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Action of mechanical cleaning implements for sugar beet

Sugar beet and soil end in the same pile as loose and adhesive components. In loosening and separation operations, soil has to be removed from the beet/earth mixture. The relevant cleaning operations are here defined in a dynamic action model. Cleaning effects occur via impulses from the cleaning machine directed into the harvested material. Adhesion and cohesion links are broken and sticking particles of earth changed to loose ones. In much the same way the impulse contribution separates loose particles from the mixture present in heaps of beet. A shock recorder was used to measure the impacts delivered by cleaning equipment.

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Because of the many products available from sugar beet, it is one of the most profitable of crops. Sugar with a purity of 99.5% is one of the valuable components. To enable efficient mechanical and chemical extraction from the raw beet, it must fulfil defined quality requirements. Representing the largest negative influence in further processing is the 'tare' of soil, stones, beet tops and leaves. In the last decade average soil proportion lay by 12%, tendency decreasing [8].

Poor harvesting conditions lead to large amounts of soil, both attached to the beet and loose, being lifted by the harvester. Despite various cleaning operations in the harvester and with the beet in headland heaps, complete soil separation is not achieved. The reduction of this unwanted soil represents an important management factor in the construction and installation of individual cleaning elements. New-developed sensor technologies help ensure that the operation of cleaning equipment can be permanently kept in optimum efficiency [1, 4, 5, 7].

To fully exploit capacities of known cleaning equipment and to develop new optimised cleaning tools, understanding of cause and effect is crucial. To best explain actions of mechanical cleaning equipment, a dynamic working model was applied.

Dynamic working model

The dynamic effect of mechanical loosening and separation equipment on individual beet/soil mix components depends on the dynamic movement conditions as well as the machine design. The harvested material experiences impacts from the cleaning equipment. This causes continuous mixing and conveyance of the material but also delivers shock forces required for loosening and separation of soil.

Adhesion constructions are broken and sticking particles separated. The geometrical differences of the tare materials than allow its diversion from the root flow. There are, therefore, two conditions which must be fulfilled before sticking particles of soil can be loosed from roots and then separated. Firstly, a minimum impulse force is required before adhesion constructions are broken. Secondly, the shocks must be delivered to the points on the beet where most soil particles are strongly attached. These points are at the root attachment surfaces and where soil may be pressed against the beet by the harvester's lifting share. Thus, not only shock intensity and frequency has to be determined by the working model for assessing cleaning equipment efficiency, but also the distribution of the shock on the surface areas of the beet.

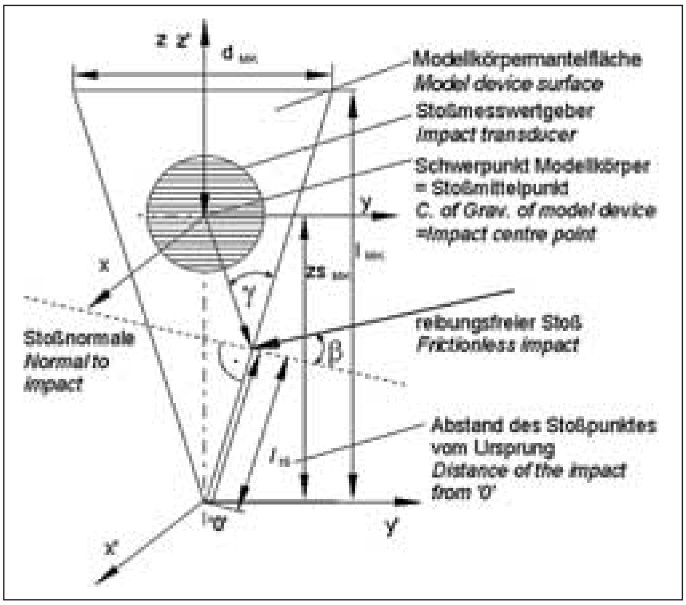

Fig 1: Impact transducer device and definition of geometrical parameters

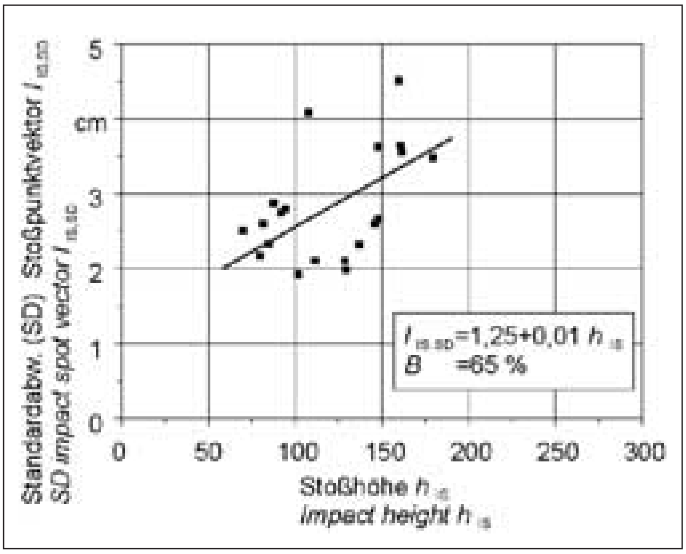

Fig 2: Correlation SD length of impact spot vector l_{IS} and impact height h_{IS}

Figure 1 shows positioning of the shock recorder within an 'artificial beet' which was added to the flow of harvested beet in cleaning equipment [6].

During its journey through the cleaning area, the shocks experienced by the recording "artificial" body from machine components and harvested particles were recorded. The recorder recognises the friction-free portion of every shock as a shock peak his in the normal shock direction:

$$h_{IS} = \cos \beta \bullet \sin \gamma \bullet \int F dt \quad (1)$$

For the investigation, the translational movement behaviour of the sugar beet stands in the foreground. This allows the six freedom degrees to be reduced to three translational movement equations in the description. Friction caused by eccentric shocks was ignored. Central shocks were recorded on the three axis x, y and z as causes of translational movement by a sensor in the centre of the model beet. The position of the impact influence point on the model beet surface was then calculated. The surface of the model beet in figure 1 was defined by the following equation:

(Gleichung einsetzen) (2)

The maximum shock peak his was produced through vector addition of the proportion in the three directions. The touching point vector b_{IS} of a shock was calculated by multiplication of the shock height h_{IS} recording with a scalar λ:

(Gleichung einsetzen) (3)

The co-ordinates which were multiplied with the scalar from equation (3) were inserted into equation (2) and solved according to λ. A physically logical result for scalar λ can only be achieved when $\lambda>0$. The length of the touching point vector b_{IS} is otherwise negative. In the case of imprecise shock inputs into the harvest mass, only the shocks which have an effect on the model beet body were defined as relevant to the cleaning process. Blows to the surface of the beet where it has been topped are not relevant in this context because no soil sticks there. For further evaluations the contact points of the reference system x, y, z of the point of gravity co-ordinates were moved onto the model beet original co-ordinate system "0". The vector product of the shock point vector 1_{IS} describes the distance of the impact point to the original point of the conical model beet and, with that, is a measurement of the distribution of impacts on the model beet surface.

Experiment and results

Taking the sieve star as a typical beet harvester cleaning instrument, the recorder was applied and the results evaluated [2, 5]. The shock peaks h_{IS} increased with the circumferential speed of the star with a high degree of certainty. The relationship of the number of lower to higher shocks reduced with rising circumferential speed. Less shock peaks were the result of collisions between the model beet and real ones. Because of the low rigidity of beet, the shock peaks were less compared with the results of collisions with cleaning equipment components. The increased collisions of the model beet with cleaner components were mainly recorded in trials with higher circumferential speeds. The input of high shock peaks increased with rising speed so that one could speak of sieve star aggressive behaviour.

The distribution of the recorded shocks on the model beet surface measured as standard deviation of the length of the shock point vector $l_{IS,SD}$, correlated with the shock peak h_{IS} with a degree of certainty B of 65%. High recorded shock peaks resulted from the beet flow becoming increasingly turbulent and unclassified shocks from cleaning equipment components and beet affecting the recorder (*fig. 2*). This is a necessary prerequisite for the cleaning of earth particles from as large an area of the beet surfaces as possible. Thus, earth particles are knocked free from the parts of beet where soil clings. Through the movement of the equipment and beet, loose soil particles are separated through the openings of the cleaning areas.

Summary

The interaction of machine components and harvest material results in a complex behaviour of the material on the implement. The cleaning effect occurs through transmission of shock impulses from components onto the beet. The recorder, as well as the evaluation algorithms described, enable a quantifying of effect height and direction within mechanical cleaning implements. Through comparing the results with the quality parameters of sugar beet such as proportion of surface damage and soil proportion, a relationship between shock spectrum and beet properties [3] can be formed. The application of this working model for other root crops and utilisation of the results for comprehensive simulation of cleaning processes would be a probable development.

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