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Deformation and Wear Analytics in Reheating Furnaces Using 3D Laser Measurement Technology

Reheating furnaces are essential in steel rolling mills to thermally treat blooms, billets, and slabs before subsequent processing. This paper describes the use of portable terrestrial lasers to investigate deformation and refractory wear in these furnaces. Over a period of 2 years, multiple measurements were conducted at Tata Steel in IJmuiden (the Netherlands) to evaluate the time requirement for reality capture of the refractory lining, with respect to scanning resolution and personnel demand. A comparison of the scanned used lining with a theoretical model created from the original furnace dimensions is also described in this article. The potential for time savings using this technology in combination with visualisation tools further substantiate the benefits of RHI Magnesita's digitalisation services for the steel industry.

Introduction

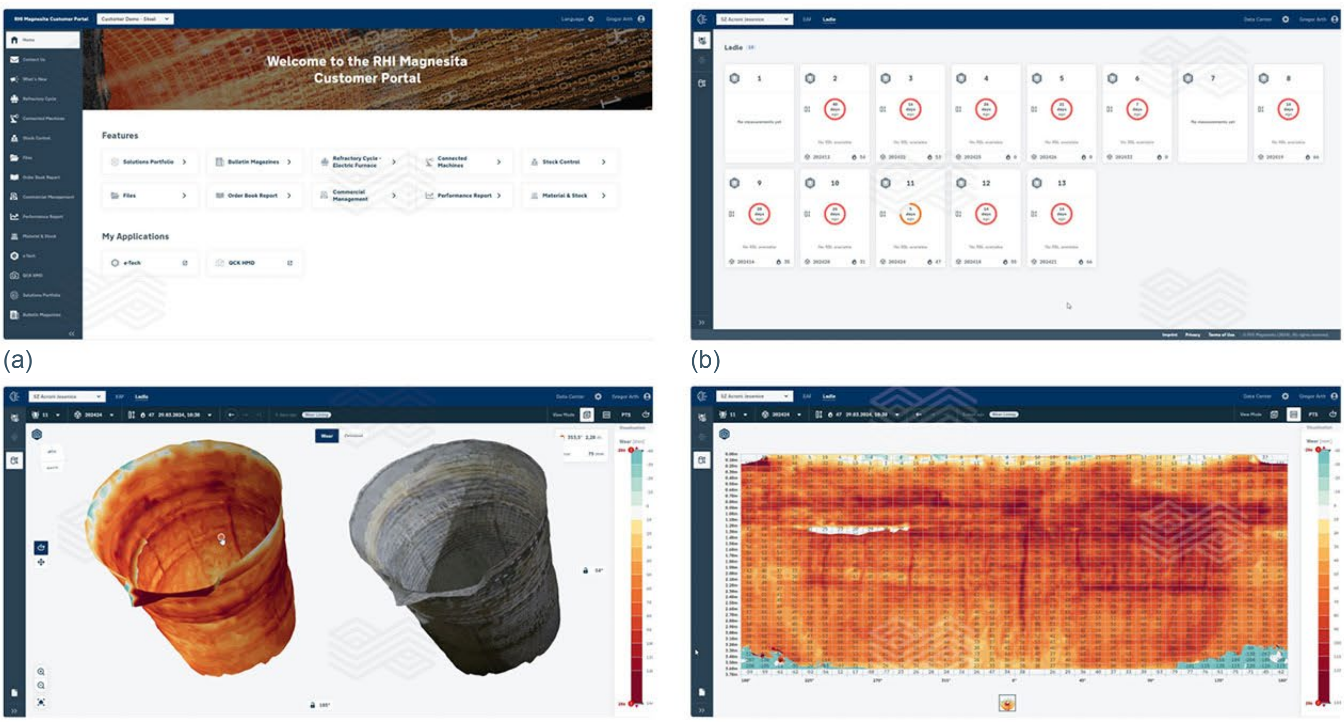
Over the last years, 3D laser scanning technology for wear analytics has been applied at several vessel types within steel plants by RHI Magnesita. The scanning of different lining conditions in the cold state, performed by on site personnel within a few minutes, followed by automated analytics on a web-based cloud architecture has now reached a mature state for ladles and RH degasser vessels. While the developments for electric arc furnaces (EAF) and argon oxygen decarburization (AOD) vessels as well as blast furnace runners and nonferrous vessels are about to reach the step of full implementation, stationary equipment with larger geometric dimensions (e.g., reheating furnaces) requires a slightly different approach.

The operation of reheating furnaces at Tata Steel Netherlands' hot strip mill is crucial for producing high-quality steel products. However, these furnaces are exposed to high temperatures and stresses that can cause deformation and damage to the refractory lining materials over time. This can affect furnace performance and efficiency, as well as have safety and environmental impacts at the plant. Therefore, it is important to regularly monitor and maintain the furnace condition to prevent any potential failures or breakdowns.

One powerful method to evaluate the status of reheating furnaces is using 3D scanning technology. This approach captures the geometry and dimensions of furnace components with high accuracy and resolution. The 3D scan data can then be analysed and compared with design

Figure 1.

(a) RHI Magnesita's Customer Portal for scan analysis and visualisation, (b) ladle fleet management overview, (c) 3D rotatable views, and (d) 2D wall plot.



(a) (b) (c) (d)

specifications or previous scans to detect any deviations or changes in the furnace structure. This can help create a predictive maintenance plan, optimise operation, and increase the furnace lifespan.

Laser Scanning Procedure and Visualisation

Currently, RHI Magnesita is using portable terrestrial lasers to measure the status of ladle refractory linings under cold conditions [1]. The laser is positioned scan-by-scan around the vessel to capture both the refractory surface as well as the ladle steel shell. The latter is mandatory to ensure reference points for the exact alignment of a created point cloud with previous ones of the same vessel.

By scanning different lining states, such as the permanent (safety) lining and the wear lining before and after operation, the residual brick lengths and amount of wear can be determined within minutes by uploading and analysing the scans using RHI Magnesita’s web-based interface. As shown in Figure 1, the scans can be accessed via the RHI Magnesita Customer Portal (Figure 1a), where a fleet management overview (Figure 1b) can be found. Additional visualisation tools include 3D rotatable views (Figure 1c) as well as 2D wall and bottom plots (Figure 1d), with the option to extract data to MS Excel.

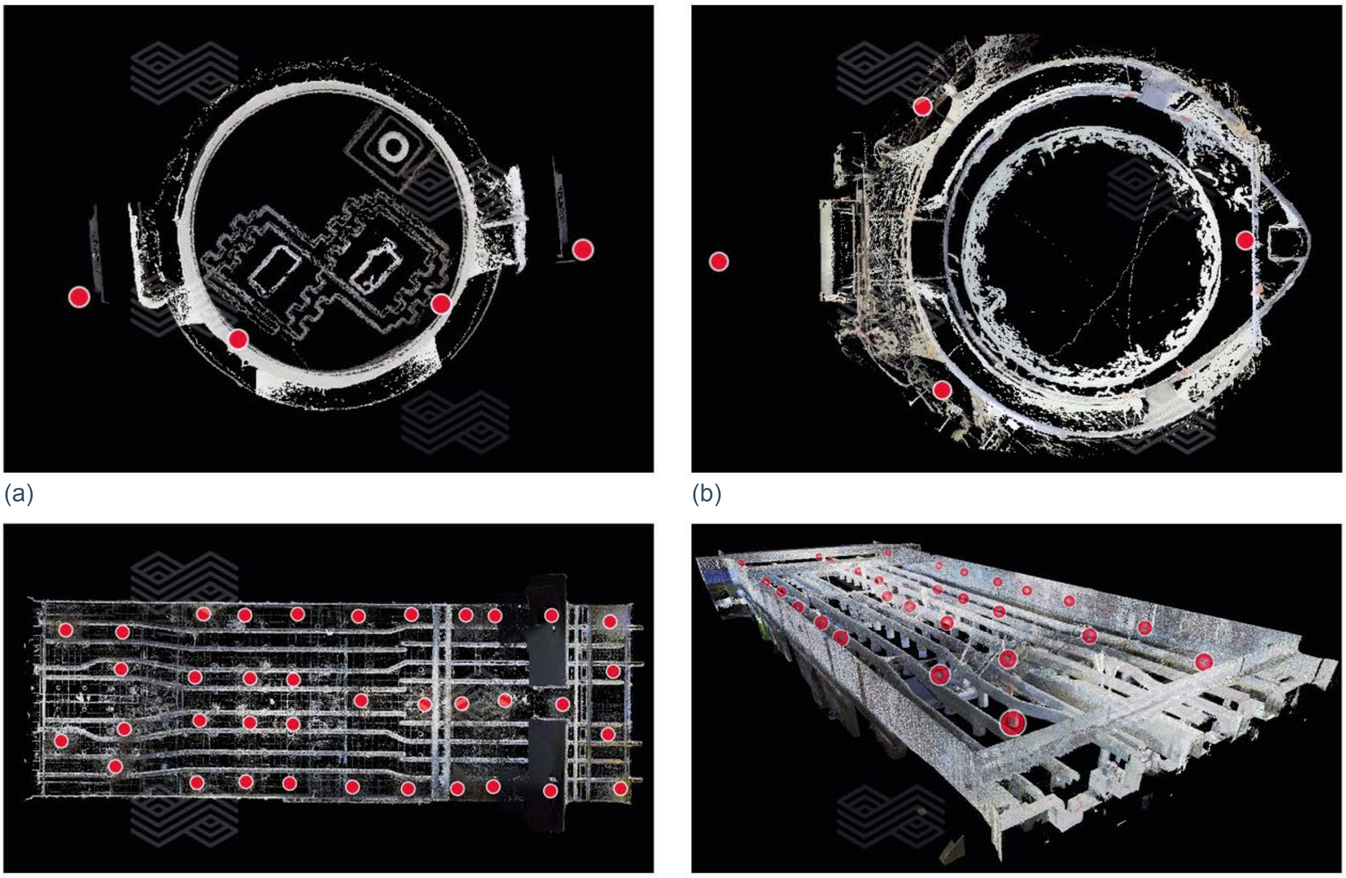
Complete vessel scanning can be performed in minutes, depending on the number of scans required to capture the entire lining and reference points, which is related to the vessel or furnace size. For example, approximately 4–5 scanning positions are required per vessel (e.g., ladle) or furnace (e.g., EAF) to encompass every critical area (Figure 2). Depending on the 3D scanning equipment, it can take about 15 minutes in total to complete all the measurements. In addition, it requires about 45 minutes to combine the scans into a single point cloud and visualise the results. While the reality capture of the aforementioned vessels takes place during liquid steel production, the following sections focus on 3D scanning a much larger, stationary furnace used for solid steel treatment in the hot strip mill.

Reheating Furnaces

After the continuous casting process, semi-finished products like slabs are typically taken to separate areas within the steel plant for cooling and storage. Before the hot rolling process, these semis must be reheated to the required temperature, which is typically performed in pusher-type or walking-beam furnaces, known as reheating furnaces. Figure 2 illustrates the major differences in the number of scanning positions (marked as red dots) used to image ladles, EAFs, and reheating furnaces. Notably, it takes only a few scanning positions for a full 3D ladle lining scan (Figure 2a) and even larger vessels such as EAFs (Figure 2b). However, this number can be more than 10 times higher for stationary equipment, such as a walking-beam furnace (Figures 2c and 2d).

Figure 2.

Overview of scanning positions (red dots) for different vessels and furnaces. (a) ladle, (b) EAF, and (c–d) walking-beam furnace.



(a) (b) (c) (d)

Tata Steel and RHI Magnesita share a common interest in optimising refractory performance in reheating furnaces, where the reality capture of the lining using 3D scanners is one approach to realise improvements. Following the recent acquisition of Seven Refractories, RHI Magnesita has strengthened its expertise in the area of reheating furnaces and the established laser measuring process perfectly complements Seven Refractories' product portfolio related to reheating furnaces. In addition to their expertise in solutions comprising refractory engineering, project management, energy saving systems, material deliveries, and installations, Seven Refractories can now also support the customer, for example, with wear measurements in the bottom of pusher furnaces. This enables very precise measurements to be obtained for the evaluation of new refractory developments related to material grades.

Over the past years during maintenance stops, multiple 3D scans were performed at Tata Steel's hot strip mill. In one case, a feasibility study was conducted by RHI Magnesita with the aim of reducing scanning duration while maintaining the scan quality at a sufficiently high level because it is necessary to keep the scanning duration inside the furnaces to a minimum, thereby avoiding time losses during production. Although precise details of how the scanning time inside reheating furnaces was minimised will not be covered in this article, another aspect of the feasibility study to assess both the potentials and limitations of this technology, as well as the general applicability to improve refractory and maintenance performance, will be described.

Currently, the most common approach for scan comparison is to create a reference to compare with the scan of interest, for example the permanent lining with the wear lining or an unused versus used lining. However, because of the long duration between maintenance stops for reheating furnaces, and thereby the time between scans, the first results of the joint evaluation presented in the next section are based on using a theoretical model as the reference.

Evaluation and Comparisons

The first 3D scans of the reheating furnace at the hot strip mill were completed in 2022. The scans covered various parts of the furnace, such as the walls, roof, floor, skids, hot riders, and burners. The scan-to-scan registration step during the manual post-processing was performed using commercial software, whereby the combined cloud was cleaned of any moving objects as well as regions of no interest like the furnace bottom/floor. The scan resolution and accuracy affect the file size used for data analyses and there is a large difference between the full scans of reheating furnaces and ladles. For example, when the registration step of a reheating furnace is completed, the resulting file size can range from 5–50 GB, whereas for ladles it is only 100–250 MB. Therefore, the resulting file of the reheating furnace was further processed and evaluated in another locally installed commercial software.

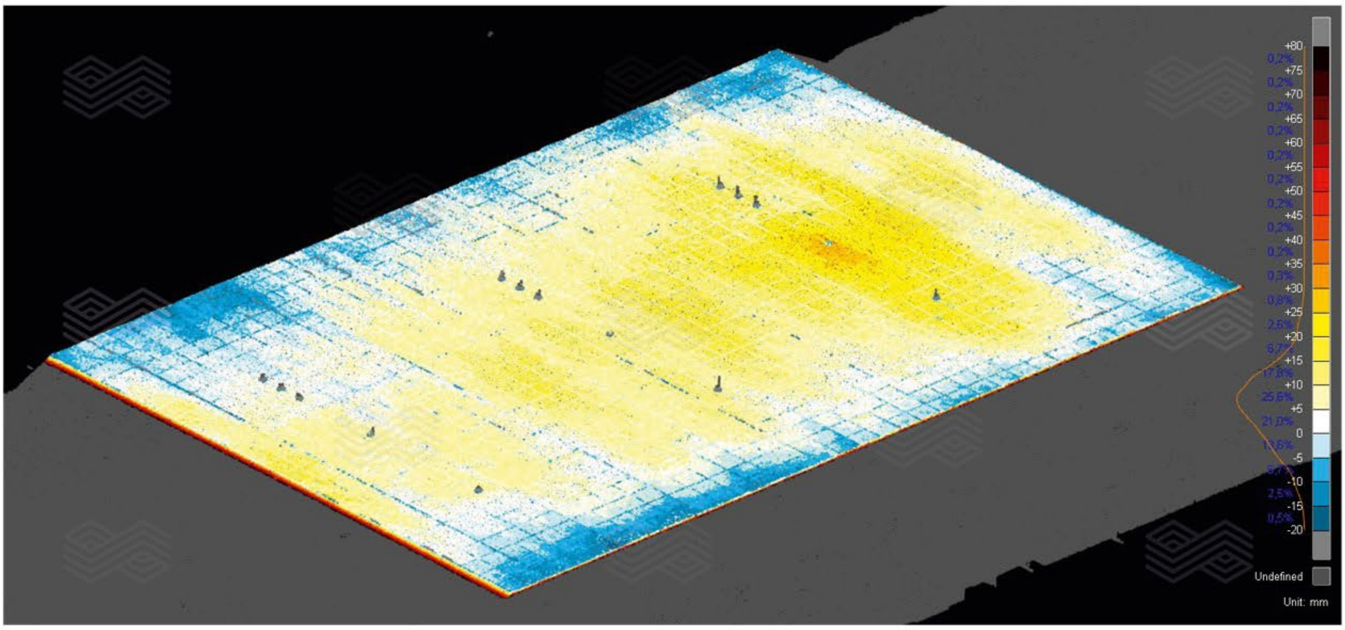
During the first discussions between Tata Steel and RHI Magnesita, the following topics were selected for investigation:

- Alignment of the roof tiles and walls.
- Skid levelness.
- Options for an optical lining status check.

The point cloud data and the associated images were processed in appropriate software to produce functional deliverables. Comparable to the web application described earlier in this article, a colour-coded evaluation is also possible with this software. The applied method enables local deviations to be detected quickly when comparing the actual scan and a theoretical ideal model. One example of the comparative results for roof tile alignment is illustrated in Figure 3, where it can be seen that the roof has a yellow colour over most of its surface, indicating that it is mainly flat. The majority of the measured values were within the range of -10 to +20 mm (91.4%) and the outer sides of the roof had values between 0 and -5 mm (17.5%).

Figure 3.

Deviation of tile positions in the middle roof section compared to an ideal reference model.



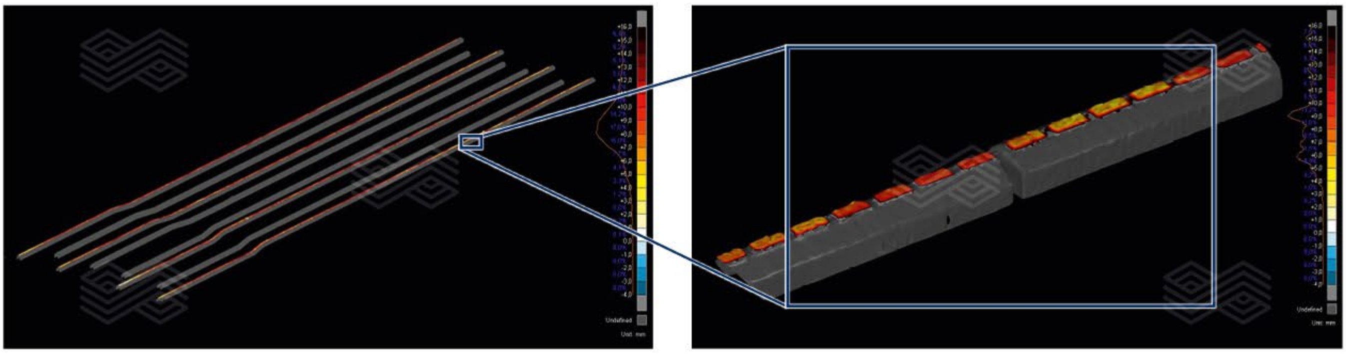
The highest roof tile area was located on the perimeter in the middle zone where it varied between -15 and -20 mm (0.5%), while the lowest roof tiles were located in the central part of the roof in the middle region, closer to the recuperative zone where they varied from +25 to +30 mm (0.8%). The vertical distance between the highest and lowest roof tiles in the middle zone of the roof was approximately 50 mm.

Whereas roof and wall sections are considered stationary objects, half of the skids are moving during operation to transport the semis through the furnace and can thus be in slightly different positions at the maintenance stop. Therefore, the moving and fixed skids were evaluated separately with tailor-made references. Figure 4 provides a magnification of a fixed skid section to underline the necessity for different benchmarks during the investigation. Furthermore, while the local deformation of the roof (see Figure 3) within a centimetre range might have low influence on the semi reheating quality, a deformation or misalignment of the skids can lead to semi deformation and subsequent issues in the hot rolling mill. As depicted in Figure 4b, the deviation of a small skid section was detected in the millimetre range, confirming the need to check the status of the skids before putting the furnace back in operation.

When scanning the furnace lining, the applied lasers can also capture high density resolution (HDR) panorama images and provide each point of the cloud with a red, green, and blue (RGB) value. Therefore, an additional benefit of this technology is the panoramic image enables optical inspection without any additional manual or drone-based visit, reducing workload in the furnace. Figure 5 provides an example of a panoramic view generated using a freeware viewer. This makes documentation of the lining sustainable and trackable compared to previous, locally captured images that lacked detailed information about image position or depth, namely the differentiation between bearing and wear.

Figure 4.

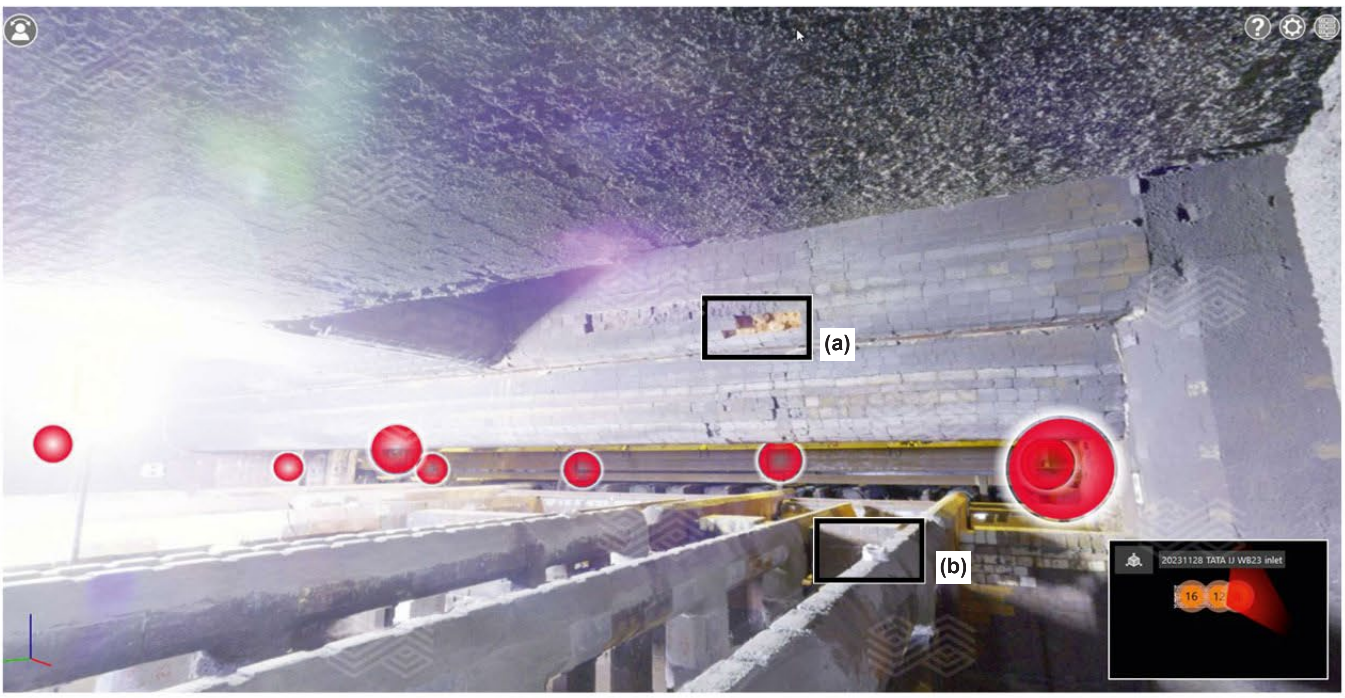
(a) 3D scan comparison to a reference model of multiple skids and (b) deformation clearly detectable in a skid.



(a) (b)

Figure 5.

HDR panoramic image of the reheating furnace interior showing (a) lining damage and (b) insulation material partially obscuring the view of a skid.



The use of 3D scanning technology is a valuable tool for predictive maintenance, providing a safe and efficient approach for equipment inspection. By creating a digital model of the furnaces, 3D scanning enables personnel to identify and prioritise areas that are most in need of maintenance and plan the actions accordingly. By constantly monitoring and comparing furnace conditions, it becomes possible to identify and predict potential issues, enabling proactive maintenance to be performed. Furthermore, by detecting potential maintenance topics before they occur, predictive maintenance using 3D scanning helps to minimise downtime, as repairs can be scheduled in advance.

Conclusion

Over the last years, open communication between Tata Steel and RHI Magnesita has led to a better understanding of the reality capture potential for reheating furnaces. Currently, data evaluation is performed manually using stand-alone software on local computers. However, all the findings are being used as the basis for developing web-based visualisation to provide a more efficient and automatised report generation. The 3D scan technology can rapidly capture and compare the geometry and dimensions of furnace components with high accuracy and resolution, thereby helping to create a predictive maintenance plan that can optimise the performance and lifespan of a furnace. Follow-up data assessment will focus on evaluating the two real scans performed during maintenance stops of the reheating furnaces after the furnaces were in operation for about a year. This will open up the potential to start determining the refractory performance per region and provide the basis for a tailor-made balanced lining within the furnace.

References

[1] Santos, J.P., Macedo, J., Avila, H., Lima, G., Arruda, E. and Lazaroni, A. Innovative Refractory Wear Measurement Method for Steel Ladles Using 3D Laser Scanning. *Bulletin*. 2023, 57–60.

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Cover picture: The image depicts the lower section of a RH degasser, a secondary metallurgical unit used in steel plants. In the RH degassing process, snorkels are submerged into liquid steel contained in the casting ladle. Argon gas is purged through the inlet snorkel, creating a suction effect that draws liquid steel into the lower vessel of the RH degasser, where a vacuum is applied. The steel treated in the lower vessel flows back to the ladle through the outlet snorkel, creating a continuous steel circulation between the ladle and the RH degasser. The strong negative pressure (vacuum) within the RH degasser facilitates various metallurgical processes that enhance steel quality, with the key process steps including degassing, decarburisation, deoxidation, and alloying under vacuum. Rail steel, flat steel for the automotive industry, and steel plates for shipbuilding are just a few examples of products that benefit from the RH degasser. Prefabricated snorkels, which RHI MAGNESITA manufactures ready for use and delivers to our globally operating customers, are essential components of the RH degasser.