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dTDR for Composting Process Control of Biomass

In a joint project with IMKO, sponsored by the BMBF, the dTDR technique was developed for the dynamic recording of soil moisture. Among other things, its purpose is to document and control the process flow in composting. The optimizing potential for process control for these facilities is assessed exceptionally high.

The development of dynamic Time Domain Reflectometry (dTDR) for an instant quotation of the prevailing field water status meets promising approaches for process documentation and control (Jantschke, et al., 2006). The basic specification of the sensor holds an exact determination of moisture up to 15mS/cm, at 1 Hz temporal resolution. Therefore promising applications of moist biomass processing can be derived.

Systematic development of dTDR-technology

The dTDR device is based on TRIME technology, which has been firstly introduced by IMKO 1990. TRIME translates TDR traces into numbers of volumetric water content. A further development to provide a dynamic TDR technique has been funded since 2002 by the German Federal Ministry of Education and Research (FKZ 0330107). The design and production of the prototype gauge has been conducted using VDI-guidelines (VDI 2221, 1993). Two modules define the functional components of the gauge. The head-cone of the gauge vertically divides the soil, to facilitate a direct sensor/soil-contact. The sensor body provides the waveguide bearing which holds the actual probe. Modified TRIME electronics are embedded within the sensor body. Various PVC (Polyvinyl Chloride) elements are used to brace the setup and protect the embedded electronics

First measures to further reveal the most appropriate technical setup were to place distinct design components of the dTDR gauge into numerical modelling context of the conducted electromagnetic field (Matlab, Maxwell 2D). Resulting, the designed depth of the gauge could be minimized, identifying an air notch within the PVC to buffer the electromagnetic field.

A second step provided an integration of the aforementioned geometrical suggestions into the design of the sensor body. Therefore the engineering software CATIA (Dassault Systems) was used for the 3D-embodiment design. Further development was iteratively conducted for the module *Product Function Optimizer*. For finite-elements method (FEM) analysis, material parameters of steel and PVC were defined to simulate construction. A potential load scenario (*Fig. 1*; top) displays assumed area-loads onto the sensor-body within 3D-space. Findings of Verscho-

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Keywords

TDR, dynamic, soil moisture, bio waste, biomass

Literature

Literature references can be called up under LT 06SH09 via internet http://www.landwirtschaftsverlag.com/landtech/local/literatur.htm.

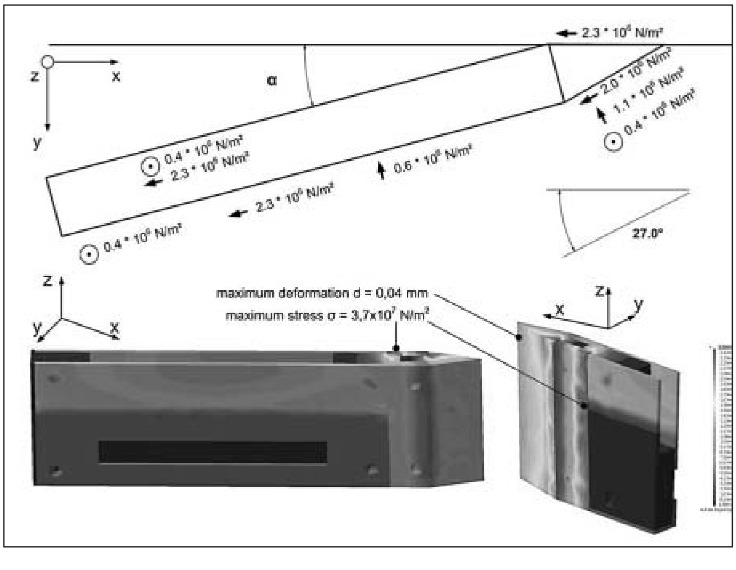

Fig. 1: Momentary load scenario for altering progression angles (top); FEM components under structural analysis for the aforementioned load scenario (bottom).

ore (2003) showed loads of 0.1-0.7 N/mm^2 (soil bin trials) and 0.3-1.0 N/mm^2 (field trials) for a comparatively similar shaped setup. Investigations of Froeba (1991) and Getzlaff (1953) are backing up this statement. Steiner (1979) declares a maximum load of 2.3 N/mm^2 at 16 % vol. water content, which is found reduced to 0.2 N/mm^2 at 25 % vol. water content.

The progression angle α was variegated for different operating conditions. Accordingly, resulting forces are changing. The load scenario shown, clarifies a specific sensor-load while proceeding within the topsoil at 2 m/s. The predicted resulting maximum deformation is found to appear at the sensor's head-cone. Deformation d is 0.04 mm. The waveguide bearing appears with unverifiable distortion, which underlines a save insert of a ceramic waveguide cover (material strain, fissure). "Van-Mises equivalent stress band" σ_v was computed maximum $3.7 \cdot 10^7$ N/m^2 at the joint of head-cone and sensor-body.

The resulting ready gauge is specified under economically optimized setup conditions as stabile and rugged. Distortion and appearing stress of PVC components are negligible. Embedded electronics are specified protected IP 55 and higher (EN 60529).

Application „Process Engineering in Waste Conditioning"

The aforementioned qualities of the developed dTDR-gauge form several types of potential applications for a treatment of biogenous residuals. The temporal and spatial change of moisture content in waste plants shows a certain analogy to agricultural field conditions for top-soils, due to environmental parameters (temperature, radiation, substrate-structure). Mechanical measures as mixing, packing and turning are potentially amplifying the described dynamics. The defined gauge-specifications of dTDR cover the application fields of compost and bio waste treatments (*Table 1*). However, its reliability to a sound method to quote biogenous residuals has to be verified during further trials.

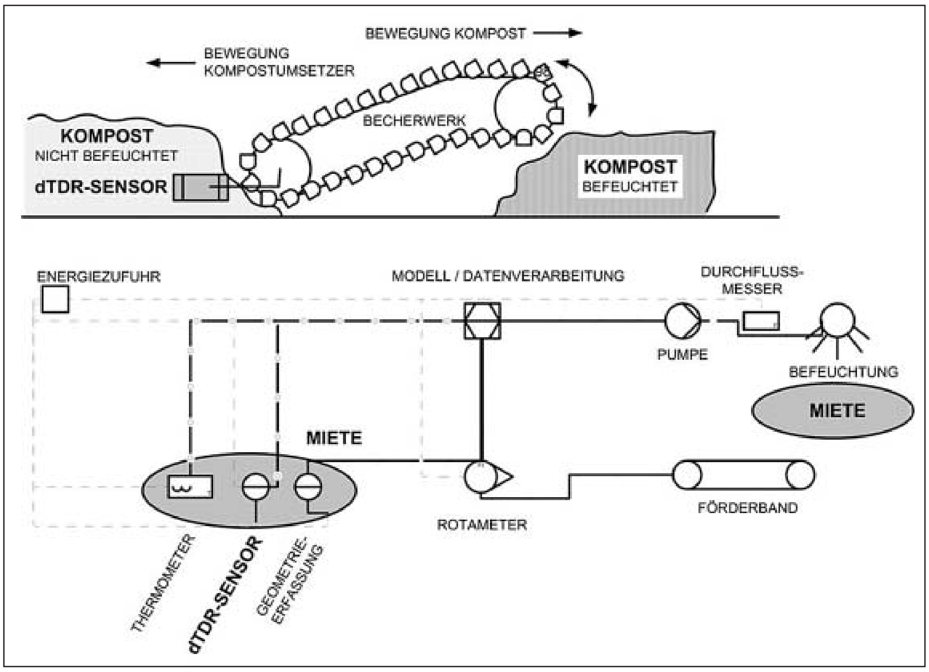

Fig. 2: Functional sketch of a compost conveyor with an implemented dTDR-gauge

Case: „composting"

An effective process of composting bio waste is desired. A characteristic course of process temperature deals as an indicator of microbiological decomposition desideratum. Therefore an optimized water content of the substrate is indispensable. Present practice mainly deals with a subjective evaluation of moistening quantities by the operators of respective plants.

With the implementation of dTDR, areas of required moistening can be identified accurately simultaneous with the movement of the compost conveyor. Therefore an objective process control enables an instant regulation of demanded moisture intermixture to achieve the desired water content. The control of additional process variables such as progression pace and admixture of aggregates can be actuated as well. Microbiological processes are intended to be optimized for compost plants in order to produce an optimal specification of compost [6, 8, 12].

Perspective

After first studies the aim of transferring the recently developed dTDR probe to composting plants and related applications of biogenous residuals processing seems expedient. With an exact determination of moisture conditions processes are to be controlled relative to their concurrent spatial distribution. This application aims towards an autonomous process control of mixing and conveying intensity. Furthermore clear and fluent process documentation is enabled. Therefore mathematical models have to be generated. First stationary results showed excellent results, predicting process water status for defined conditions. The novel dynamic soil moisture sensor (dTDR) enables a fluent data acquisition at a resolution of 1 Hz, which is already found adequate for a potential process control. Limitations of dTDR are revealed in a shallow penetration depth. Minimum fill levels should be 5 cm. A single sensor represents one horizontal layer of 3 cm size. The alignment of more datasets is promising. Substitute values verify the recorded moisture proportions (penetration force, temperature, bulk density; e.g.). Therefore the dynamic measurement delivers a substantial advance of application as a supportive information module for process regulation. The applications mentioned are analytic surveys, to quantify potential benefits from the novel introduced technique. Further tests are intended.

		Soil	Biowaste	Compost	Blend*
pH		3.0 - 7.5	7.55	5.0 - 8.5	7.5
Density	$[g/cm^3]$	1.1 - 1.8	0.7	0.35 - 1.1	0.5 - 0.7
Electric conductivity	[mS/cm]	0 – 0.9	2 - 5	2 - 7	2 - 3
Moisture range (humid)	[% Vol]; humid	50	55	90	40
Moisture range (dry)	[% Vol]; dry	2	50	30	20

* Biowaste/Paper-Mixture (52 / 48)

Table 1: Relevant parameters of soil, compost, biowaste and biowaste mixture (extract)