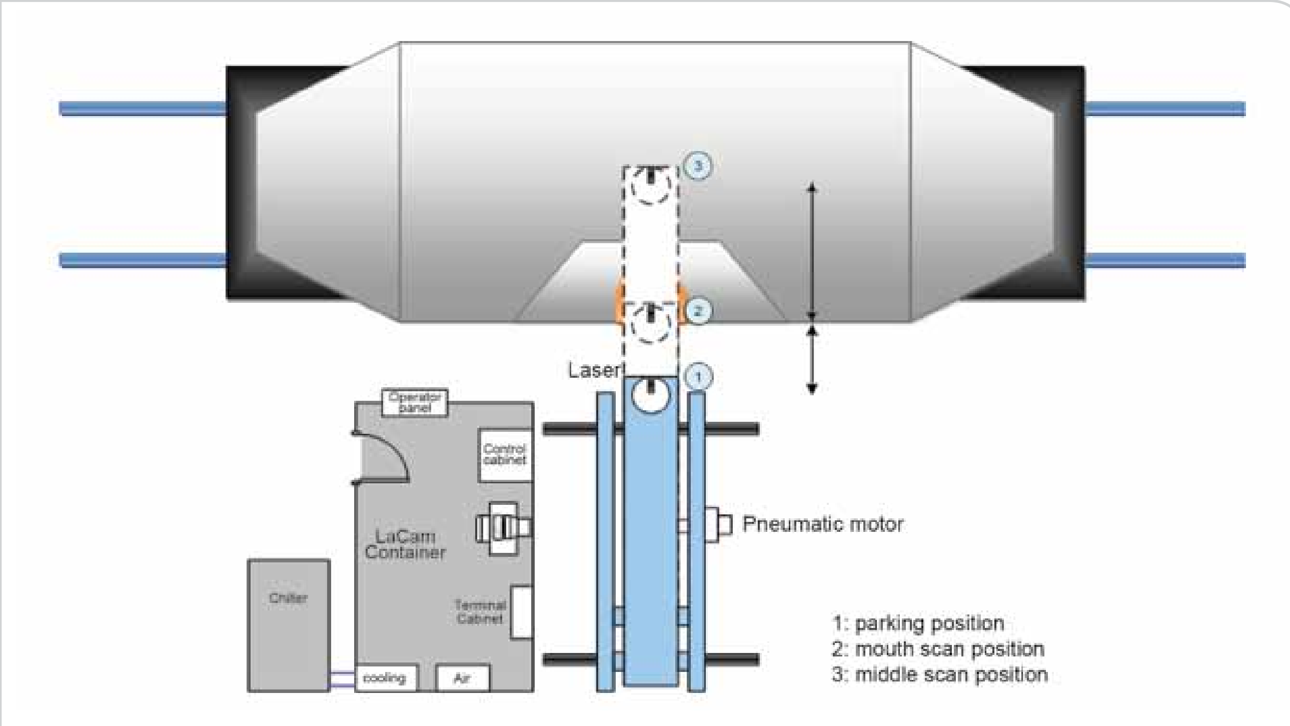
The measuring time for the 360° grade scan of the inner torpedo ladle takes less than 40 seconds. This high measurement speed, as well as the robust cooling system and consequent insulation of all components of the laser scanner, allows measurements in such high ambient temperatures. The measuring system 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 three minutes and more than 3.9 million points with accuracy better than 5 mm are created in the torpedo ladle scan.

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 systems allow for the direct use of the measuring results.

Figure 4

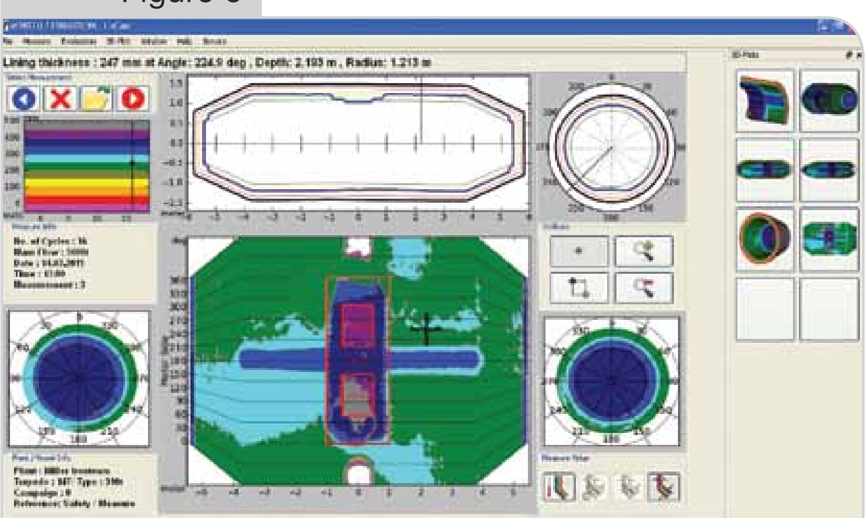
Laser head with advanced cooling system immersed into the hot environment of the torpedo ladle with a temperature of 1,000°C (1,832°F). A 360° measurement is taken in less than 1 minute inside the ladle. A fully automated manipulator allows push-button operation. A complete scan sequence comprises 3.6 million measuring points.

Figure 5



System overview with components and three different positions in the measurement procedure.

Figure 6



Graphical user interface (GUI) shows different presentations of the measurement results.

Evaluation and Presentation of the Results

The newly developed evaluation possibilities allow for a wide choice of presentation alternatives, from tabular reports to virtual walkthroughs by means of configurable 3D images. The measurement results are presented on a graphical user interface (GUI) and can be documented in various ways (Figure 6).

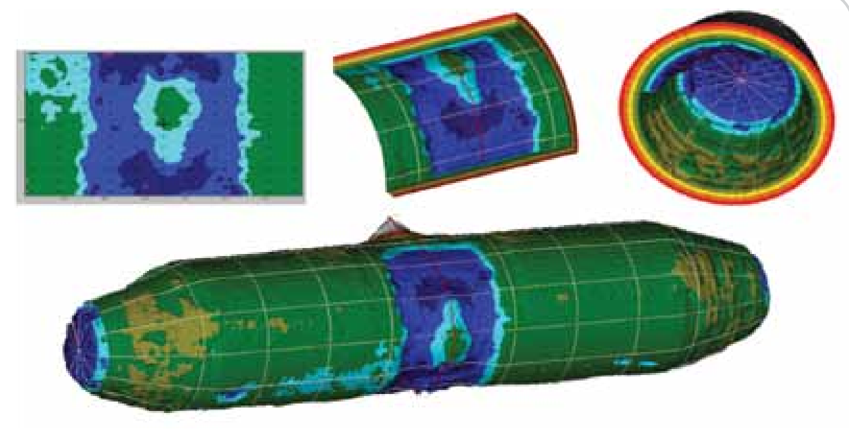
During the scan evaluation, the position of the torpedo ladle is determined for each scan within the LaCam coordinate system. The measuring data of the different scans of one measurement are filtered, transformed and superimposed so that a 3D scatterplot is created, which describes the entire surface of the refractory lining. If this measured surface is compared to the former measured safety lining (reference), the current thickness of the wear lining is maintained. By means of importing former wear measurements, tendencies and trend lines of the refractory lining can be seen and graphically presented. This history allows one to determine weak points and to optimize the lining of torpedo ladles. Areas of interest can be focused on and presented vividly within the 3D presentation. By placing a cursor on an area of interest, the vertical and horizontal sections are shown in different windows. The information is completed by the exact location within the ladle, residual brick thickness exact to the millimeter, wear speed and rate. A virtual inspection tour through the torpedo ladle on a 3D monitor is possible (Figure 7).

For verification of the measurement result, a torpedo ladle, which was measured before with the LaCam Torpedo system, was cooled and a manual inspection of the refractory lining was made. Several refractory bricks were taken out at different locations of the ladle, and the torpedo ladle was measured again by the LaCam Torpedo system. The laser measurement identified the "cavities," which are shown in the picture and the wall scan. The laser measurements correspond with the manual readings (Figure 8).

Furthermore, the surface temperature of the lining is also supplied by the measuring system in the same resolution as the residual brick thickness. Hence, "hot spots" and possible iron penetrations can be shown (Figure 9).

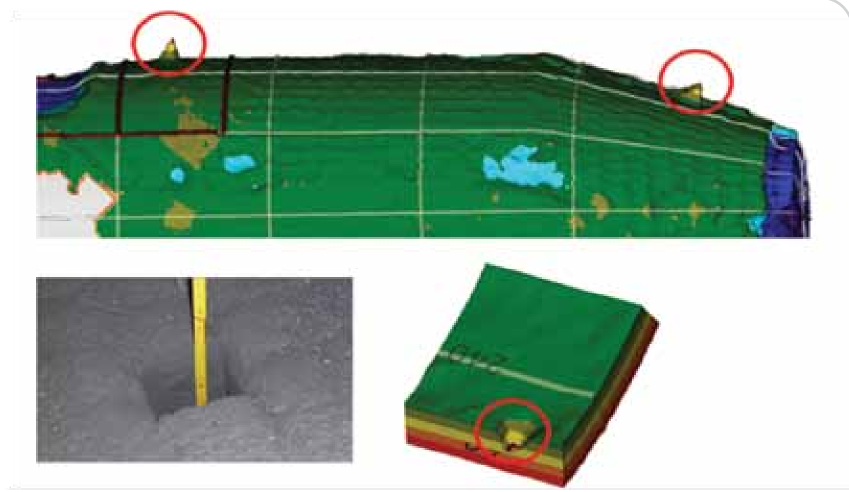
Additionally, the laser measurement enables the determination of the ladle volume, so that plants using railcar scales at the tapping position of the blast furnace can fill the torpedo ladle at an optimum, knowing the bath level (Figure 10).

Figure 7



Examples of 3D evaluation pictures, where the colors represent refractory lining thickness.

Figure 8



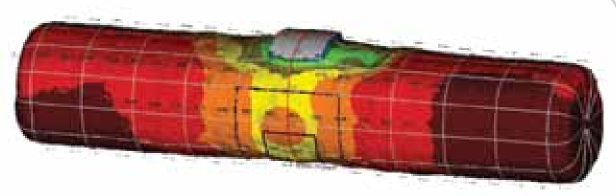
Missing bricks were identified, and cavities correspond with laser measurement.

Results

At the steel plant where the first LaCam Torpedo installation is installed, these major observations were made:

- **Increased Safety:** Safety will increase significantly. The risk of breakthroughs can be reduced on public railways or important locations that could stop the whole steel works or blast furnace and would lead to dramatic incidents. It is difficult to consider this advantage as a calculated financial benefit.
- **Increased Availability:** Discontinuation of 30% of cold inspections will gain 339 days of additional availability or increases the charging capacity 62% of one torpedo ladle campaign (1 ladle life = 550 days).

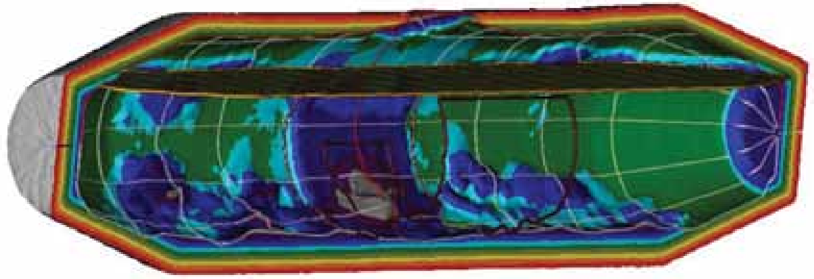
Figure 9



Temperature profile of entire inner torpedo ladle surface. Color represents surface temperature. Red color is >1,000°C.

- **Cost Savings in Energy/ Material Maintenance:** Discontinuation of cold inspections will save more than $78,000/year of energy costs (heat-up with gas of one torpedo ladle costs $1,600).
- **Extended Refractory Lifetime:** An increase of 7% of refractory lifetime increases the throughput of iron, which is equal to 3.5 ladle linings per year.
- **Downsizing of Ladle Fleet:** Increased availability allows reduction of the number of torpedo ladles. Thus, the maintenance cost for the torpedo ladles will go down. Rejection of one torpedo ladle would pay off the investment for the LaCam Torpedo in one year.

Figure 10



Indication of bath level in brick thickness presentation.

The economic benefits of such a measuring system can be achieved easily by the regular measurement of hot torpedo ladles, resulting in raised efficiency, torpedo fleet reduction and increased production volume. Even if the safety aspect, which is difficult to define in economic figures, is not considered, and the increased life of the refractory lining is implemented with a low percentage, energy savings, reduction of maintenance costs as well as the increased availability result in a payback period of less than 1.5 years. The parameters and the results of course vary from steel plant to steel plant.

Summary

With this world premiere, Ferrotron introduced a laser profile measurement system that makes a contactless measurement of the refractory lining of a hot torpedo 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 prolong the refractory life span. This new measurement technology, using a submerged laser scanner, can also be used in other confined spaces, e.g., RH degasser. Further developments will follow.

Acknowledgments

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