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Sugar beet harvester design

Nowadays over 60% of sugar beet is harvested with six-row lifters. The implements are highly-integrated harvesters with lifting and cleaning systems designed to cope with differing harvesting conditions. Additionally, the requirement for long operational periods and higher harvesting performance mean that demands on machine configuration have increased.

Over 50% of sugar beet harvesters (header/lifter/bunker, HLB) have a six-row defoliating and lifting system [11]. Six-row header/lifter/loaders (HLL) are also used, and within this configurations there are also a few eight or nine-row lifting machines, offering higher area performance potential and reducing wheelings during harvesting [8, 10].

Defoliating and root lifting machinery

With the HLB machines the harvesting machinery is placed in front of the front axle and so is in the operator's optimum field of vision. The beets are defoliated, topped and moved out of the soil. Advantages include better lifting quality and reduced tare pressed onto the beets [2].

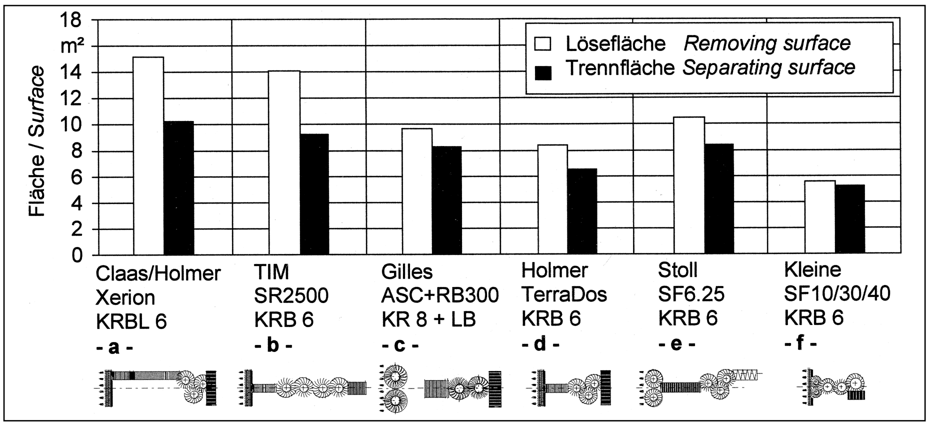

Fig. 1:Removing and separting surfaces in multi -stage cleaning systems in sugar beet harvesters

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The leaves separated by the flail chopper are distributed over adjacent already harvested ground via an auger and spinner-disc or discharge drum. In inline systems the intensively chopped foliage is deposited between the beet rows thus achieving a very even distribution of foliage over the field. Remaining foliage and the beet top are removed by skid-mounted topping knives. Some machines use powered longitudinal or lateral cleaners to clean the topped area. Precise adjustment and application of the topping machinery is critical in that 1 cm of top loss represents around 10% of the harvest mass.

Suspended polder shares have become established as lifting equipment in Germany whereby there's a difference between the direct and alternate phase drive of the shares. Disc shares are often used in France and wheel-lifter shares (Oppelwheels) with north European or American harvesters. Polder shares push around 15% less soil into the harvested beet flow compared with disc shares thus giving better precleaning conditions [4].

Cleaning machinery and bunker

After the beets have been lifted from the field they are then freed from soil, stones, leaves and other plant parts in a multi-stage cleaning process. The main operation catered for by the design of the cleaning system is reduction of the tare or soil proportion in the harvested roots. In this a difference is made between loose particles of soil and those attached to the roots. Two different effects are defined for the cleaning process. In a first phase, soil sticking to the roots is loosened so that it can then be separated from the flow of harvested beets in the following phase.

Cleaning machinery design was investigated according to this requirement and the relevant areas presented in *figure 1*. Loosening surfaces within a cleaning system are where harvested material is subjected to mechanical impact shocks. Separation surfaces are all the open elements of a system where geometric differences caused by forces of gravity and acceleration lead to the separation effect [3].

All harvesters presented in figute 1 feature the three separation tools webbing belt, eccentric and starwheel sieves. Because of its very long webbing, the mounted HLBL Holmer harvester built onto the Claas Xerion has a loosening surface of 15.2 m^2 and a separation surface of 10.2 m^2. Also featuring large loosening and separation areas is the TIM SR2500 lifter with 14.1 m^2 and 9.3 m^2 respectively. With separated harvesting systems consisting of tractor mounted HL and self-propelled LB, and with the three remaining HLB systems, the cleaning surfaces are more compact with smaller loosening and separation surfaces of from 5.2 to 10.4 m^2 and 4.7 to 8.2 m^2 respectively.

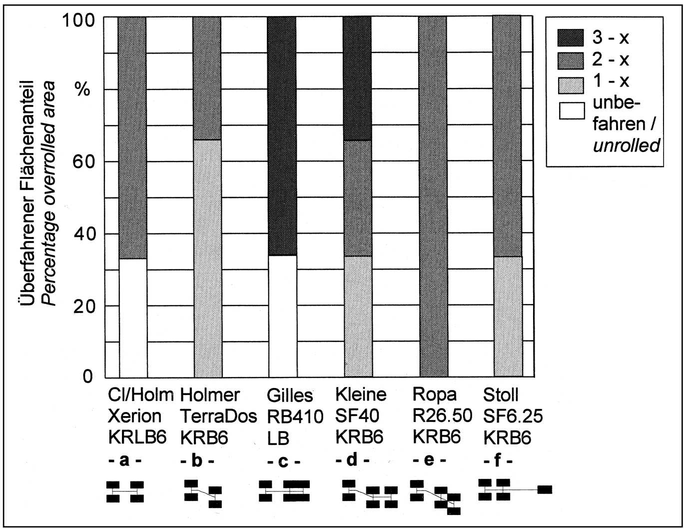

Fig. 2: Percentage of passed area with different chassis concepts for sugar beet harvesters

As a rule, all cleaning systems are hydraulically driven with speed adjusted according to operator instructions – increasingly by the operator in the cab supported by camera visual control. Main parameters here are throughput, cleaning intensity, damage and losses. In addition to speed adjustment, separation surface can be changed with the starwheel sieves through altering the distance between the sieve grid and starwheel sieve floor.

Eccentric rollers have a high soil loosening, but limited separation, capacity. Through their conical shape, beets are retained well on the loosening surface with resultant good loosening of soil sticking to the roots. Radial transporting eccentric roller beds first start to reduce soil to under 50% of initial tare after 2 m length [1, 7]. This system is used in the post-cleaning phase. Complementary eccentric roller beds that transport the beet radially/axially are used for bringing the beets together, e.g., after the lifting shares, see *figure 1 a, b, d, f.*

Starwheel sieves are used in beet transport after the lifting shares (figure 1 c, e) and also during subsequent cleaning. Because of the wide variation of construction forms, large separation surfaces as well as large loosening surfaces are available in these cases. The root flow on the starwheel sieves should be such that movement brings contact for over 150° of the beets because this is where the maximum rubbing off of soil occurs [3].

Webbing belts have a limited cleaning effect because the real beet velocity is the same as that of the belt. This alters when obstruction fittings hold back the root flow to increase relative velocity and thus achieve the cleaning-relevant exchange of impulses.

Bunker elevators transfer the lifted beet into the hopper. These serve only the transporting of the beets with very little cleaning effect. Because the unloading of roots from elevator into bunker is not evenly distributed, a distribution auger ensures even-filling of the bunker. This is necessary for improved exploitation of available volume and also for weight distribution (fig. 1 c, d, e, f). The bunker is emptied through a moving floor onto a left or rear positioned unloading belt. Unloading time is under two minutes.

Chassis and driveline

Beet harvester chassis must satisfy the following demands:

- Vehicle manoeuvrability, even under difficult conditions
- Secure support of heavy implements
- Capacity for harvesting and cleaning machinery, the bunker and also the drive equipment
- Construction according to legal rules (size, weight)
- Costs

To help in these requirements all wheels are direct-driven and steerable in self-propelled harvesters. This improves vehicle traction. Through its steerability of the wheels, high manoeuvrability is achieved with turning circles under 11 m for machines of up to 14.8 m in length.

The net weight of the six-row self-propelled harvester averages nowadays 25 t with two-axle and 30 t with three-axle models. With HLB machines gross weight with full bunker is 41 t (two-axle) and up to 60 t with three-axle. With the former, bunker capacity is up to 18 t and up to 28 t with the latter. Balanced support of such high masses on the chassis is achieved with three-axle models through regulation of bunker load level and axle-load. Individual wheel loads of up to 12 t have been recorded, the average is 9.8 t. Differences of more than 37% between the individual wheel loads on a single axle have been recorded caused by inefficient positioning of the bunker.

The high wheel loads have to be supported by suitable tyres such as low cross section tyres with 800 to 1050 mm widths because these operated at permitted pressures between 1.8 and 2.4 bar. For soil-structure protection, chassis configuration is aimed at wheelings covering the entire working width. The proportion of surface not driven over is reduced to zero through an articulated chassis and steerable rear wheels (*fig. 2 b*). With a three-axle design (*fig. 2 d*) with double articulated chassis with rigid axles, the proportion of thrice-wheeled field surface is reduced from 66% (*fig. 2 c*) to 33%. Total working width is wheeled over only twice with articulated chassis and twin steerable rear axles (*fig. 2 e*).

In total, increasing the proportion of wheeled field surface makes sense from the structural protection aspect but the effect caused by of high individual wheel loads during wet soil conditions has yet to be finally clarified [6, 9]

The drive for chassis and harvesting machinery is nowadays exclusively hydraulic. The hydraulic pumps and the electro-hydraulic control equipment drive all components powered by a combustion engine fitted at the rear or in the middle of the harvester. For two-axle machines the engine power requirement is around 300 kW on average, and 360 kW with three-axle machines. Some harvesters have CAN-bus control [5] with which critical chassis operations and harvest material flow can be logically linked and regulated via sensors and driver-adjustment.

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