WORLD´S FIRST LASERPROFILE-MEASUREMENT-SYSTEM FOR THE REFRACTORY LINING OF HOT TORPEDO-LADLES[1]

LaCam® Torpedo measuring system shows a new way to measure refractory lining thickness and wear in hot torpedo ladles.

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Abstract

Torpedo ladles are used to transport liquid iron from a blast furnace to the steel plant via rail. The Torpedo measuring system has an innovative, yet simple and rugged design that allows immersion of a laser head into a hot torpedo ladle with surrounding temperatures of more than 1000 °C. The system's laser-beam rapidly scans the lining thickness of the entire surface, collecting millions of data points that are generated in a wide range of computer displays from simple tabular reporting to a virtual walk-through of configurable 3D images. This new development allows steel makers to measure refractory-lining thickness in hot torpedo ladle cars in less than three minutes, reducing the need to cool down the vessel for up to two days before a manual inspection of the totpedo ladle can be done. This measuring system can provide steel makers with improved safety, increased ladle availability and capacity, extended refractory life and cost savings in energy, material and the maintenance of hot torpedo ladles.

Key words: Refractory; Pig iron transport; Laser-measurement; Safety.

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1 INTRODUCTION

Since the introduction of high speed laser scanners, they become more and more important for determination of the 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 of the bath level, optimization of the tapping angle, evaluation of the bottom tuyeers 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 by avoiding of dangerous breakthroughs are important criterions as they have top-ranking significance for pig-iron transport from the blast furnace to the steel making plant. Worldwide, torpedo ladles transporting liquid iron on railways, partly on public railway tracks. Especially here, breakthroughs would have serious effects.

The significance of torpedo ladles is increasing as steel plants without pig-iron mixer often need 90 % of the torpedo fleet for its standard operation and as a buffer between blast furnace and converter shop. An outage of one torpedo ladle already results in severe disturbance of the production process.

Ferrotron, a division of Minteq International GmbH, introduced the newly developed 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 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.

2 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 (TOF- **T**ime **o**f **F**light Measurement with a NIR -**N**ear **I**nfra **r**ed- 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 assure reproducible measuring accuracy in combination with high speed scanning the laser-pulse-repetition rate is up to 300 kHz or 125,000 measurement /sec. in combination with "echo-signal digitization" and "online waveform analysis". To use the LaCam® technology without special safety measure a laser of safety class 1 (eye safe) is used.

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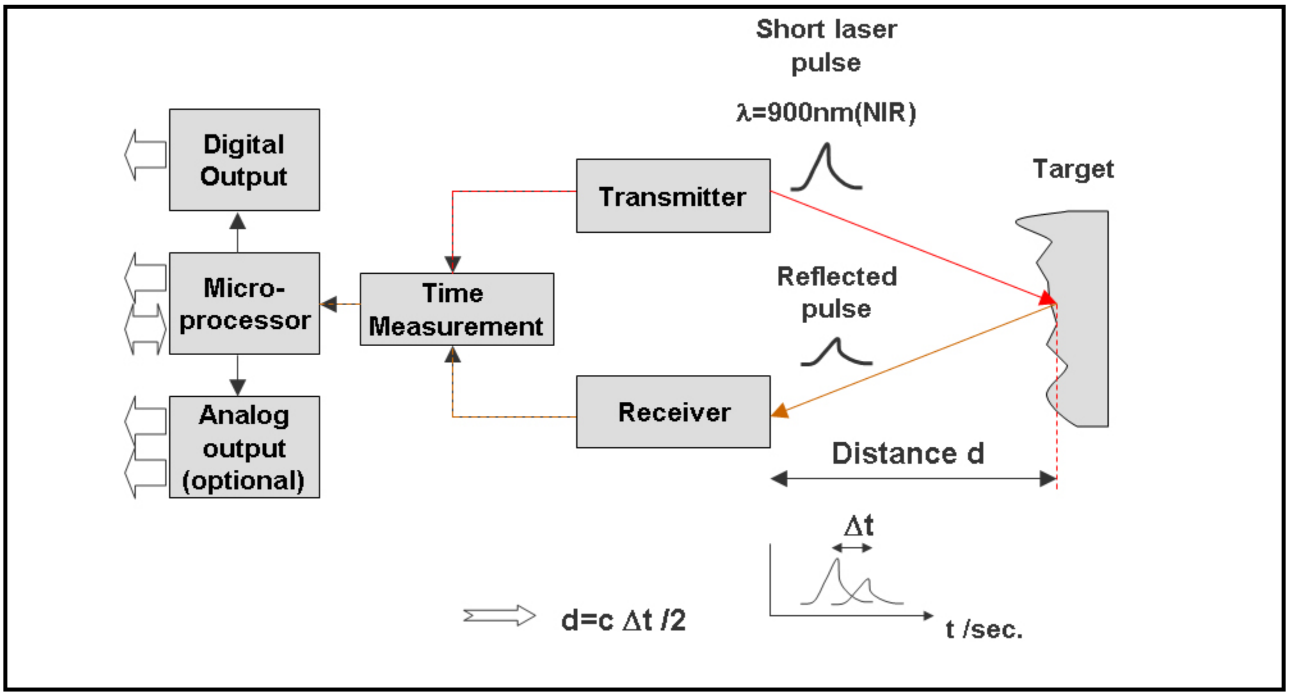

Figure 1. Principle of flight of time measurement for determining distance.

3 TODAYS PRACTICE

Today most of the steel-plants are doing 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 down up to three days. An inspector will climb into the cold torpedo ladle and breaks off refractory bricks at location which look obviously weak. After measuring manually the brick-thickness 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 just put the torpedo ladle back in the production cycle. The repairs needs additional 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 ready again for further transport of pig iron.

4 NEW METHOD

Doing regular measurements in hot conditions, methodical cold inspections can be reduced and four to five days availability of the torpedo ladle can be attained. Furthermore, energy costs can be saved and emissions reduced. The measurement in hot condition was the target of the introduction of the new LaCam®-torpedo technology.

4.1 Operational Application

The first test set up was installed in an European steel-plant with an annual production of pig iron 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 where the torpedo ladle cars stop to be cleaned (Figure 2).

Figure 2. Set up of LaCam® Torpedo during laser measurement.

The system consists of a 3-D laser profile measurement- head mounted on top of a cooled movable boom, a cooling system, automated mechanical manipulator and the determining and evaluation industrial PC station (Figure 3). The special cooling system and application of specialized heat protection material, the easy but 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 getting damaged. The whole measurement sequence runs automatically and takes less than three minutes.

4.2 Measurement Procedure

When the torpedo ladle car enters the inspection stand area it has to be positioned by means of position markings next to railway tracks. Indicating the right position the torpedo ladle must stop in order for the LaCam® boom to be directly in front and central to the torpedo mouth for scanning (Figure 3).

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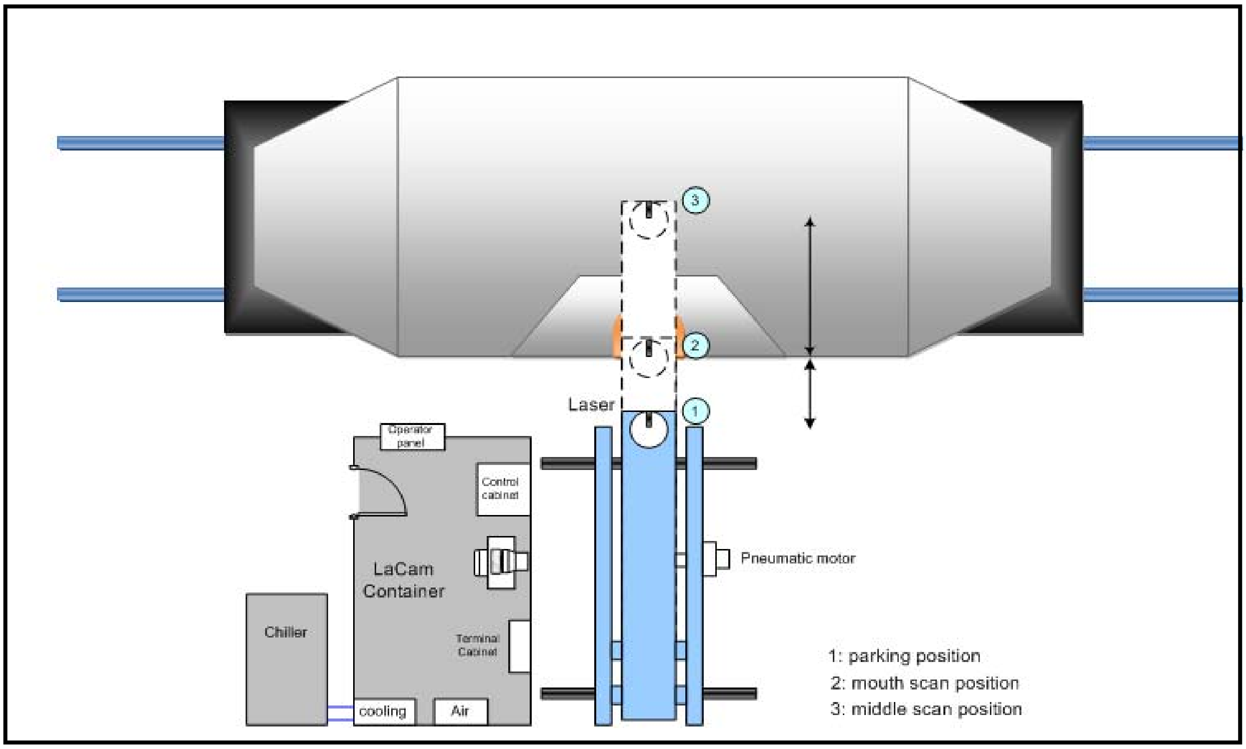

Figure 3. System Overview with components and three different positions in the measurement procedure.

After placing the torpedo ladle in front of the measuring unit and a 90° turn into 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 3-D-structure finding software, the exact position of the torpedo ladle is recognized and the impact area is measured (approx. 20 sec., 180 °grad measuring area). A second scan in the mouth area enables the measurement of the tapping area below the mouth (Mouth-Position-Scan [2]). Afterwards, 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° grad scan of the inner torpedo ladle takes less than 40 sec. 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 3 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-system allow the direct use of the measuring results.

ISSN 1982-9345

4.3 Evaluation and Presentation of the Results

The new developed evaluation possibilities allow a wide choice on presentation alternatives from tabular reports to virtual walk-throughs by means of configurable 3D-images.The measurement results are presented on a **G**raphical **U**ser **I**nterface GUI and can be documented in various ways (Figure 4).

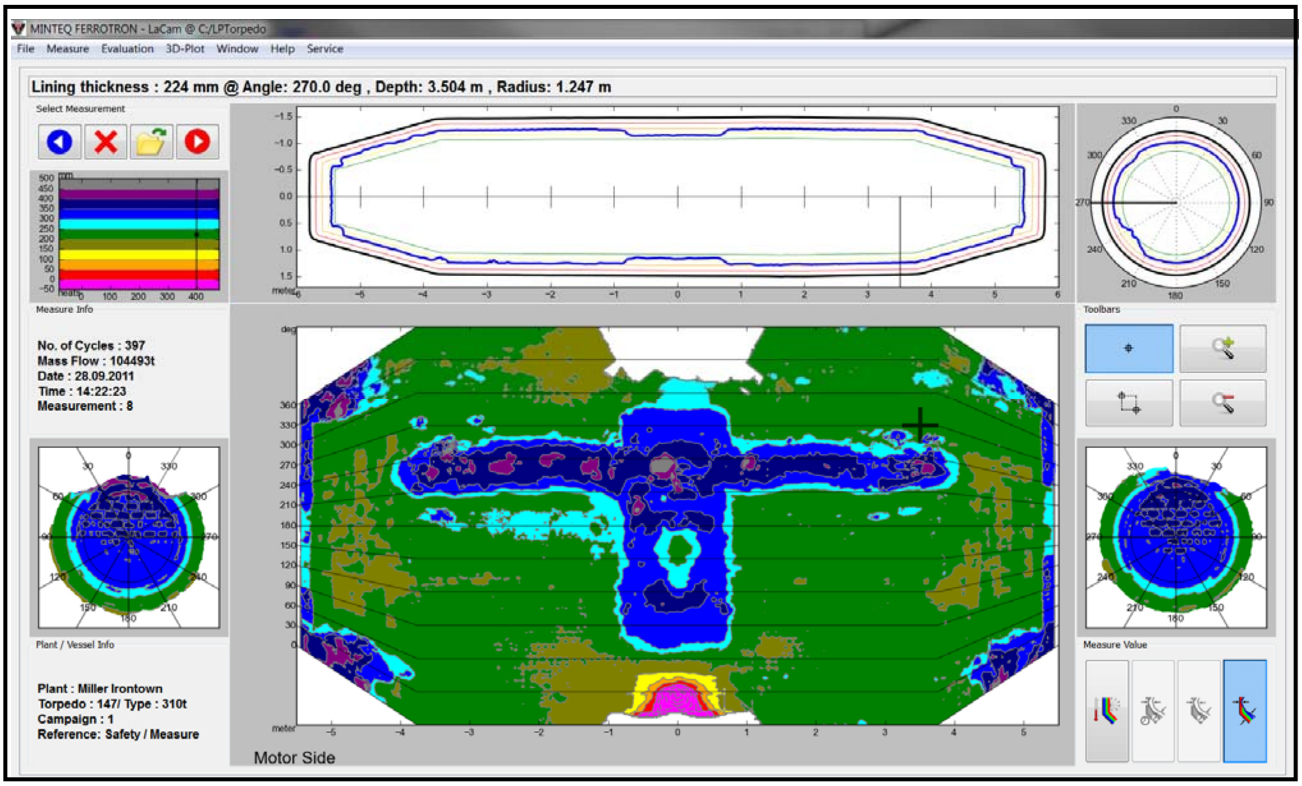

Figure 4. Graphical User Interface – GUI, shows different presentations of the measuring results.

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 3-D 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 Interests can be zoomed in on and presented vividly within the 3-D presentation. If you place the 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 4, 5).

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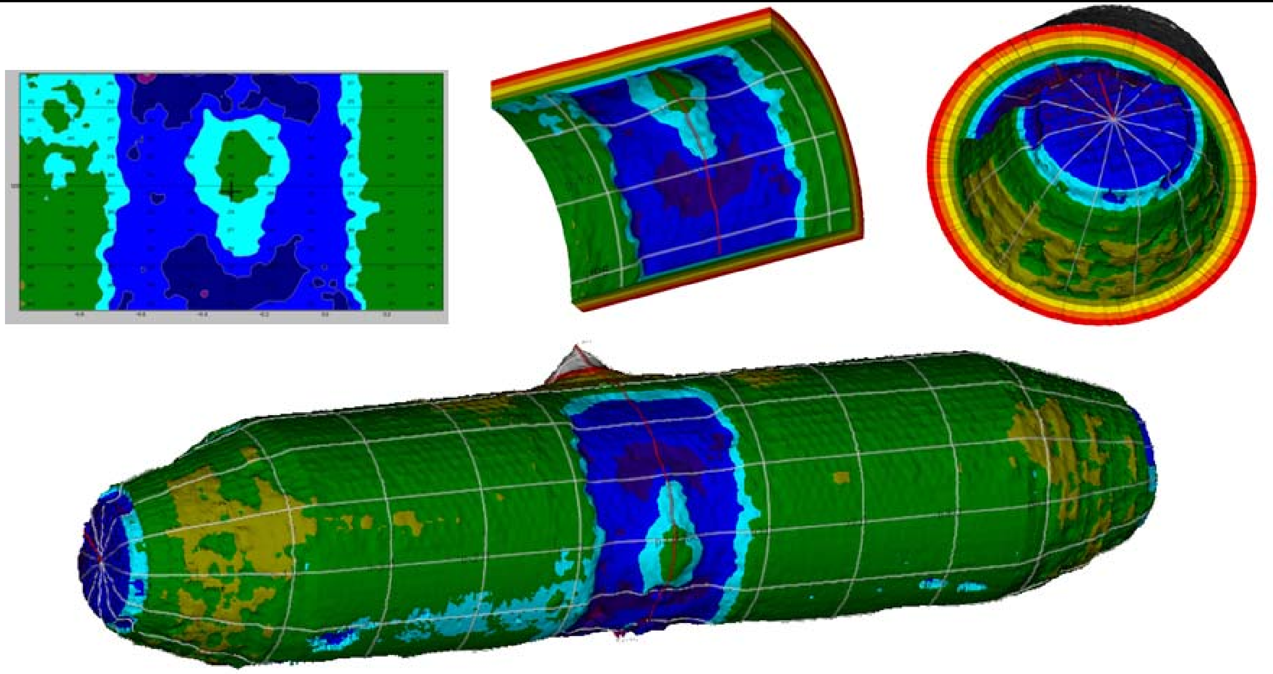

Figure 5. Examples of 3D evaluation pictures colors represent refractory lining thickness.

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 6).

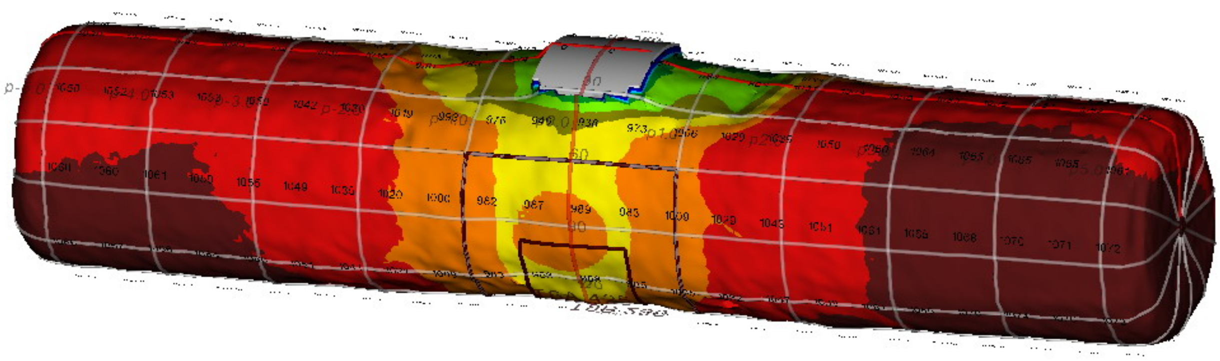

Figure 6. Temperature profile of entire inner torpedo ladle surface color represents surface temperature red color is >1000°C.

Additionally, the laser measurement enables the determination of the ladle volume so that plants using rail-car scales at the tapping position of the blast furnace can fill the torpedo ladle at an optimum knowing the **bath-level** (Figure 7).

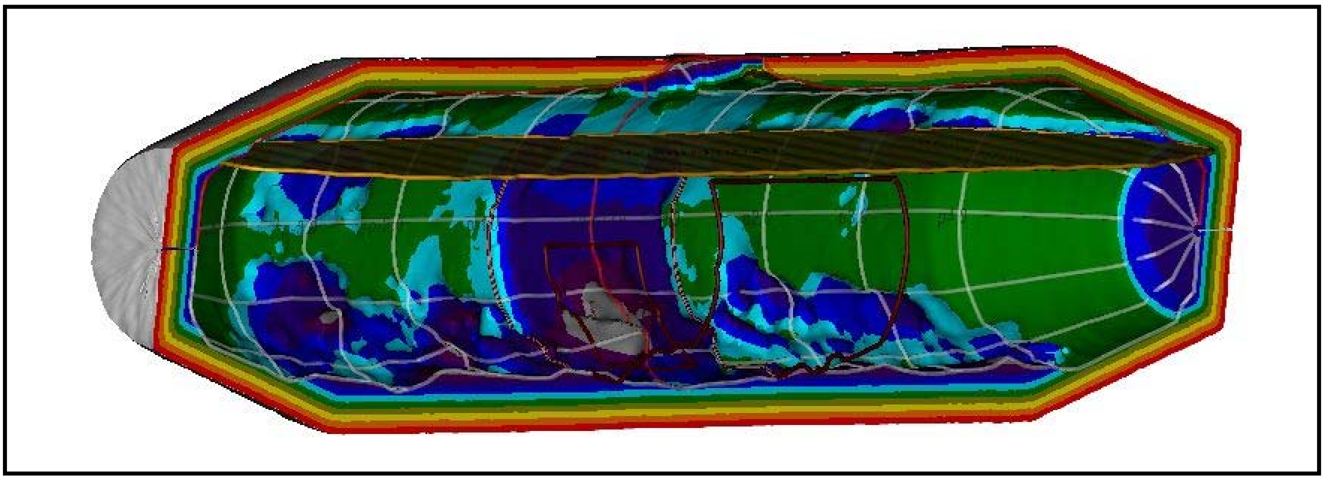

Figure 7. Indication of bath level in brick thickness presentation.

5 RESULTS AND DISCUSSIONS

At the steel-plant where the first LaCam® Torpedo installation is installed this major observation were made:

- *Increased Safety:* Safety will increase significantly. The risk of break- throughs on public rail ways or important locations that could stop the whole steelworks or blast furnace and would lead to dramatic incidents can be reduced. It is difficult to consider this advantage as a calculated financial benefit.
- *Increase of availability:* Discontinuation of 30% of cold inspections will gain 339 days additional availability or increases the charging capacity 62% of one torpedo ladle campaign (1 ladle life = 550 days)
- *Cost Savings in Energy-/Material-Maintenance:* Discontinuation of cold inspections will save more than $78k/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 gains the throughput of iron, which is equal to 3.5 ladle linings per year.
- *Downsizing of ladle fleet:* Increase of 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 LaCam Torpedo in one year.

The economic benefits of such a measuring system can be easily achieved 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 life increase 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 are of course varying from steel-plant to steel-plant.

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6 CONCLUSION

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 prolonging 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.