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AUTOMATIC TAPPING AT BOF CONVERTERS*

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Abstract
The emerging demands on higher steel grades call for improvements in the operation of production units and a corresponding increase in automated processes, and therefore international steel producers require viable functions. The avoidance of slag carry-over to secondary metallurgy processes is essential for achieving steel grade qualities and reducing alloys in order to compensate slag residues in the downstream unit. The automatic tapping procedure in BOF converters will be supported by the implementation of reliable measurements used in high-end steel plants. Automatic tapping will help to achieve the following: Reduced slag carry-over, improved yield, increased reproducibility, improved working environment and safety and operation with minimum possible crew. The automatic tapping procedure is capable of being implemented in new or retrofitted installations.
Keywords: Tapping; BOF; Slag carry-over; Automation; Steel grades.

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1. INTRODUCTION

The emerging demands on higher steel grades call for improvements in the operation of production units and a corresponding increase in automated processes, and therefore international steel producers require viable functions.
The avoidance of slag carry-over to secondary metallurgy processes is essential for achieving steel grade qualities and reducing alloys in order to compensate slag residues in the downstream unit.
The automatic tapping procedure in BOF converters will be supported by the implementation of reliable measurements used in high-end steel plants.
Automatic tapping will help to achieve the following:

- Reduced slag carry-over
- Improved yield
- Increased reproducibility
- Improved working environment and safety
- Operation with minimum possible crew

The automatic tapping procedure is capable of being implemented in new or retrofitted installations.

2 MATERIAL AND METHODS

2.1 Why automatic tapping?

The avoidance of slag carry-over to secondary metallurgy processes is essential to achieving steel grade qualities and reducing alloys in order to compensate slag residues in the downstream unit. The automatic tapping procedure in BOF converters will be supported by the implementation of reliable measurements used in high-end steel plants.

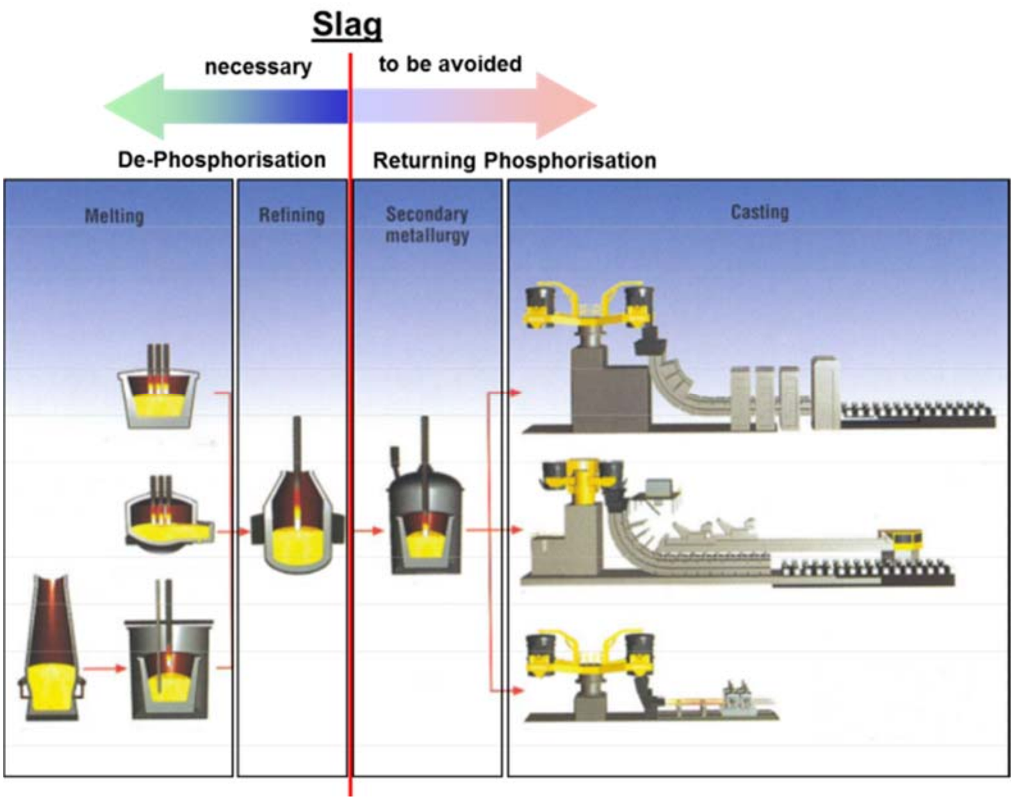

Figure 1: Avoidance of slag carries over to secondary metallurgy

During primary steel refining in BOF converter, slag-making additions are made to form a slag which absorbs impurities form the steel (such as sulphur and phosphorus). During converter tapping, in addition to the crude steel tapped into the ladle, some converter slag is also carried over into the steelmaking ladle, hence the name “carry-over slag”. Since slag contains impurities from primary refining, it would be very desirable to have zero slag carry-over, as these impurities can revert to the steel in the ladle. However, some carry- over slag also causes undesirable variations in the ladle top slag composition, and it is important to control the consistency and level of the slag carry-over.**[1]**
Therefore stepwise reputed international steelmakers either implemented successfully or inquire the automatic tapping**. [2] [3]**

2.2 Requirements for automatic tapping

Most of the steel meltshops invest in additional monitoring equipment to supervise the BOF process. These functions may be divided into process equipment, safety measurements or process monitoring systems. Process equipment is installed to support the sequence of steelmaking such as ladle transfer cars or slag retaining device, bottom stirring or alloying systems.
These units are monitored by process monitoring equipment such as slag detection systems or weighing systems in tapping crane or steel ladle transfer cars. Safety measurements are mandatory for a reliable process. Redundant converter tilting angle monitoring with interlocks to the blowing lance are standard applications. The above basic functions are completed by steelmakers to collect information on maintenance-intensive areas such as measurement of the refractory life and condition inside the converter vessel.
The necessity of these equipment units allows the integration into one automation package.

- Lining profile measurement
- BOF tilting angle monitoring
- Transfer car positions
- Weighing equipment on steel ladle transfer car
- Slag retaining and detections
- Pyrometers
- Wireless controls.

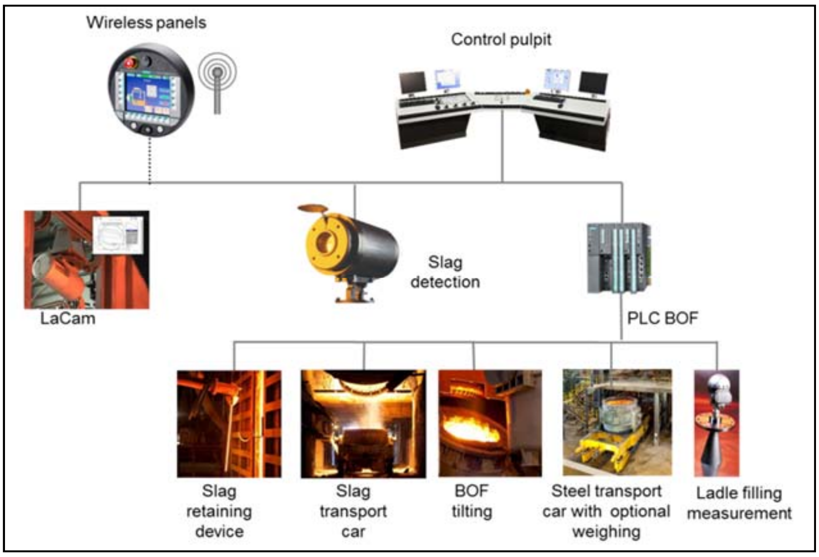

Figure 2: System components

2.3 BOF automatic tapping procedure

Automatic tapping of a BOF can be divided into three essential functions:

1. The referencing measuring part to establish the tilting angle, referred to the life cycle of the refractory lining
2. Automatic BOF tapping
3. Automatic slagging and emptying of the BOF

2.4 Establishing of tilting angle:

Worn refractory material causes the fill level of the full converter to drop continuously. As wear progresses, the resulting start of tapping from the BOF taphole is delayed and, respectively, the necessary tilting angle becomes larger. In addition, taphole wear changes the free flow of steel in the taphole. For the correct positioning of the ladle under the taphole, therefore, it is necessary to continuously adjust the tilting angle and the position of the ladle in line with the BOF vessel age.

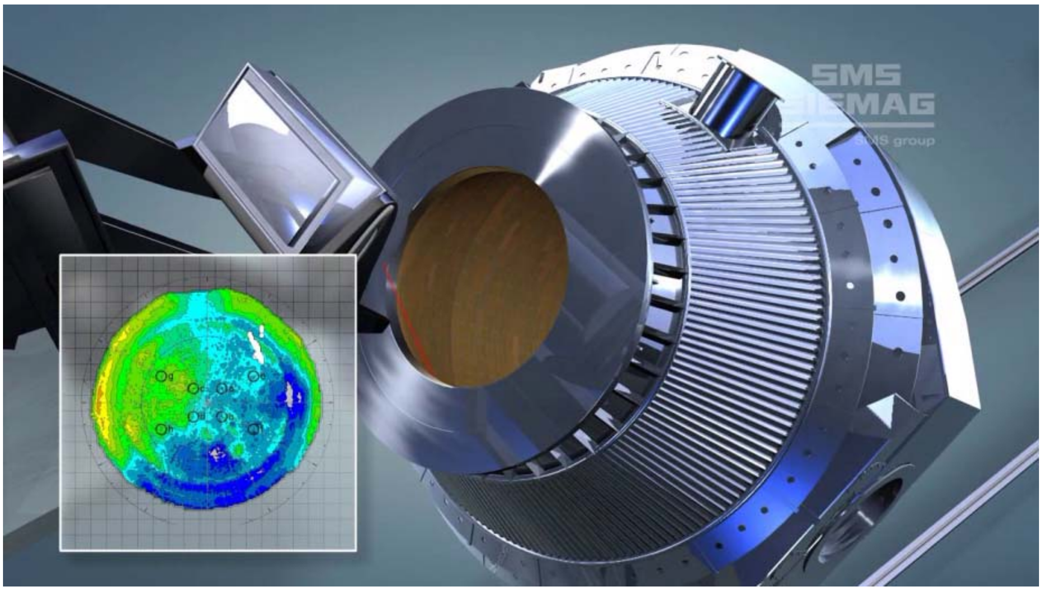

Figure 1: fixed mounted lining measurement at BOF

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To establish the degree of refractory wear, many steelworks owners use mobile or permanently installed wear measuring facilities. The use of a stationary measuring unit (LACAM®) on the BOF offers a variety of benefits for the introduction of automatic BOF tapping:

- The measurement can be repeated without any problems several times a day (e.g., on a change of shifts) during waiting periods by an automated system.
- An associated update of the bath level via the integrated calculation allows the blowing distance of the lance to be adjusted.

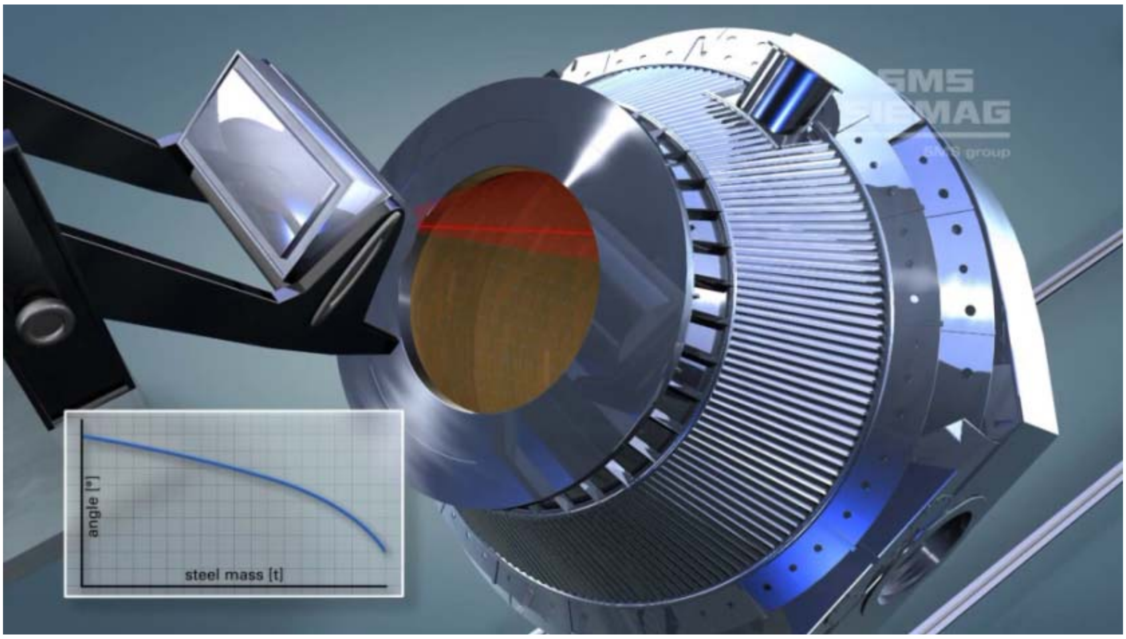

Figure 2: Steel mass versus tilting angle

3 RESULTS AND DISCUSSION

Of special interest is the following function implemented in the LACAM® device:

- Steel mass vs. tilting angle

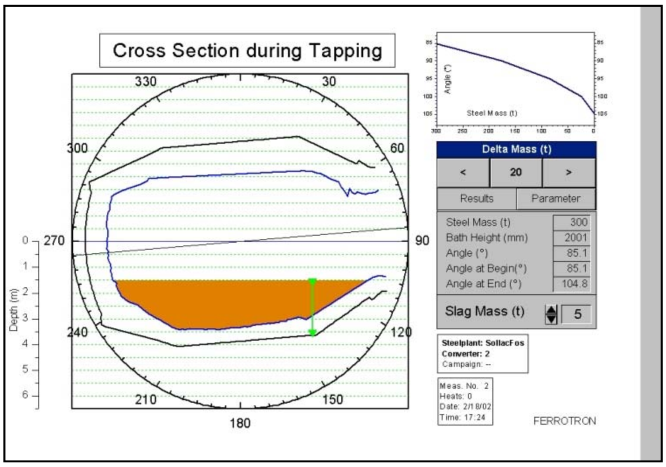

Figure 3: Steel mass vs. angle filled BOF

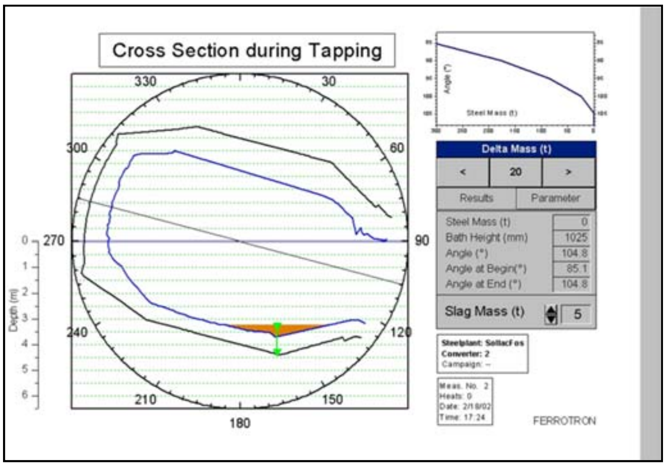

Figure 4: Steel mass vs. angle empty BOF

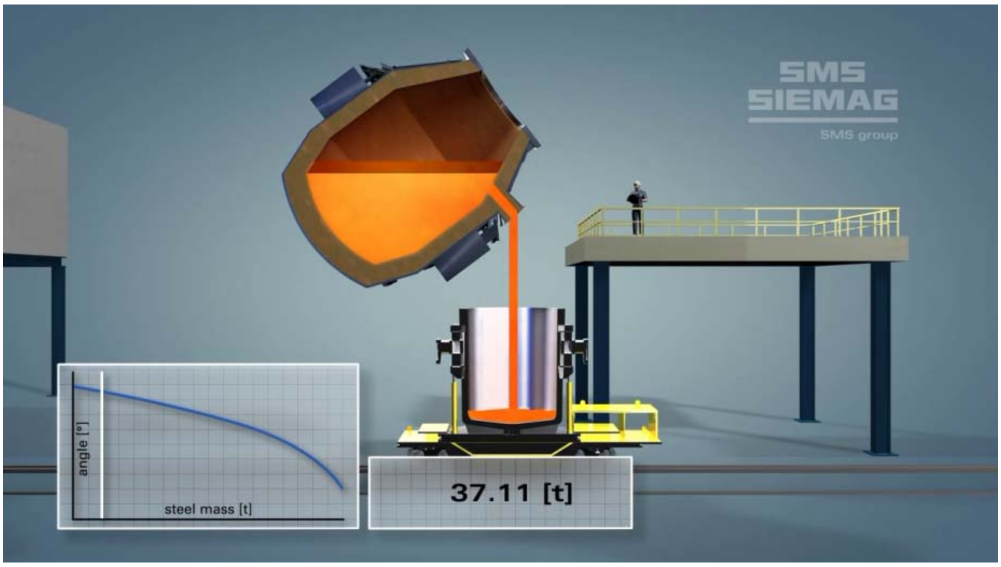

Figure 5: Reference weighing measurement at steel ladle transfer car

To check and guard against overfilling of the ladle, the full ladle should preferably be weighed on the ladle transfer car.
Before the start of tapping, the ladle is tared by the operator.
The preselected automatic BOF tapping procedure is started by pressing the start button on the tapping control desk. Once pressed, no further operator interventions are needed; his activity of continuous observation must not be interrupted at any time. Video cameras showing the transfer car and taphole assist in observing the process from the central control pulpit.
As tapping starts, the LACAM-calculated tapping stream acting as starting point automatically aligns the ladle transfer car with the center of the ladle. On reaching the ladle position, the BOF starts to tilt. Tilting of the BOF follows a preset curve which is based on the tapping weight versus the BOF lining condition as a programmed family of curves. The weighing signal of the ladle transfer car acts as reference signal.
If an incorrect curve of the tilting angle versus BOF age is selected, a stationary pyrometer directed at the BOF mouth guards against tapping out of the converter mouth.

Fig.8: Pyrometer tilting angle monitoring

With the risk of liquid steel pouring out of the BOF detected, the BOF is immediately and automatically tilted back at maximum speed. During tapping, the ladle transfer car automatically follows the tapping stream, guided by a laser-assisted detection of the transfer car position.
After approx. 80 per cent of the ladle's filling weight has been reached, the slag retaining device is activated and starts to place the dart.
The depth of insertion and angle of the dart-placing arm are stored as offset in the system, based on the preceding wear measurements versus BOF age.

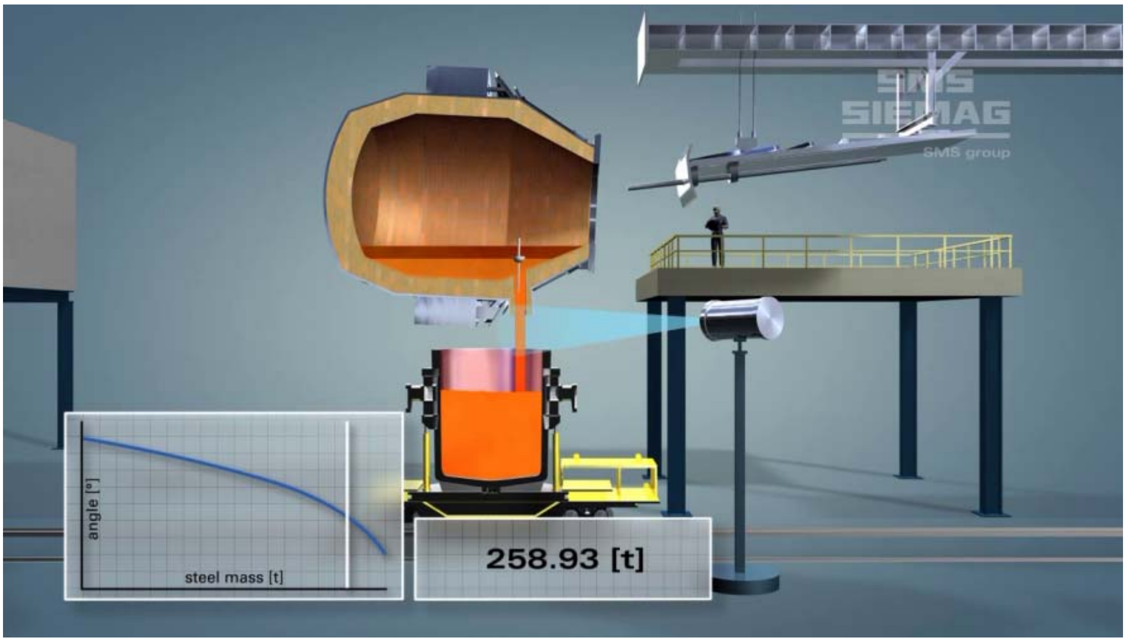

Fig.9: Slag detection system for automatic BOF rising

The stationary thermographic camera for early slag detection releases an automatic signal for tilt-back of the BOF in case slag spills into the ladle, thereby minimising the amount of slag carried over.
As an additional safeguard to minimise the amount of slag flowing into the ladle, the tapping stream is slowly redirected towards the ladle edge after the center of the ladle has been reached. In case slag is carried over into the ladle, this allows the transfer car to be moved off the tapping stream more rapidly.
To save the melt in case of slag carry-over into the ladle and a malfunction of the slag retaining device, the operator manually moves the ladle transfer car away from the tapping stream.
The risk of splashes hitting the car is given priority here over the carry-over of slag that deteriorates the steel grade. At the same time, this manual intervention aborts the automatic function. As the tapping weight is attained, the BOF is automatically raised. The ladle transfer car moves up to the temperature measuring and sampling position and stops automatic tapping there.

4. CONCLUSION

Sophisticated measurement tools are already in operation in most of High-end Steelmakers shops, Added values will be generated by combining of these individual equipment units into one combined automation system

The integration of a stationary lining profile measurement system (Lacam) with its determination of the tilting angle as a function of steel mass, a slag retaining device with slag early detection camera, position measurements of the tilting angle and of the ladle transfer car combined with an onboard weighing equipment to form an automation package, provide a fully automated operation with optional wireless control on the tapping side.
Additional safety equipment such as pyrometers and redundant tilting-angle monitoring systems support the functionality by satisfying the safety requirements in automatic operation. Automatic slagging of the BOF into the slag pot car may be added as an option, offering simultaneous positioning of the slag pot transfer car and converter tilting angle. The combination of measurements and detection systems arranged on the BOF provides fully automatic tapping at reduced slag carry-over and reproducible results.
Consequently, the automatic tapping functionality is suitable for new or retrofit installations in modern steelworks.

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