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Density distribution research of silage round bales with a penetrometer test bench

The average density of bales can easily be calculated by mass and volume of the sample. To get a more detailed view to the density distribution of the bale other measurement methods are necessary. One of them can be realised by the use of a penetrometer which has been implemented in a test bench to use the methode in a semiautomatic way. The developed software gives the opportunity to visualise the penetration resistance of the cone during the measurement in a two dimensional map. The data processing of the hole bale allows a three dimensional view into the bale density. The system was calibrated by parallel measurements with the radiometric test bench of the DLG in Groß-Umstadt and shows in a comparison test similar results.

Keywords
Penetrometer, test bench, density mapping, bale quality

Abstract
Landtechnik 68(1), 2013, pp. 26–29, 7 figures,
7 references

The penetrometer technique is a common method in soil science, where it is used to detect density differences and soil compaction. In this case the vertical penetration resistance of a cone is measured by a force sensor and logged versus the dept of penetration. Basic investigations at round bales with the technique used in soil science gave the impulse to develop a semi automatic test bench [1]. This test bench enables a differential penetrometer measuring of the whole bale by only one operating person.

The requirement of differential density measurements in bales has also been in focused of the DLG Test centre in Großumstadt. The test bench developed in 2005 uses a radiometric test method which is based on a gamma-ray source (CS 137) [2]. The absorption of the gamma ray is directly connected with the density of the penetrated material. With a correct calibration the radiometric measurement method provides a high accuracy independent of other material properties and the measurement does not damage the bale itself. Using of radioactive sources needs always special security treatment and operating persons who are accomplished to handle these materials. Another handicap is the transport and the application as mobile system because of the CS 137 source.

Fig. 1

Test bench for measuring the bale density in side view. The bale is rotated by the electric driven roles below. (Photo: Büscher)

Fig. 2

Penetrometer unit of the test bench in front view (Photo: Büscher)

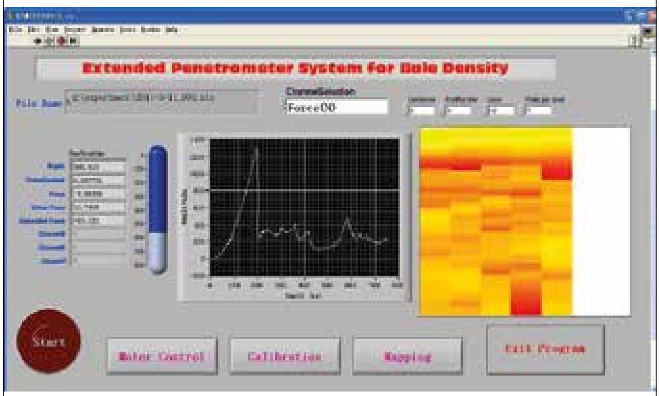
Construction and function of the test bench

Since 2011 the penetrometer test bench is used for the measurement of round bales with a horizontal driven cone (**Figure 1**). The penetrometer unit can be moved sideward by a sliding carriage which is controlled by the process computer. The rollers on which bale is standing are used to turn the bale electrical in every axial position (**Figure 2**). To control the penetration direction in the centre of the bale the slide carriage with the penetrometer unit can be vertical adjusted.

On the one hand the process computer controls the active drive of the penetrometer and its position. On the other hand it shows online the penetration resistance in a two dimensional graphic on the Lab View interface and records all data of the measuring (**Figure 3**). The whole test bench is based on load sensing equipment to catch the total weight of every bale without additional weighting system. In combination with a manual measuring of the bale volume the average density can be calculated. To prevent inadvertent rolling of the bale during the measurement a pneumatic bracket fixes the bale position. The complete unit can be loaded with a forklift, transported by a car trailer and used at every place where a 400 V electrical connection is available. In 2011 and 2012 the test bench has been approved in measuring more than 80 bales with a measuring time of approx 100 minutes per bale [1; 3; 4; 5; 6; 7].

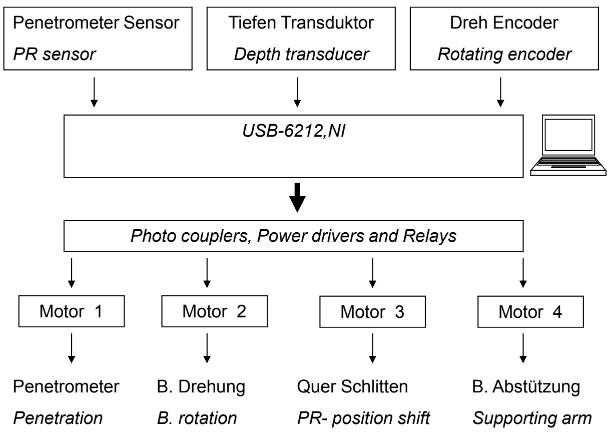
Penetrometer measurements using cones with force sensor at the base need always an observance of the friction at the cone side. This additional force has to be tested in calibration measurements under controlled conditions and have to be included in the calculation of the practice measurements. In general the effect can only by observed in more elastic material. To eliminate this effect during the measurement a special cone with a force sensor in the cone end was developed. To connect the sensor with the system a data cable through the cone centre is necessary. Otherwise the cone has to be stable also at forces until 2 000 N which needs a high quality spring steel. **Figure 4** shows the schedule of the electronic parts of the test bench. The measurement range has been extended from 1 000 to 2 000 newton to measure high density bales.

Fig. 3



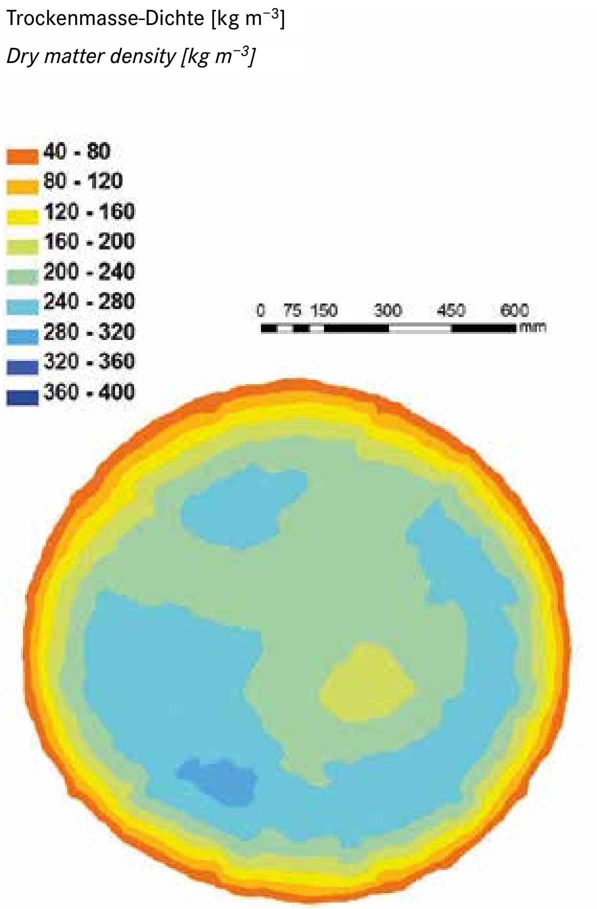
User interface of the software during the measurement. The actual force at the cone and the two dimensional mapping is shown

Fig. 4



Schedule of the main functional elements of the test bench

Fig. 5



Example of the density distribution of grass silage in round bales

Results

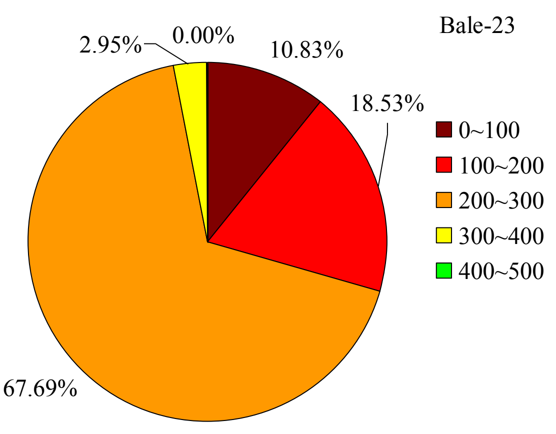
Figure 5 shows the differential density of a round bale pressed by a fixed chamber baler (Claas, type Rollant 455). The bale was pressed using the complete 25 blades and the maximal hydraulic pressure of 18 Mpa at the back holder and 12 Mpa at the MPS System. The average bale density of this bale is at a high level of 206 kg m^{-3} (**Figure 6**).

The data of the density map can be presented in a two dimensional (**Figure 5**) draft as an average of the 8 different layers or separate for each layer. The data can also be used to generate a three dimensional map which allows a direct view in the different parts of the measured bales (**Figure 7**).

Figure 7 shows the comparison of the bales pressed with different shopping lth effected by the number of blades cutting the material. This comparison obviously shows an effect of the cutting intensity during the crop collecting especially in the centre of the bale. The volume of the soft bale centre is much smaller in case of the short shopped material (bale 1). The problem of a soft bale centre is given at every fixed chamber baler because of the not existing compaction at the beginning of the chamber filling, but an effective shopping in addition with more effective compaction tools like the MPS can help to minimize the soft bale centre.

Regarding the reheating of the silage after opening the bales (more than 5K) material with low compaction is much more critical because of the faster exposing to air inside the bale. Oxygen comes easily in the deeper parts of the material and gives the microbe the opportunity of aerobic metabolism. In case of a fast feeding (one bale in one day) all these effects does not really matter, but many bales especially for horses have a low fermenting intensity and are fed for more than three days. Another aspect are leaks in the film caused of different things in practice. In that case the amount of damaged silage near to the leak is also effected by the bale density. In both cases the silage can be contaminated by mycotoxins which are a product of moulds growing in the silage under air influence. Mycotoxins can be the cause of different heath problems which make reheated silage and the additional effects not only to an economical problem.

Fig. 6



Volumetric content [kg m^{-3}] of five different density levels

Conclusions

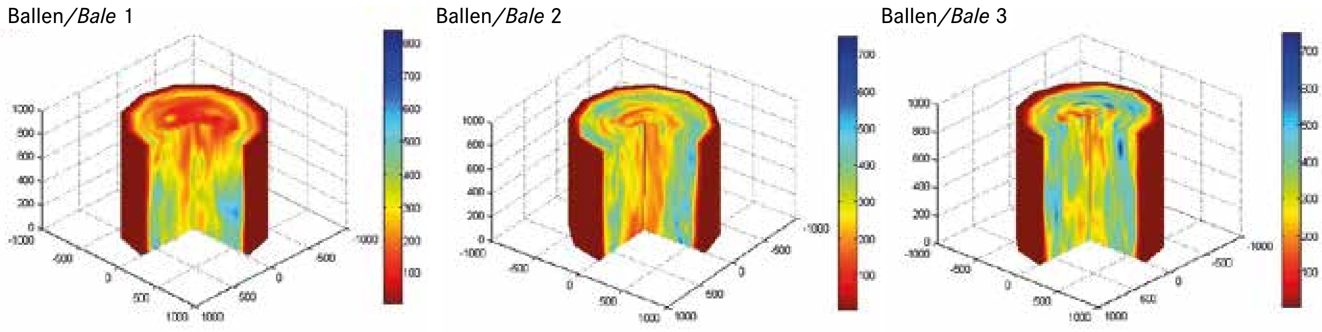
The function of the penetrometer test bench for round bales has been verified in many cases and gives detailed information about the differential density of the bales. This basic view inside the bale can be used for the further development of the compaction tools in balers. For the scientific aspect the measuring technique gives information about the crop density of different silage crops which can be used at many questions of silage making especially in case of hard fermenting crops.

The test bench can be used at every place where 400 V electric power is available. This is important because the transport of bigger amounts of bales can be quite expensive. The accuracy of the results is quite high. Especially the differences inside the bale are detected with a high resolution.

The results can be used for the following aspects:

- Improvement of the compaction tools for round bales.
- Improvement of the tools effecting the mass flow in front of press chamber
- Evaluating of reheating risks and fermenting of difficult silage crops like alfalfa.

Fig. 7



Effect of the cutting intensity during the crop intake shown at a three-dimensional diagram (bale 1: without blades, bale 2: 12 blades, bale 3: 25 blades)

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