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State of the Art of Combine Harvesters for Grain Harvesting

The tendency toward larger combines has consistently increased in the last three years. More engine power, further improvements in threshing and separation technology, as well as combines without shakers, have moved the maximum grain throughput to more than 50 t/h with cutter bar widths of 9 m, even under European conditions. Automatic control and adjustment devices, like guiding the combine along the edge of the crop, adjusting the driving speed to harvesting conditions, adjusting threshing and separation elements to grain variety and moisture content, as well as optimally designed driver cabins make work easier.

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Keywords
Combine harvesters, grain harvest, separation

Starting at an already high state of development, it has been possible in the last 3 years for manufactures to boost the performance and operational ease of combine harvesters. Nearly 90 % of the German market is , according to Kutschenreiter [1], served by three manufacturers: Claas (~47 %), CNH (~22 %), and John Deere (~11 %). The remaining 11 % is divided among five other brands: Deutz-Fahr, MF, Fendt, Laverda and Sampo.

A total of about 90 different models can be purchased in Germany. One can choose from those having 4 straw walkers starting at 59 kW, to high-performance, 353 kW non conventional combines. While the engine power of the smallest machines has risen 3-fold in the last 50 years, the engine power of each of the largest combines has jumped 7-fold (*fig. 1*). A weakening of this trend is not visible, and all the more since more engine power already exists in self-propelled forage harvesters. The larger of the combine manufacturers offer up to 4 different model series, which differ mainly in their threshing and grain-straw separation units; however, the same combine element groups, such as cabins and cleaning units, are sometimes used within the models of a particular series.

Conventional combine harvesters

Combines with 5 - 8 straw walkers cover the medium- to maximum-performance category. Few combines on the market in the lower-performance classes have only 4 straw walkers. The performance of conventional combines has also been considerably improved in the last years. Above all, multiple-drum threshing units with up to 4 threshing and beaters drums, preceded by either an acceleration drum or

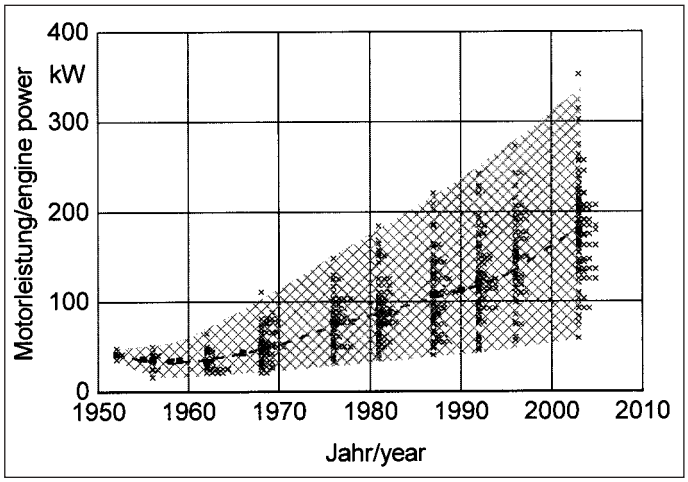

Fig. 1: Increase of combine engine power

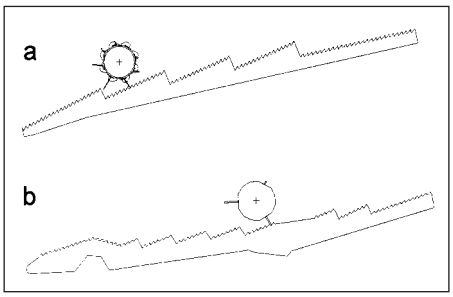

Fig. 2: Rotary elements for grain separation improvement
a) Multifinger-Separator-System (Claas)
b) Power Separator (John Deere)

succeeded by a separation drum, have led to a noteworthy increase in grain separation in the threshing unit and, as a result, to a lower burden placed on the straw walker. Of the conventional combines offered in Germany, almost half are equipped with multiple-drum threshing units. Manufacturers promise performance advances through the increasing of the threshing drum diameter from 600 to 660 mm (John Deere), from 450 to 600 mm (Claas) and from 600 to 750 mm (CNH). To improve the separation of remaining grain by the straw walker, AGCO (MF, Fendt) uses 8 straw walkers with a constant channel width of 1.68 m. At the Agritechnica 2001, newly developed rotary elements, which have guided spikes to improve the function of straw walkers were introduced (*fig. 2*). The Power Separator in the WTS combine from John Deere increases the separation of the remaining grain by the straw walker through additional loosening of the straw mat in the rear zone of the straw walker. The Multifinger-Separator System (MSS) from Claas is fo-

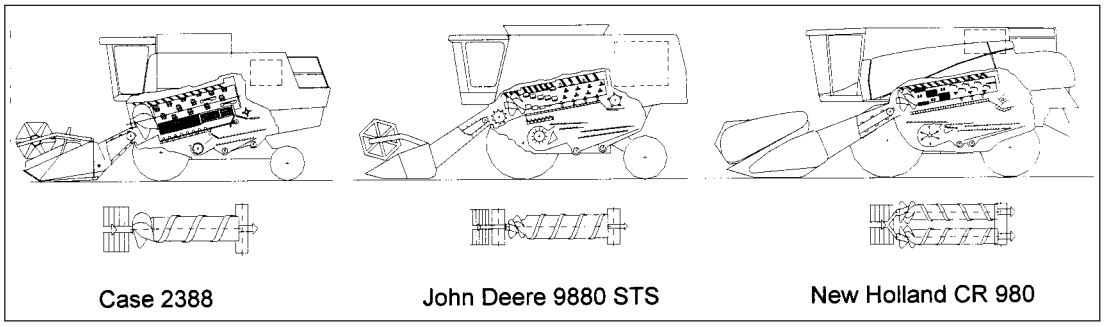

Fig. 3: Cross section and material flow of rotary combines, offered in Germany

und in the forward zone of the straw walker and loosens the straw mat, therefore improving the separation of remaining grain.

Non conventional combine harvesters

In combines that have tangential threshing units but no straw walkers, the straw walker is replaced by rotating separation elements - the separation rotors [2]. Claas has expanded its offer of threshing drums downwards to 1.42 m in the Lexion 470. Both of the separation rotors have a diameter of 445 mm. John Deere`s CTS has a threshing drum width of 1.40 m and two separation rotors with diameters of 462/502 mm. CNH has halted the manufacture of the TF combine, which has a separation rotor arranged perpendicularly to its multiple-drum threshing unit.

Non conventional combines with axial rotors that simultaneously combine threshing with separation are now offered by Case, John Deere and New Holland (*fig. 3*). Case has further developed the axial rotors for the Axialflow model 2366 and 2388, promising a performance increase of up to 25 %. The three-piece intake shovels have been replaced by an intake auger; furthermore, the rotor assembly in the separation zone was changed. Along with the non conventional CTS tangential combine, John Deere offers the STS 9880 rotary combine. The axial rotor of the STS 9880 comes with a diameter of 750/834 mm and a length of 3.13 m. It operates within a housing, expanding in 3-stages. The crop intake is accomplished by an intake drum and an intake auger. CNH has brought, stemming from the TR models, the U.S.-manufactured CR models, CR 960 and CR 980, to the German market. In these axial combines, 2 axial rotors each take over the threshing and separation. The crop intake also occurs using an intake auger. The diameter of the axial rotors is 430 mm for the smaller and 560 mm for the larger combine. Both of these rotors have a length of 2.64 m. In a short operational test of the CR 980 conducted by the dlz, a grainharvest capacity of 59 t/ha was calculated by using the driving speed, cutting bar width and the average yield [3].

Combine harvester guidance, flow-rate control

With the introduction of the Laser-Pilot from Claas in 1999, the first-ever contactless sensor for guiding a combine along the edge of standing grain came onto the market [4]. In the last years, other contact-free guidance systems have been evaluated and some of these have been marketed (*fig. 4*). Examples of these are ultrasound sensors for swath and plough furrow scanning. John Deere uses its own Starfire DGPS network, which sends reference signals over geo-stationary satellites to the Starfire Dual Frequency GPS receivers. This system offers sufficient exactness for edge-to-edge driving [5].

Starting with research in the early 1970`s, automatic flow-rate control has been an important development goal for easing stress placed on combine operators. One of the first related products to come onto the market was the Autopilot from MF, which controls driving speed using the torque of the threshing drum measured over the slippage of the drive belt due to rpm differences. John Deere introduced a comprehensive system for flow-rate control in the STS 9880 [6]. The signals of different sensors (torque at the header and rotor, separation and shoe losses, power requirement) are used to control driving speed. The operator can intervene in this control system using the hand lever and through entering standard values.

Further developments

Aside from the described improvements, other developments in combine harvesting have come about, including those for harvesting on sloped terrain, yield mapping, cutting bars, and stone guards. In the future, the most desirable of all improvements would be those for straw choppers and the horizontal distribution of straw and chaff, especially for large swaths, and further developments on tires or tracks with the goals of reducing soil compaction and adhering to the allowed width for public roads.

Summary

The maximal capacity of combine harvesters has been raised to more than 50 t/ha. Along with the Case Axialflow, two other axial combine systems are being offered in Germany: the CR models 960 and 980 from CNH and the STS 9880 from John Deere. The maximal engine power has increased nearly linearly since 1950. To relieve the operator, an automatic guidance system for steering along the edge of standing grain and a comprehensive flow-rate control system are to be introduced.

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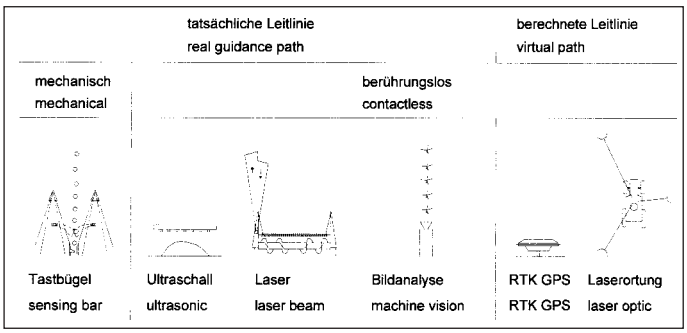

Fig. 4: Automatic guidance systems for farm machines