Winfried Fechner and Wolfgang Büscher, Halle

Electronic Sugar Beet with six Acceleration Sensors

"The electronic sugar beet" was developed in Halle for the analysis of cleaning elements in sugar beet harvesters. Reduced in size and weight, the development now contains six acceleration sensors and enables a considerably improved record of the movements and accelerations of the roots on the cleaning elements. The modular construction allows also the direct siting of sensors within the natural sugar beet for a comprehensive analysis of root damage through different forces.

Dipl.-Ing. Winfried Fechner is a member of the scientific staff at the Institut für Agrartechnik und Landeskultur der Martin-Lüther-Universität Halle-Wittenberg, Ludwig-Wucherer-Str. 81, 06108 Halle (Salle); e-mail: fechner@landw.uni-halle.de; Prof. Dr. Wolfgang Büscher is director of the institute; e-mail:buescher@landw.uni-halle.de.
Special thanks to the Saxony-Thuringia Association of Sugar Beet Growers e.V., Zeitz and the Südzucker GmbH, Zeitz for their financial and material support.

Keywords

Sugar beet harvest, damage, acceleration, measuring system

The technology of the 6-row sugar beet harvesters has nowadays reached a high level of development. Separation of soil and roots is an important part of the technology but one which does not always give a satisfactory result. Simply increasing the intensity of the cleaning action increases unwanted damage to the root substance [1 to 3]. The aim is thus to encourage the efficacy of the cleaning elements whilst at the same time reducing damaging effects on the beet.

With an institute-developed electronic measuring device („electronic sugar beet") resembling the natural root, forces on the root within the harvesting machine were to be investigated and analysed [4, 5, 6]. Aim of the new development from 1998 is to use an extended sensor capacity for more information on the movement of the roots as a basis for the planning and construction of cleaning elements and also to enable improved forecasting of possible damage during harvesting.

Construction of the „electronic sugar beet"

With the improvement of the „electronic sugar beet" compared to previous models, the number of integrated acceleration sensors was increased from three to six and outer measurements and weight were greatly reduced (*fig. 1*).

Every unrestricted body has six degrees of freedom in space. Only when the values for all six are known can the movement of the body and the effective acceleration forces be described. The six acceleration sensors were thus attached outwith the mass centre of gravity in adjacent pairs on a cube (*fig. 2*). When the cube is accelerated in a straight line, all particles experience the same acceleration (Condition: no change in body shape, no turning of body). The measured straight-line acceleration particle a_{ti1} and a_{ti2} (t: translation, i:x, y or z direction) is the same for both sensor groups for magnitude and direction (Eq. 1). Should the cube be rotated about its centre of gravity, the sensor acceleration forces a_{di1} and a_{di2} act against one another. The magnitude of the accelerations is proportional to the distance from the centre of gravity (Eq. 2). Additionally, the sum of straight-line acceleration and revolving acceleration equates the measured accelerations a_{i1} and a_{i2} (Eq. 3 and 4).

$$a_{ti1} = a_{ti2} \qquad (1)$$

$$\frac{a_{di1}}{l_1} = \frac{-a_{di2}}{l_2} \qquad (2)$$

$$a_{di2} = \frac{a_{i2} - a_{i1}}{1 + \frac{l_1}{l_2}} \qquad (3)$$

$$a_{ti1} = a_{ti2} = a_{i2} - a_{di2} \qquad (4)$$

$$a_{tL} = \frac{a_{tz1} + a_{tz2}}{2} \qquad (5)$$

$$a_{tQ} = \sqrt{\left(\frac{a_{tx1} + a_{tx2}}{2}\right)^2 + \left(\frac{a_{ty1} + a_{ty2}}{2}\right)^2} \qquad (6)$$

$$a_w = \cos\left(\gamma - \arctan\frac{a_{dx}}{-a_{dy}} + a_{dy} > 0 * \Pi\right) * \frac{\sqrt{a_{dx}^2 + a_{dy}^2}}{r} \qquad (7)$$

$$a_z = -\sin\left(\gamma - \arctan\frac{a_{dx}}{-a_{dy}} + a_{dy} > 0 * \Pi\right) * \sqrt{a_{dx}^2 + a_{dy}^2} \qquad (8)$$

Further, built on the components in directions x, y and z, the straight-line acceleration of the electric beet can be calculated in beet longitudinal axis (Eq. 5) and also vertically (Eq. 6). Both can be taken together as the straight-line acceleration.

Included in the calculated revolving acceleration a_d produced by rotation, are the components angular acceleration a_w and centrifugal acceleration a_z. With regard to the effective direction of these two components can be found, for example, the equations 7 and 8 in the longitudinal axis of beet.

The angle γ is constant and construction-conditional. Whilst the centrifugal acceleration is a measurement for the revolutions of the body (rotation about centre of gravity) the angular acceleration represents its change. From the acceleration components in the directions x, y and z can then be calculated the angular and centrifugal acceleration according to the root's longitudinal axis, its vertical, or for the sugar beet as a whole.

Results

So that trial results could be proved, the „electric sugar beet" was fixed into a lathe beforehand and measurements repeated at various revolution speeds. In *figure 3* the results of three on/off switch actions, each of about 5 s duration, are given.

A straight-line acceleration of the centre of gravity did not occur. With the three-sensor electronic beets used up until now, and described in the literature, no accelerations were able to be proved. On the other hand, the various revolution speed settings, as well as the positive-drive and free-running revolution speeds, could be made clearly visible because of the centrifugal acceleration (diagram right). The centrifugal power increases with increasing revolutions. The acceleration behaviour of the lathe is evident from the angular acceleration and is not equal.

Following this, the modified „electric sugar beet“ was also operated under practical conditions. This took place on different, as far as possible single, harvester cleaning elements directly in the field. It was apparent that with increasing damage the various stress values increased in various ways on the different cleaning elements. The evaluation started with the analysis of the dependence of the straight-line accelerations on the revolutions of the cleaning element because, in this case, comparative results were available from earlier measurements [7, 8].

To this was linked the regression analysis – based on the damage on assessed beet. For surface damage, the greatest dependence was from the stress values from straight-line acceleration total with classification according to time spent in the element (cumulative effect). For root breakages, on the other hand, the best adjustment in total (occurrence-oriented effect) was achieved (as in past years) with the maximum value storage classification of the straight-line acceleration.

Significant associations were also given by the new stress values from the angular and centrifugal acceleration. Because of the small extent of the spot controls it is not, however, possible to give satisfactory guaranteed statements on this subject just now. This is because the difficult weather conditions in autumn 1998 made it impossible to achieve a sufficient number of repeat tests.

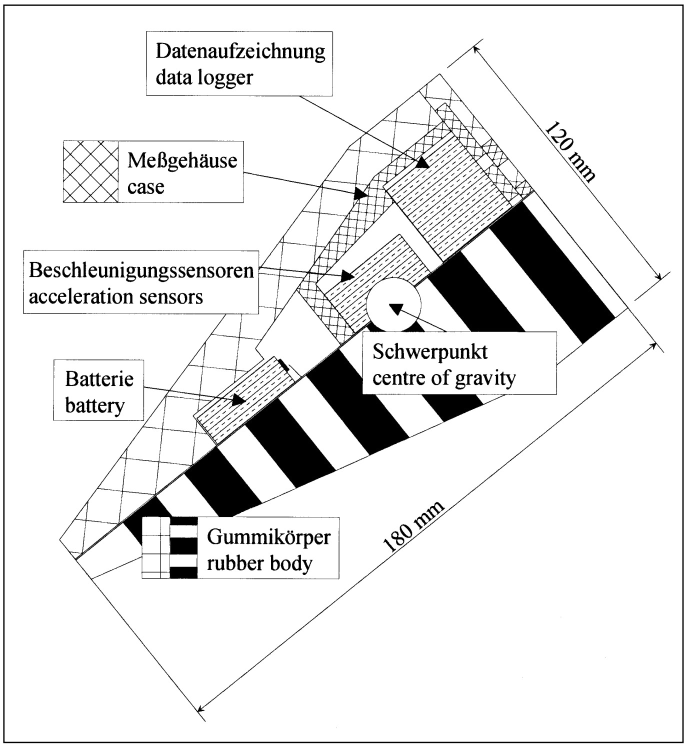

Fig. 1: Factors influencing sugar beets

Conclusions

With the reconditioned „electronic sugar beet” the basis was created for comprehensive analysing of the movements of sugar beet within the harvester. The sensors could be used to give reliable results, even under difficult conditions. From the data thus collected the sites where most damage occurs can be identified and dealt with.

A further advancement is the prognosis of damage on the basis of the stress values recorded in the investigations. This ability depends, however, on further investigations in laboratory and in the field. For the reduction in the effort required in research came the idea of siting the sensors directly within the natural sugar beet. Successful testing of this concept took place in autumn 1999.

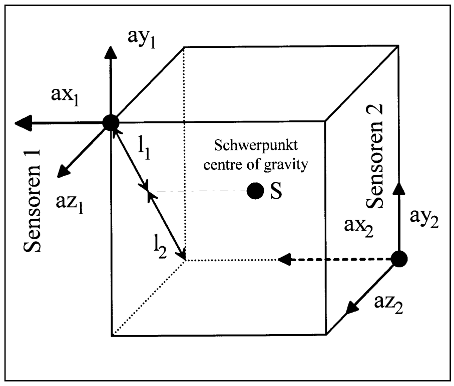

Fig. 2: Placement of acceleration sensors

Literatur

[1] *Schäufele, W. R.* und *U. Bosch*: Untersuchungen zur Rübenerde. Zuckerindustrie 119 (1994), H. 8

[2] *Tschernjawskaja, L. I.* und *M. S. Chelemski*: Zuckerverluste bei der Lagerung und Verarbeitung von Zuckerrüben. Zuckerindustrie 122 (1997), H. 6 und H. 12

[3] *Karpol, F.*: Zuckerverluste beschädigter Rüben durch Auswaschen. Zeitschrift für Zuckerinustrie 25 (1975), H. 8

[4] *Kovtun, J. I., V. F. Natarov* und *I. T. Derka*: Künstliche Messrübe als Mittel zur Untersuchung von Rübenerntemaschinen (russ.), Traktory i Selchozmashiny (1977), H. 8, S. 22 – 23

[5] *Fechner, W., J.-P. Schuh* und *N. Uebe*: Untersuchungen zur mechanischen Belastung von Zuckerrüben mit Hilfe elektronischen Messrüben. Kühn-Archiv 91 (1997), H. 2, S. 229 – 240

[6] *Schuh, J.-P., W. Fechner* und *N. Uebe*: Untersuchungen zur Anwendung elektronischer Rüben in der Zuckerrübenernte. Agrartechnische Forschung 3, 1997, H. 1, S. 59 – 65

[7] *Fechner, W.*: Untersuchungen zur Belastung von Zuckerrüben in der Erntemaschine mittels elektronischer Messrüben. Forschungsbericht 1997, Institut für Agrartechnik, Halle

[8] *Fechner, W.* und *Al-Ibrahim Zieb*: Untersuchungen zur Belastung von Zuckerrüben in der Erntemaschine mittels elektronischer Messrüben. Forschungsbericht 1998, Institut für Agrartechnik und Landeskultur, Halle

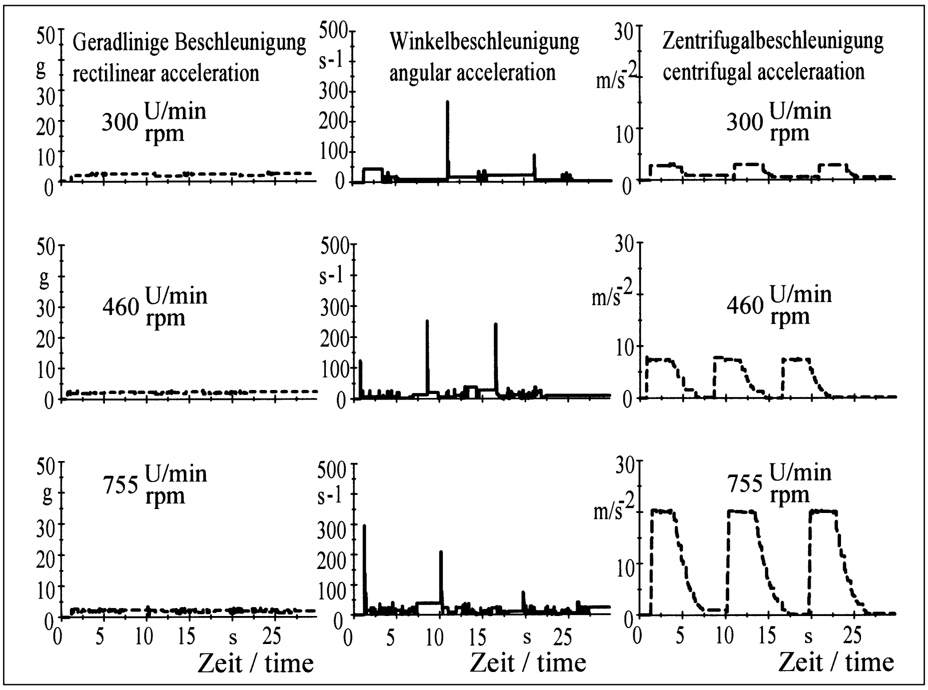

Fig. 3: Acceleration of electronic sugar beet in a lathe at 3 on/off switches