

3D TOPSCAN: THE NEW THREE-DIMENSIONAL RADAR PROFILEMETER FOR BLAST FURNACES*

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Abstract

This paper presents the TMT “3D TopScan” profilometer, which is a Radar-based profilometer that measures the total burden surface within a few seconds and on a continuous basis. This equipment is based on an electronically steered solid-state radar scanner, such that a very large amount of surface data is collected within short time intervals. These new electronically steered antenna systems are the key to meet the demands for both accuracy and speed. The TMT probe is installed at a fixed location at the top cone, such that it does not interfere with the charging, enabling a continuous measurement and a compact design.

Blast furnace charging optimization can be achieved based on its measurement data. The burden surface is continuously measured every few seconds, enabling the blast furnace operator to detect any details including asymmetries or irregularities in the surface pattern. A variety of process analysis tools are available. Due to the continuous and fast measurement, the burden descent speed can be supervised without process interruption on an ongoing basis. More accurate process models (layer models) than ever are obtained which fully consider the unsymmetries.

This technology, developed by TMT Tapping Measuring Technology, is successfully in operation at Salzgitter Flachstahl GmbH at their blast furnace B. The probe and the data evaluation tools combine today’s technological capabilities in measurement technology with the practical requirements of blast furnace operation.

Keywords: Blast furnace process control; Burden and charging model; Probe; Process efficiency.

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1 INTRODUCTION

1.1 State of the Art

Today, in performant blast furnaces (BFs), continuous supervision and monitoring of the charging process has become crucial. Due to high economic constraints and to increased raw material prices, the BF process has to operate at best possible efficiency. This leaves no space for a safety margin on the process parameters. At the same time, the process is steadily subject to changes and readjustments as a result of varying raw ingredients, which are selected according to their current prices. Various measurement possibilities to assess the burden distribution have appeared in the last decades, for instance, profilemeters or scanning probes [1-3]. Due to maintenance advantages and a higher versatility, the profilemeter has emerged as the most common measuring probe for BFs [4]. Its main asset is that it is comparably simple to keep it operational on the BF. The device is not subject to aging, and service times of more than 20 years have been achieved. The system can be retracted and isolated from the operating BF, to perform servicing during BF production.

1.2 Novelties of the “3D TopScan” Profilemeter

The main benefit of the “3D TopScan” profilemeter is that it collects more process data. With the conventional profilemeter, the profile can only be recorded on one predefined radius on the BF. However, it is known that the BF burden surface is not symmetric, i.e., that the radial profile is varying depending on the location. The “3D TopScan” profilemeter determines the complete burden surface topology and includes the information on unsymmetries.

Additionally, this information is obtained at any time and not just in between charging cycles. Existing profilemeters potentially interfered with the charging; therefore, it was generally limited to one radial measurement per charging. The new probe does not interfere with the charged material and can measure the surface at any moment, thereby recording the surface steadily. Such a continuous measurement also provides more data on the process dynamics, such as the local burden descent speed.

Ultimately, the increased amount of data delivers more detailed internal information on the BF in real-time to the operators. The “live” monitoring provides a more clear understanding of the current process situation than, for instance, the observation of trends of scalar sensors. The continuous supervision of the burden surface enables an early detection of irregularities, including burden hanging or slipping and blow-throughs. This may prevent damage or production loss. Furthermore, the layer model, which is the main result of the profilemeter, benefits from improved accuracy and reliability.

The development and the first results of the TMT “3D TopScan” profilemeter have been presented in [8].

2 MATERIAL AND METHODS

2.1 Concepts for a 3D Profilemeter

The wish for a three-dimensional surface measurement has been in the mind of BF operators for some time. It comes that a number of trials have been carried out.

Generally, to obtain three dimensions, there are several possibilities:

- Using a 1D radar (a common radar distance gauge) and combining it with a 2D mechanical motion.
- Using a solid-state radar scanner (a radar that is electronically steered into different directions) and installing it statically inside the BF.
- Using a solid-state radar scanner and combining it with a mechanical motion (a mixed solution to obtain a maximal result with a minimal effort).

2.2 “3D TopScan”: Solution with a Solid-State Radar Scanner

In order to meet the demands of time and accuracy, the use of a solid-state radar scanner is required. It is possible to install such a fully electronic radar in a static position on the BF top cone, as shown in Fig. 1. Similar to a camera, the radar has a view of the complete surface and can measure the complete topography. With a solid-state radar scanner, there is no necessity to expose a mechanical system to the harsh BF atmosphere: the complete measuring technology can be embedded inside a hermetically isolated probe body. This results in a compact layout and in maintenance friendliness.

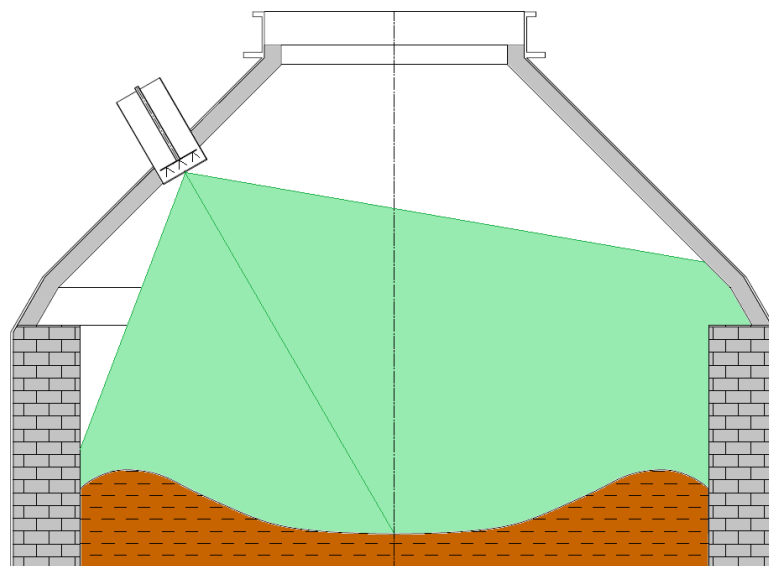


Figure 1: The TMT “3D TopScan” profilemeter has a field of sight of $\pm 60^\circ$ from the centerline axis and thereby covers the complete BF burden surface.

In a solid-state radar scanner, as shown in Fig. 2, at least two different receiver antennas are placed within a reasonable distance [7]. In addition to the distance to a target, which is obtained in a similar way as in conventional radar gauges, information on the horizontal location of a target is obtained from the difference in time-of-flight to the respective receiver antennas and triangulation.

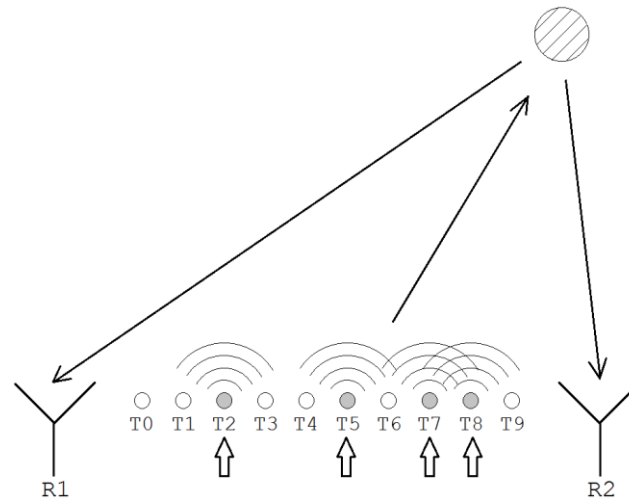


Figure 2: Principle of the solid-state radar scanner. Information on the lateral position is obtained from the triangulation of the time-of-flight to several receiver antennas. The procedure is repeated with several different transmitter beams to increase the resolution of the target.

During normal BF operation, the applied radar scanner system identifies an average of ~1000 different targets per second (reflection points) of the BF burden surface. A well-detailed surface, suitable for the calculation of a layer model or a burden descent speed profile, is already obtained in less than 20 seconds.

2.3 The TMT “3D TopScan” Profilemeter Design

For the TMT “3D TopScan” profilemeter, a compact “delivery system” has been designed to optimally meet the demands of the BF application, shown on Fig. 3 (left). The purpose of the probe is to protect the radar system in the operating BF and ensure continuous measurements. The space limitations on the BF top cone and the desire for uncomplicated and safe maintenance resulted in this new probe system. One of the main arguments for the success of the profilemeter has always been its maintenance friendliness. The probe can be maintained during BF operation. The radar system is fully integrated inside the lance. The system can be retracted and shut off from the process with an isolation valve. A service intervention can then take place even though the BF is in operation.

The probe is designed in a modular way, such that any part can be removed as a sub-unit from the system. For instance, the solid-state radar scanner is one sub-unit that can be replaced in less than one hour by two people. With this, the servicing can be performed in a more convenient location and in less time.

The solid-state radar scanner is installed inside the lance and hermetically isolated from the BF atmosphere by a front protection plate. This protects the system efficiently from the heat, dust and corrosion. In the measuring position, the 3D profilemeter does not enter into the BF top cone area. No mechanical parts can interfere with the charged material or the charging device, be it a Bell-Top or a Bell-Less-Top.

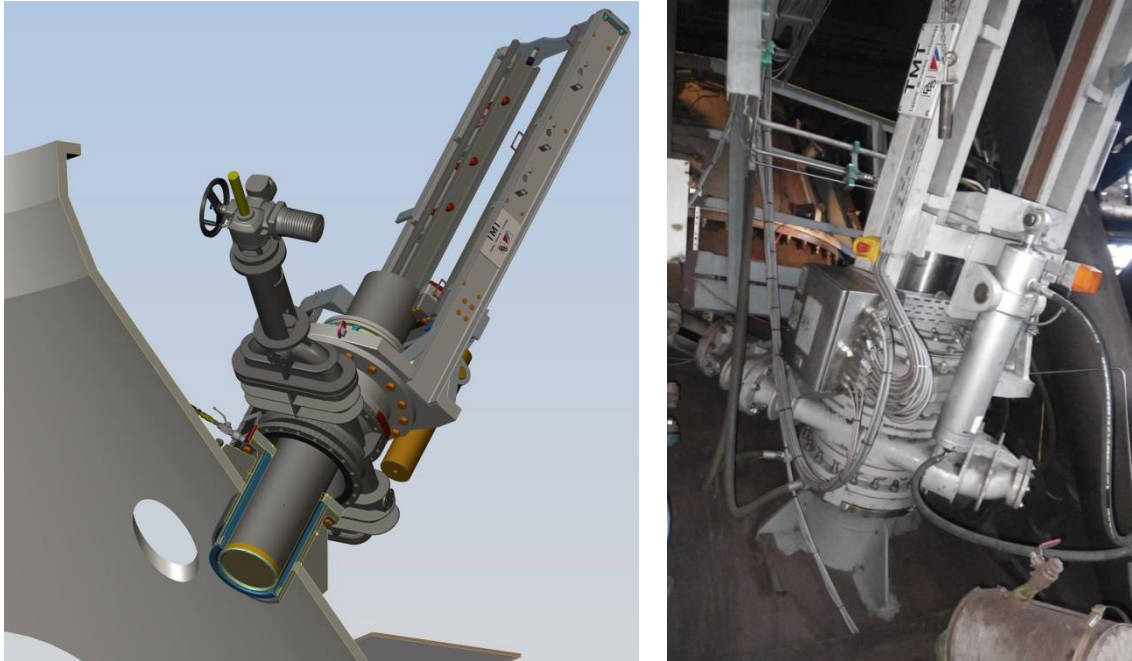


Figure 3: TMT “3D TopScan” profilometer consisting of a water-cooled BF nozzle, an isolation valve, a stuffing box seal, a lance carriage, and a lance. The complete radar system is embodied inside the lance and hermetically isolated from the BF. The TMT “3D TopScan” profilometer is flanged on the BF nozzle and requires no other support.

Additionally, the installation of the probe has been simplified, as shown on Fig. 3 (right). Even though a full maintenance system has been implemented, the probe design is very compact and comparably lightweight. The complete system is bolted on a BF nozzle, and no additional support is required. The probe is delivered in one assembled piece.

3 RESULTS AND DISCUSSION

3.1 3D Burden Surface

In Fig. 4, the raw data points from the solid-state radar scanner are displayed. These are the reflection points that have been collected in 20 seconds during BF operation. A total of 20.000 points that originate from the burden surface are collected within these 20 seconds. As the main result, the complete BF burden surface is covered. There are no shadows, despite the probe having to look through the dusty BF center and interferences of the above-burden temperature probe and the BLT chute.

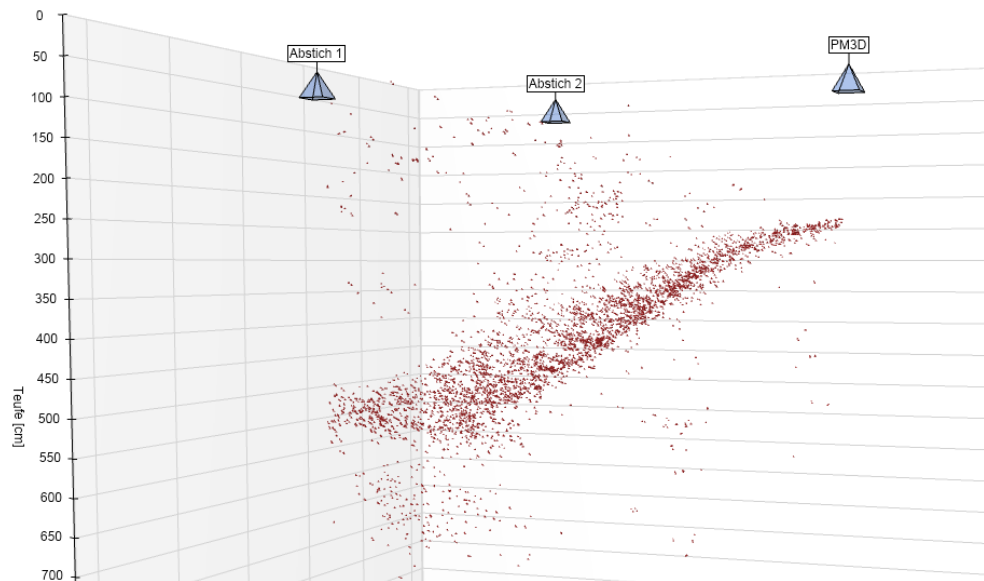


Figure 4: Raw data points collected with the TMT “3D TopScan” profilometer during 20 seconds. The black point indicates the position of the probe. The burden surface can already be clearly recognized. The BF top cone is partially within the field of sight.

This raw data is processed based on geometric and statistical filters. The data points that stem from the burden surface can be uniquely characterized, while false reflections can be removed. In the final step, the data points are interpolated to the BF burden surface. In general, a resolution of 5 cm is achieved. This value has been verified in workshop tests and in the BF by comparing the results with those of existing BF probes.

The measured burden surface is shown on Fig. 5. Here, a considerable surface tilt can be recognized. The measurement was performed during restart of the BF after a stoppage, which explains the low burden level. The correctness of this tilt has been verified by the stockline gauges. Additionally, the surface tilt explained a pressure difference measured in the blast of the tuyeres.

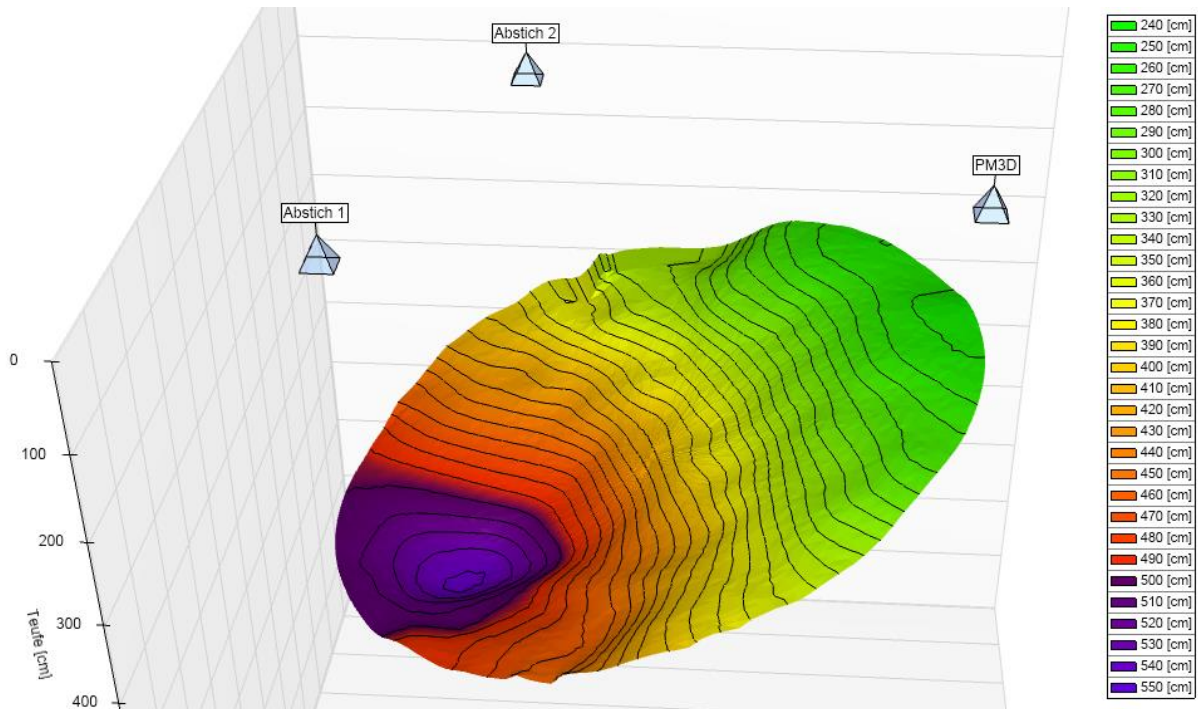


Figure 5: Burden surface measured by the TMT “3D TopScan” profilometer based on the raw data of Fig. 7.

In Fig. 6, the burden surface during regular BF operation is shown. First, a general surface tilt can be recognized. Near taphole 2 (rear side), the level is slightly increased. This increase appeared on a sequence of individual surfaces. Therefore, this tilt only marginally affects the layer thickness. However, the 2D profile along the radius, as known from a classical profilometer, varies with the chosen radius. Both the shape and the slope of the profiles are quite considerably affected.

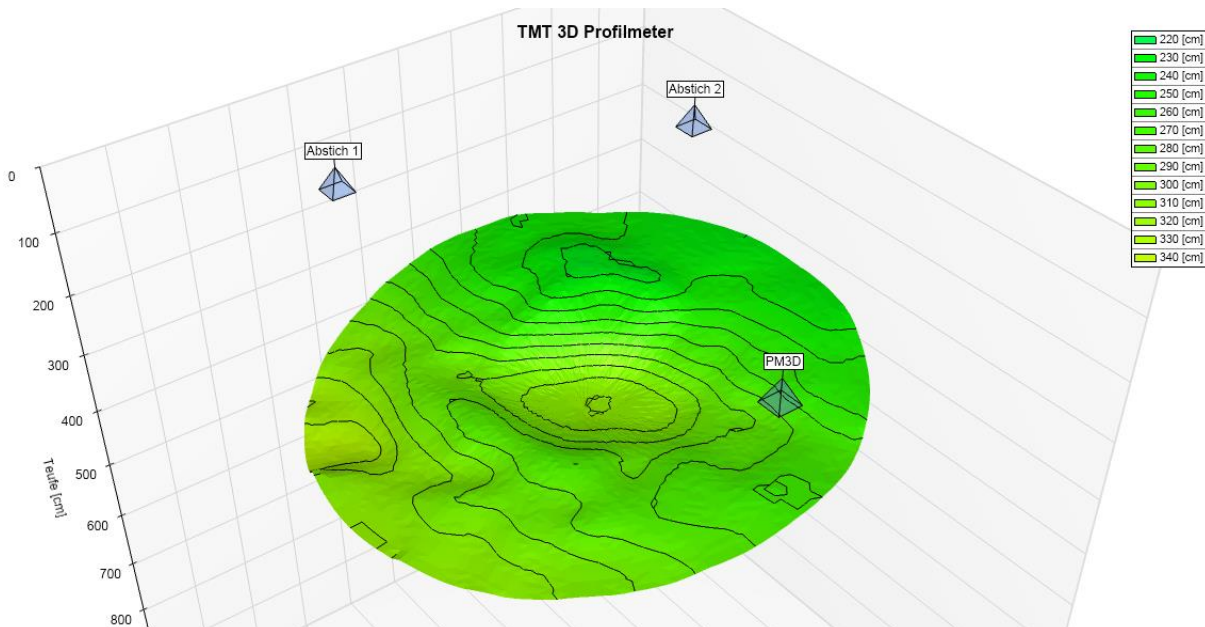


Figure 6: The burden surface measured during regular BF operation with the TMT “3D TopScan” profilometer within 20 seconds.

In addition, the disturbing influence of the above-burden temperature probe is quantified. A valley is recognized from the front right side (PM3D marker) to the rear

left side (taphole 1 position), which is the location of the above-burden temperature probe. The coke/ore-relation is perturbed all over the BF diameter. This non-symmetry can not be controlled by any means of the charging process. As a solution, it is foreseen to install the contactless temperature measurement “TMT SOMA” [5] on the next opportunity.

The main benefit of the 3D profilometer is that it observes the burden surface continuously and over the complete BF surface. This way, abnormalities in the BF process can be detected early, which leads to a faster and more appropriate response of the BF operators.

3.2 3D Burden Descent Speed

The local burden descent speed is a main parameter to measure the stability of the BF process [4]. A non-homogeneous speed indicates either a funnel buildup (faster burden decent in the center) or a wall-working process (faster burden descent near the wall).

The TMT “3D TopScan” profilometer can measure the burden descent speed on the fly, without interrupting the charging process. This is achieved by the fast measurement and the fact that no interference with the charging happens. To calculate the burden descent speed, the first measurement after charging and the last measurement before the following charging are considered, as shown in Fig. 7. A derivation directly leads to the descent speed profile. This way, one burden descent speed profile can be obtained for each layer.

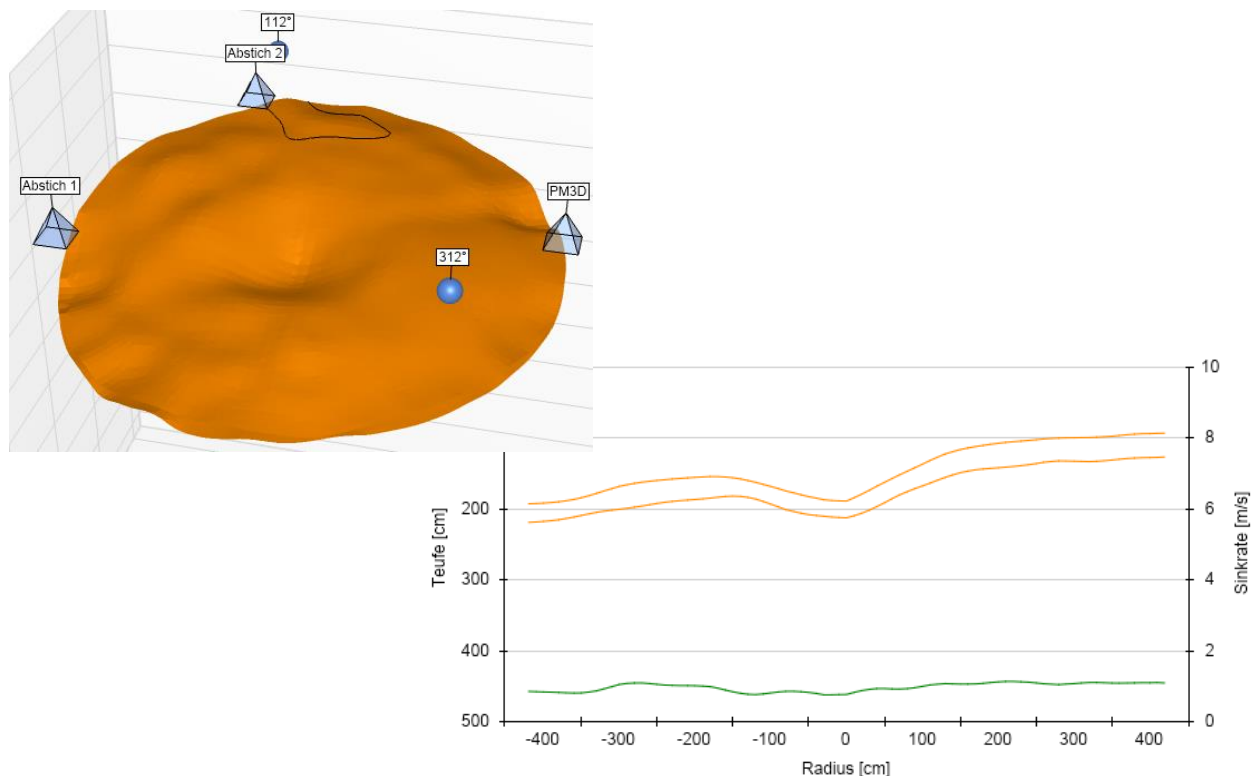


Figure 7: With the “3D TopScan” profilometer, the burden descent speed can be calculated online. As the speed is obtained from the derivation of two measurements, the high accuracy of the applied radar scanner is beneficial.

3.3 3D Layer Model

The 3D burden surfaces of the individual layers in the charging matrix are processed to a layer model. This model indicates the shape and the thickness of the different layers in the burden column.

To inspect the layer structure in 3D, the operator can influence a cut-through-view of the 3D layer model: Two radiuses can be freely selected, and the layer segments in between are removed to obtain insight. The 3D layer model appears as a kind of pie. In parallel, the software continuously outputs the 2D projections over the two selected radiuses, as shown in Fig. 8. This way, a convenient analysis of the high amount of data is achieved.

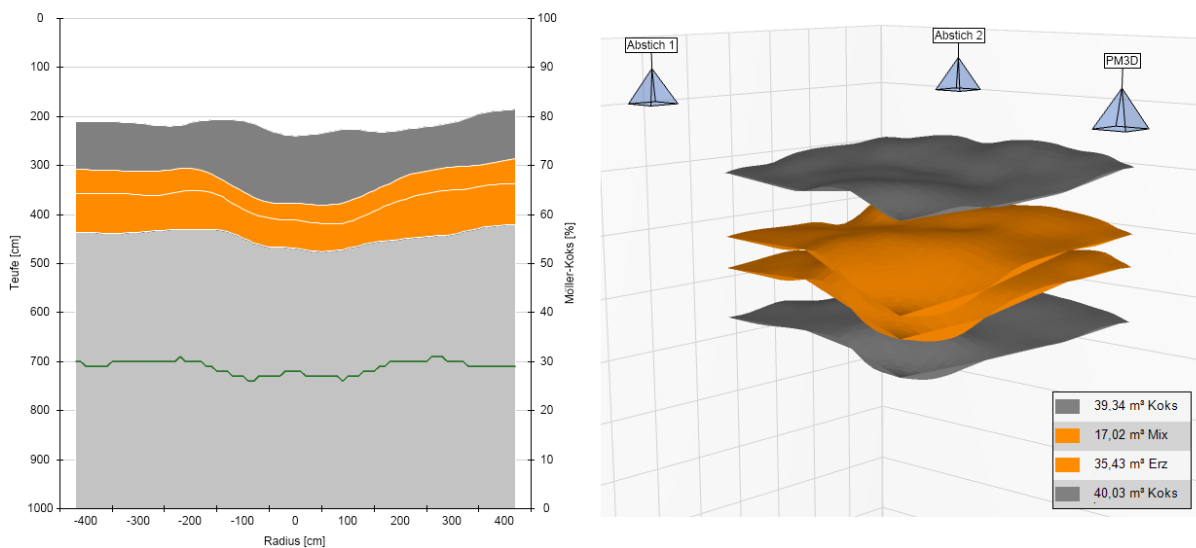


Figure 8: The three-dimensional Layer Model obtained with the TMT “3D TopScan” profilometer. The operator chooses two radiuses, at which the 2D layer model is extracted on the fly.

The 2D extractions of the layer model provide the common understanding of the charging process, as it is known from the literature. However, as the 3D layer model provides the information for any arbitrary radius on the BF, an interpretation can provide deeper insight into the process, especially as the unsymmetries are visualized and quantified. It becomes clear that the unsymmetries are of high importance, and that they should be considered for the BF process optimization.

4 CONCLUSIONS

The three-dimensional profilometer “3D TopScan” has proved its performance in the BF. It can measure the complete BF burden surface within a few seconds. It is based on a solid-state radar scanner to ensure fast and accurate measurements. The probe can be isolated from an operating BF for servicing purposes. The measurement results are reliable and show high precision.

They also demonstrate that the burden distribution inside a BF should not be assumed as radially symmetric. The accuracy and the information content of the layer model are increased with a 3D profilometer.

The increased amount of data leads to more precise and more “realistic” layer models, and will lead to new insights into the BF charging process. With the “3D TopScan” profilometer, not only the complete burden topography is measured, but also, the burden descent speed is observed on the fly. Furthermore, as the surface

topography is not assumed to be symmetrical, the burden behavior can be monitored.

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