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Mobile Test Station for the Radiometric Measurement of Density Distribution in Bales

Conventional methods of determining density distribution, such as peak density measurement or other penetrometer based systems, are unable to non-destructively calculate density distribution in small spaces in round and square bales. This can be done with the radiometric system applied by the DLG. An automated version of this technology is now being employed in a mobile test station. For the first time in preliminary practical applications and further laboratory trials, high resolution radiometric results have been achieved, graphically depicting bale density distribution in a new quality.

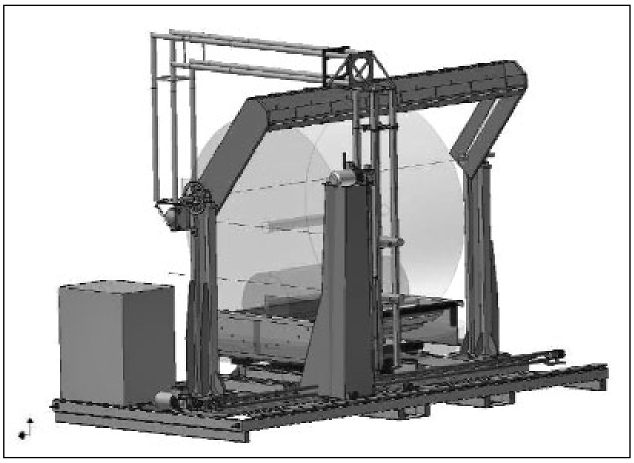

Fig. 1: Constructional design of the test stand

The technical basis for radiometric determination of density distribution in round and square bales has been published already in LANDTECHNIK 3/2007, pages 146-147. An important difference applies to the activity of the gamma scanner used. The Cs.137 spot scanner with 258 MBq activity used up until October 2007 was replaced by a similar model, but one with a total activity of 5550 MBq (factor 20). This gives a technical error of < 1% for silage bales with very high wet densities >700 kg/m^3. The half-life-period of the nuclide will be taken into account in the achieving of a sufficiently high gamma activity for the planned working life of the test station of over 10 years.

Technical construction

The test station was conceived for use in tough field conditions and comprises four core components:

1. Horizontally and vertically adjustable measuring axis members (steel/aluminium traverses attached on one side)
2. Swivelling round bale platform with rotating rollers
3. Tilting square bale platform
4. Control terminal in air-conditioned cabinet

Axis member drive is via five SEW electric motors, three of them controlled via drive inverters. The horizontal and vertical measuring members as well as the round bale platform rotating rollers are fitted with rotary speed sensors to enable precise positioning.

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Keywords

Square bales, round bales, radiometric density measurement, density distribution, density progression

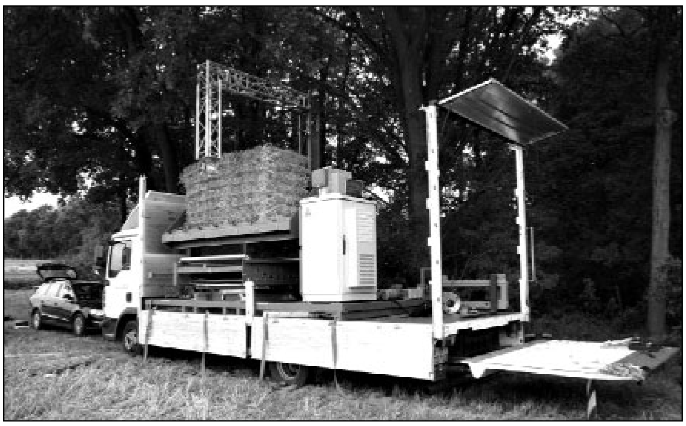

Fig. 2: The mobile test stand on a 7.5 t lorry while measuring a square bale in the field

For safety reasons both linear axes are fitted with limit switches for restricting travel distance.

The total test station was externally manufactured according to the requirements of the DLG Test Station specification document. The most important requirement was that the round bales could be rotationally scanned from the base and lateral surfaces and square bales from the sides and from above. A special requirement in this respect was that a sufficiently good strength-to-weight ratio be achieved for the test station components so that no problem might be caused by, for example, wet silage bales that can easily weigh over 1.5 t a piece. The test station can be applied as static facility or as mobile facility for fieldwork mounted on a lorry with minimum 2.5 t load capacity.

Controlling and programming

Measuring parameters can be variably programmed. Bale size, distances between density measurement points and levels, measuring time for equipment at the measurement points and the rotation angle of round bales can be keyed into the software according to requirements. Three different methods of measuring the round bales are possible:

1. Radial measurement without vertical movement (bale rotation)
2. Radial measurement with vertical planes (without bale rotation)
3. Axial measurement without vertical movement (bale rotation)

Square bales can be scanned from the side (horizontal) and from above (lateral) with horizontal and vertical movements possible. For this, the bale is moved 90° from its first measurement position “bale breadth“ to position “bale height”.

Measurement parameters can in each case be selected from the set-up menu before each measurement procedure begins, or can be selected as new parameters. Required round bale information to be entered comprises respective bale size, horizontal and (for measurement method 2) vertical distances between measuring points and, for measurement method 1, the keying-in of rotation angle (0 to 180°).

With square bale measurement, only the bale size and the distances between the measurement points need be entered. On starting the process, measurement is fully automatic. For data transfer and operation of the test station the station is fitted with a W-LAN transmitter. This allows the operator free movement around the station with the operating and control panel.

Calibration of the complete density measurement sequence takes place immediately before the beginning of measurement using calibration pipes of known length and density.

Fig. 3: The test stand measuring a round bale in the laboratory

Operation and communication

All test station operation and ray tracing takes place via the graphic operator interface (WinCC Flexible) of a robust Toughbook computer with ultra-bright monitor. The Toughbook and the programmable logic controller (PLC S7-313) communicate reliably via wireless encoded Ethernet connection. The Toughbook transmits parameters and operation orders to the PLC. Actual axis member positions and all facility readings are reported to the controlling notebook. Operation and monitoring of the drive converter is via PLC through Profibus DP. Bale density values measured by the detector are imported by the PLC via serial interface and wirelessly transmitted to the control notebook. Together with the location coordinates of the measurement points the values are visualised, depicted in csv format and made available for evaluation immediately after the end of the measurement procedure.

Results

In practical work during August 2008 square bales measuring 2.20 • 1.20 • 0.90 m and (in the laboratory) round bales of 1.45 m diameter were scanned. The measuring grid was 5 cm in x and y direction so that with square bales 1505 (602 horizontal + 903 lateral) density values were able to be recorded and 744 (axial) for the round bales. The square bale shown in *Figures 4 and 5* was produced in a baler with pre-compaction chamber and pressure set at highest level. As shown by the measurements from the horizontal scanning the highest density with square bales was, as expected, in the upper and lower outer areas (*Fig. 4*). At these points bale re-expansion is limited by the bale channel and the twine with baled material density only able to expand into the inside of the bale. Maximum interval is ~ 70 kg/m³. The right and left sides of the bale from the lateral aspect have also a slightly higher density than the bale centre (*Fig. 5*). However, the scatter turned out less because the bale sides were not compressed by twine and the bale movement and compressing strokes by the baler mechanism had an equal effect on sides and centre. The interval here was only ~ 50 kg/m³.

The density distribution effect with square balers depends on the way the machine is operated, its setting, specifications (e.g. with or without pre-compression chamber), the

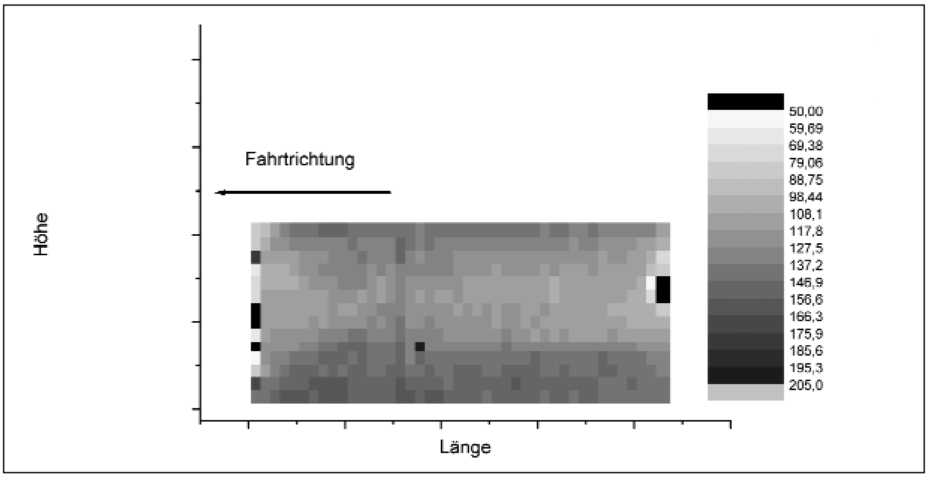

Fig. 4: Horizontal radiometric scan of a straw square bale (5 • 5 cm recipe). The highly compacted areas at the upper and at the lower side of the bale are well noticeable.

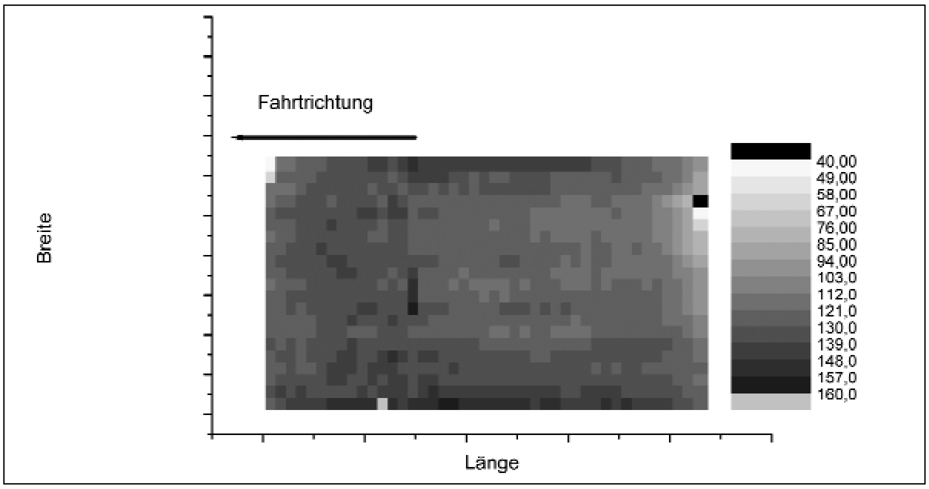

Fig. 5: Lateral radiometric scan of a straw square bale (5 • 5 cm recipe). Scattering is smaller than in horizontal scanning.

swath form and size, as well as the characteristics of the material being baled. Intense investigations into these influences are to follow in the 2009 harvests.

Radiometric measurement of round bales takes place in axially (*Fig. 6*) with, firstly, the upper half of the bale scanned and then the bale turned 180° so that the lower half is scanned. The illustrated straw bale was produced in a variable chamber baler with maximum 150 cm diameter although not actually scanned until two weeks after baling. As expected the bale centre, the core, is very loose. Only in the core periphery does the bale density increase to maximum before once again decreasing towards the bale outer layer. Clearly noticeable is the markedly differentiated layering of bale density. Layering and distribution of density depends on the type of material being baled and the baling conditions (moist, swath form) the baler specifications, its setting and whether it has a fixed, part-variable or fully variable chamber and, of course, the operation mode. Under comparable conditions it is, therefore, possible within the framework of R&D investigations to carry out comprehensive comparisons of function examples, makes of balers and different baler settings.

Summary

The DLG Test Centre's radiometric test station enables rapid and destruction-free automated determination of bale density distribution in round and square bales. With help of the new gamma scanner with increased activity, the technical measurement errors could be markedly reduced, especially in the case of very highly compacted silages. Helped by the very high resolution and the free selection of parameters, comprehensibility of the received measurement values was unmatched by other systems. No radioactive radiation of the baled material took place –i.e. no contamination remained in the bales following the measurements. Specially trained personnel carried out the observation of all radioactive contamination protection, as required in all storage and working permits.

In the first place the test station is envisaged for comprehensive investigations in the R&D sector, but in future will also find application within the DLG Fokus and Signum Tests.

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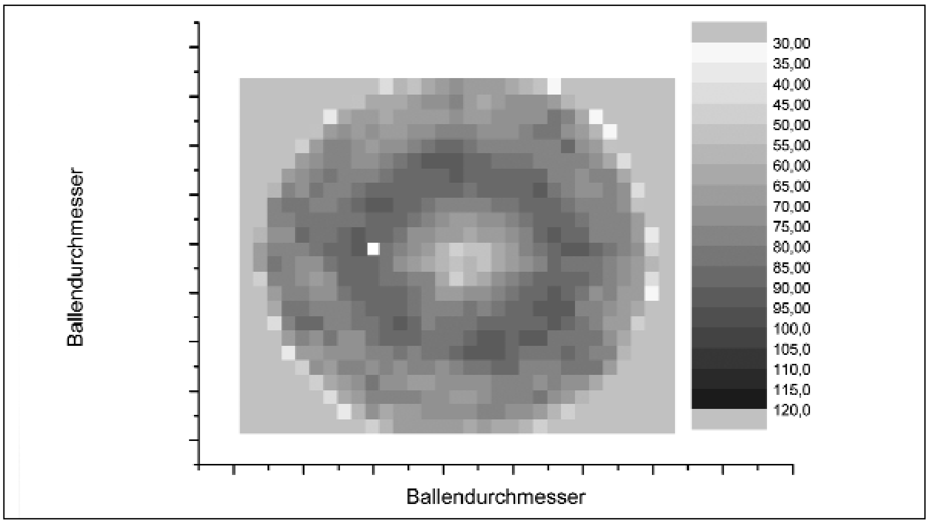

Fig. 6: Axial radiometric scan of a straw round bale (5 • 5 cm recipe) from a variable press chamber. The axial formation of the pressing density with a maximum in the boundary area of the core is well recognisable.