Peter Droll and Heinz Dieter Kutzbach, Hohenheim

Laserscanner for 3D-measurments of surfaces

In order to be able to better describe the relationships occurring when rolling a tyre over a malleable ground surface, a 3D laser scanner was developed at Hohenheim and used, along with a laser measuring instrument for the measurement of the inner contours of a rolling tractor tyre, to measure tyre-caused plastic deformation of the ground. The scanner design suits it for other purposes, for instance, determination of surface roughness, depth of plough or drill furrows. The construction and function of this scanner is presented along with first results from laboratory and field trials.

Dipl.-Ing. sc. agr. Peter Droll was a member of the scientific staff at the Chair of Procedural Technology in Plant Production with Agricultural Engineering Basis at the Institute for Agricultural Engineering (director: Prof. Dr.-Ing. Dr. h.c. H.D. Kutzbach), University of Hohenheim, Garbenstraße 9, 70599 Stuttgart, e-mail: *droll.peter@web.de*, *kutzbach@uni-hohenheim.de*

Keywords

Laser scanner, tyres, soil deformation, tyre-soil interaction

Literature details are available from the publishers under LT 01310e or via Internet at http://www.landwirtschaftsverlag.com/landtech/local/fliteratur.htm.

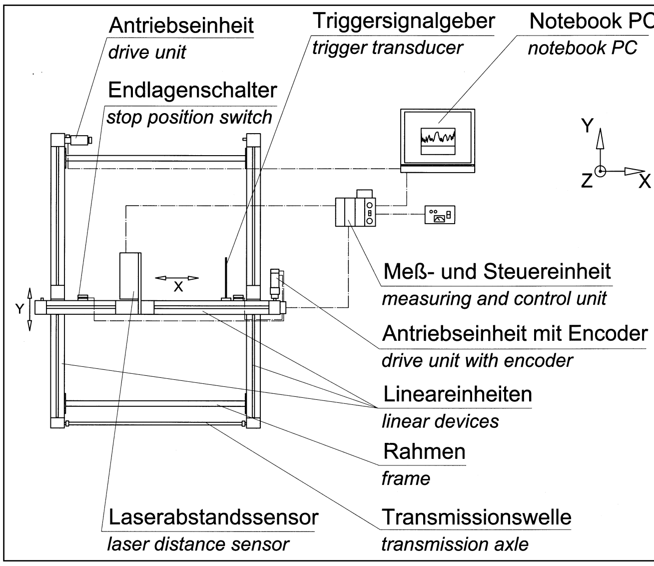

Fig. 1: Set up of the 3D laser scanner

Field compaction damage from increasing wheel loads and high tyre pressures can lead to crop yield penalties. Less rut formation through wider tyres with larger contact area and less air pressure offers a possibility of avoiding compaction damage. Exact knowledge of the extent of such soil deformation is important for describing tyre-soil interaction. Whilst tyres deform elastically, ground deformation takes place, depending on soil type and condition, both elastically and plastically.

Alongside laser measuring equipment for recording the interior contours of tractor tyres [1] a laser scanner was developed at the Institute for Agricultural Engineering enabling the profile imprint of a tyre on a malleable surface to be measured and, with this, determination of the influence of various tyres and soil parameters on lasting soil deformation and tyre-ground interaction. The laser scanner can scan a maximum area of 800 • 1000 mm. Further applications might be, e.g., the measuring of plough furrows and the work of soil cultivation implements and drills, or the determination of surface rough-ness (*table 1*). Able to be calculated from the measured profile imprint can be contact areas, displaced soil volume and, with the additional help of existing or still to be developed models, tyre-ground contact area pressure.

Set-up and function

The basics consist of two parallel linear units

Table 1: Possible *of application for the 3D laser scanner*

Procedures	Targets	Literature
3-dimensional imaging of objects (surfaces)	Visualisation of hollow structures	
Determination of surface roughnesst	Calculation of coefficients for roughness of field surface, road surface, concrete	[2, 3]
Measurement of profile imprints	Calculation of displaced volume of soil, conclusions regarding deformation energy and thus ground-related, rolling resistance.	
Comparison of styre profile and profile impression	Statements on ground condition (driveability) determination of contact areas, compaction investigations. Conclusion regarding tyre and ground deformation (influence of speed, pressure, wheel load, soil type, tyre type)	[4 to 13]
Determination of the-processing effects of soil cultivation implements	Calculation of length, lateral and depth distribution coefficients	
Measurement of sowing precision of drills-	Levelling effect, the results of crumbling, furrow formation, processing of parameters/coefficients	

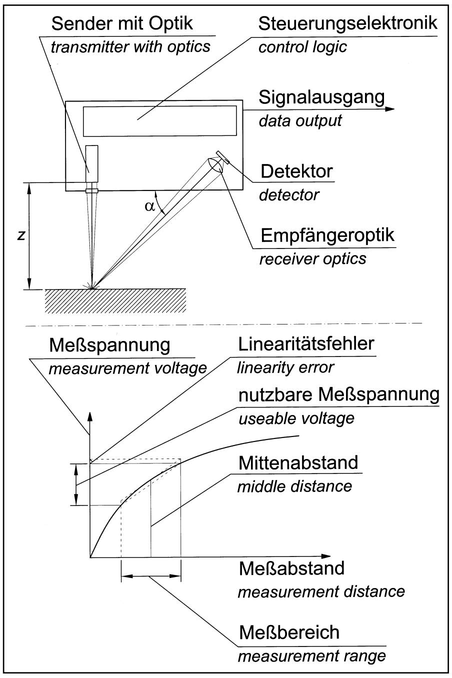

Fig. 2: Functional principle of a laser distance sensor (triangulation method)

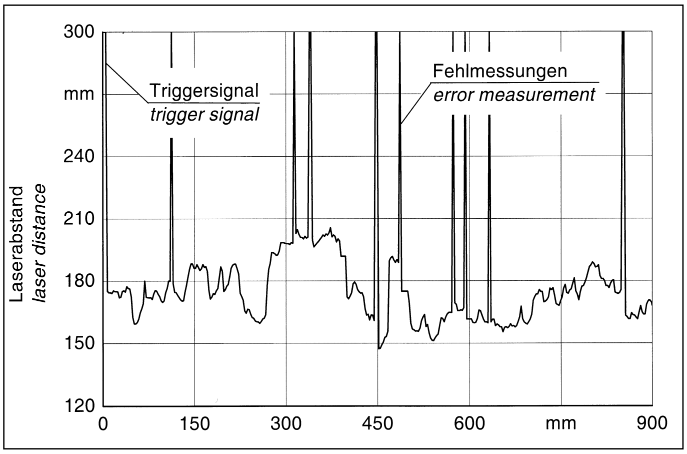

Fig 3.: Laser distance signal vs. covered distance

linked rigidly by two frame parts (*fig. 1*). A shaft helps to synchronise drive to both linear units by transferring it from one linear unit to the other. A step motor provides the drive.

A further linear unit screwed onto the flange plates of both other linear units and driven by a DC motor with encoder, supplies the lateral drive for the laser sensor. The distance covered can be recorded by step counting. For all three linear units, the drive is delivered via double track toothed belt with a gear ratio of 41 mm/rev. The non-slip drive via toothed belt enabled a repetition precision of 0.5 mm for the positions in X and Y direction. A vertically and horizontally adjustable trigger signal transmitter serves over the laser start signal as start impulse producer for each measuring track.

All electronic and electrical construction elements are linked with a central measurement, control and current supply unit from where the encoder measurement and the laser sensor signal are transmitted to the portable PC with measurement evaluation recording card. The step motor control card is also in the PC which, with the aid of a specialised software serves to control the longitudinal drive in Y direction.

The laser sensor used has a maximum measuring area of 180 mm. The mid-point of the measuring area is 200 mm and maximum measuring frequency is 3 kHz with a measuring sensitivity of 0.1 V/mm. The laser sensor works according to the triangulation method (fig. 2). The ground surface was scanned by the laser. A portion of the reflected rays was imaged on a photo receiver with the help of a receiving lens. The angle of reception altered in relationship to the measurement distance, whereby different points of the photo receiver were hit by the reflected rays and different measurement currents produced. Because of the angle relationship, there occurred a non-linear association between measurement distance z and reception angle (. A linear association between measuring current and measuring distance was produced by an internal linearisation and maximum error limited to ± 0.8%.

In that the measurement point of the laser sensor had a diameter of around 1.5 mm, an average distance between the measurement points of 1.75 mm was produced with a travelling speed of 35 cm/s in x direction and a measuring frequency of 200 Hz. In y direction there was also a practical longitudinal movement interval between 2 and 5 mm from the point geometry of the laser ray.

The measured data – position and distance – were processed with a measurement evaluation recording software and saved. False measurements were filtered out during further processing, the data controlled and then exported in appropriate data format. The displaced soil volume could be approximately calculated with this data. With the help of 3D software a three dimensional image of the tyre imprint can also be reproduced.

Results of preliminary trials

In different preliminary trials with different tyres and loads the function of the measuring equipment was checked in a ground rut and on the field. These trials have shown that the soil structure of the trial ground to be measured must not be too rough. This results in false measurements because of poorer reflection conditions (*fig. 3*). Ground that is too dried out also leads to result errors in that the distance measurement expands over the measurement area through shrinkage cracks. In this exceeding of the measurement area, as well as by the so-called refraction effects, the sensor used delivered an initial current of 9 V and, with that, a distance of 300 mm. This false measurement could, however, be corrected during revision.

Figure 4 shows the three-dimensional imaging with two-dimensional projection of a tyre imprint in the Hohenheim ground rut. Through the classification into different grey steps the depth of the imprint and, with that, ground compaction is indirectly defined. In this way pressure distribution can be estimated through the different colour reproductions in the two dimensional image.

Outlook

The 3-D laser scanner presented here enables horizontally expanded objects or surfaces to be measured with a maximum expansion of 88 • 1000 • 180 mm (l + b + h). The function of the measurement equipment was tested in preliminary trials and improved. Alongside the utilisation as profile imprint scanner presented here, this equipment can also be used for the measurement of a large number of other objects and surfaces.

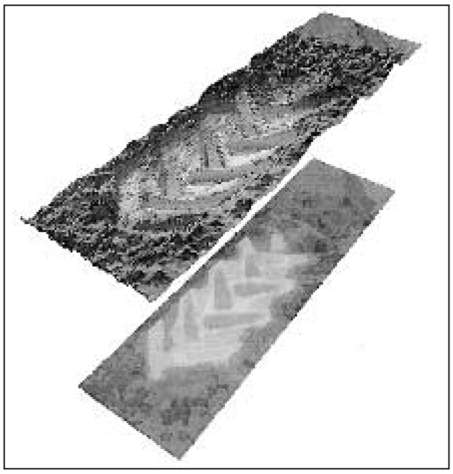

Fig. 4: 3D image and 2D projection of a profil imprint