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Performance and technological development of self-propelled forage harvesters

The self-propelled forage harvester is regarded as a key machine in forage production enterprises and their machinery operators. The capacity development within a comparatively short history of 30 years is remarkable. The technological development is characterised by the continuous development of the silage preparation process.

The development of the self-propelled forage harvester is determined by key requirements within the silage production chain in the context of harvest time, capacity and quality.

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Keywords

Forage harvester, agricultural machines

The self-propelled forage harvester (SFH) can be described as a logical further development within the silage harvester history which began at the end of the 1920s. The beginning and development of material chopping have already been repeatedly described and are summarised in [1, 2, 3], whereby European development is closely associated with the name Segler. Prof. G. Segler, predecessor of Prof. Matthies in Brunswick and later director of the Institute for Agricultural Engineering in Hohenheim, was especially responsible for the encouragement of the development through his initiative. Early on, Prof. Matthies laid the scientific bases for today's definitive forage harvester development through own contributions and through work at his Institute. SFHs first came onto the market at the beginning of the 70s. The usual reasons such as intake overview, opening-up the field, better manoeuvrability were responsible as well as the limits to tractor power all of which led to the move from tractor drawn machinery to self-propelled. Maize silage played an important role in developing forage harvester power requirements and the change to wilted silage had an important role in the expansion of forage harvester use and in the technical layout of the silage preparation process.

Market developments and requirements

Following a building-up phase, the annual sales of western-technology machines reached between 1200 and 1600 in Western Europe since the beginning of the 80s. This reflected the worldwide picture featuring annual turnovers of between 1500 and 2500 units with a lightly increasing tendency in the last 20 years.

Growth in specific capacity means the total installed capacity brought onto the market has substantially risen Market shares are notable here with Claas leading with nearly 50% of world market share and the other half being almost evenly split between John Deere and CNH.

With the support of science the knowledge of economically viable forage quality and harvesting process developed within agriculture allowing the formulation of technical requirements. Important factors include feeding and digestion potential of feed structure as well as grain-bursting with maize. Additionally, the quality of fermentation in the silo is important and, in turn, this depends on the compaction characteristics of the forage which also rests on pre-compaction processes. From these, one can deduce the demands on the chopping and preparation processes as well as on the harvesting system.

Performance development

Harvesting development is integrated with the continuous structural change in farming and the resultant pressure for continual efficiency improvement. For contractors there is the challenge, despite the weather risks, of being able to bring-in the harvest of all cus-

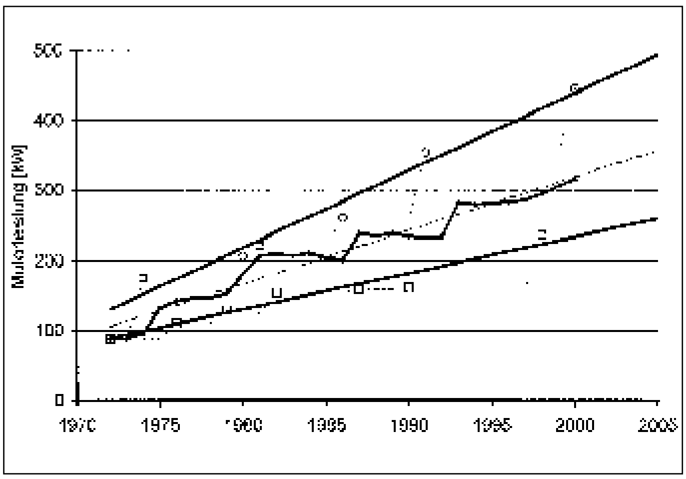

Fig. 1: Power development of CLAAS SP-forager series since start of production [4]

tomers swiftly at the right time, and this too explains the development of forage harvester performance (*fig. 1*). Here, the development in terms of time in engine performance range since the beginning of self-propelled forage harvester serial production by Claas is presented with maximum and minimum engine power of machines as well as average engine power according to weighted turnover figures. The development trend is determined via linear regressions through the points of the first production years.

The curve progress is characterised by several notable points: The maximum engine power rose steadily almost linearly at 11 kW per year. A degression is not yet identifiable whereby the range of available machines has widened. The average power over the period of product life cycles tends in each case to higher values. The development is therefore mainly customer-driven. The market volume lies, however, in the mid-performance segment.

Similar trend analyses from Busse for combines in the 80s [6] have confirmed this to a large extent up until now. Along with forage harvesting performance, that of silage making and its economical viability could also be increased. Regarding application of high-performance machinery, the important limit is the consolidating capacity at the silo. Required time for careful consolidation can often only be assured though parallel filling of several silos.

There are developments for special applications that enable breaks in the continual loading of forage from the harvester through harvester-bunkers, being introduced usually for the direct marketing of chopped material or its drying before storage or further processing. For greater transport distances trucks are then filled directly from the harvester-bunkers or from transport wagons delivering from the bunkers.

Chopper process technology

Along with engine power development, demands on material uptake have greatly changed. Whilst the first SFHs were equipped with two-row cornheads, nowadays these are up to 10 rows wide and foldable for road transport. The important changes in the last 10 years comprise the changeover to row-independent and, at the same time, no-chain maize headers. Alongside the flexibility of row independency, desisting from of intake chains leads to reduced servicing and spare part costs and reduction in corn loss risks, although such advantages can act against higher harvesting capacities.

With a few exceptions the development of the grass silage collector has taken another route. The required higher pickup performance is not met through the breadth of the pickup but from other parts of the production chain comprising use of mowers and swathers with greater working widths. Grass can now be swathed in a single pass with mowers working widths up to 15 m. Although here the installed engine power in the forage harvester is often not fully exploited in that driving speed for full use of the harvester capacity is not technically possible across a field. Regarding processes within the machine, material continuous flow, similar to that in *figure 2*, has become established with almost all important producers, or is being worked upon now. Abrupt directional and speed changes have a negative effect on energy efficiency. For a specific application case, e.g., the division of performance in such a silage harvester is reproduced here. Over 70% of the energy flows into the quality-decisive chopping and preparation process. For this reason the aggregate is subject to continuous optimising whereby different development philosophies have been followed. The aim of a reduced power input in cutting, non-sensitivity against stones and optimum material flow in the aggregate leads to the presented drum construction form. The roller conditioner entered the forage harvester in the 80s replacing friction floors and recutter systems. Here too, the main reason was preparation quality (breaking of maize grains) and capacity requirements. More complex preparation aggregates such as multi-rollers or disc conditioners have so far been unable to establish themselves.

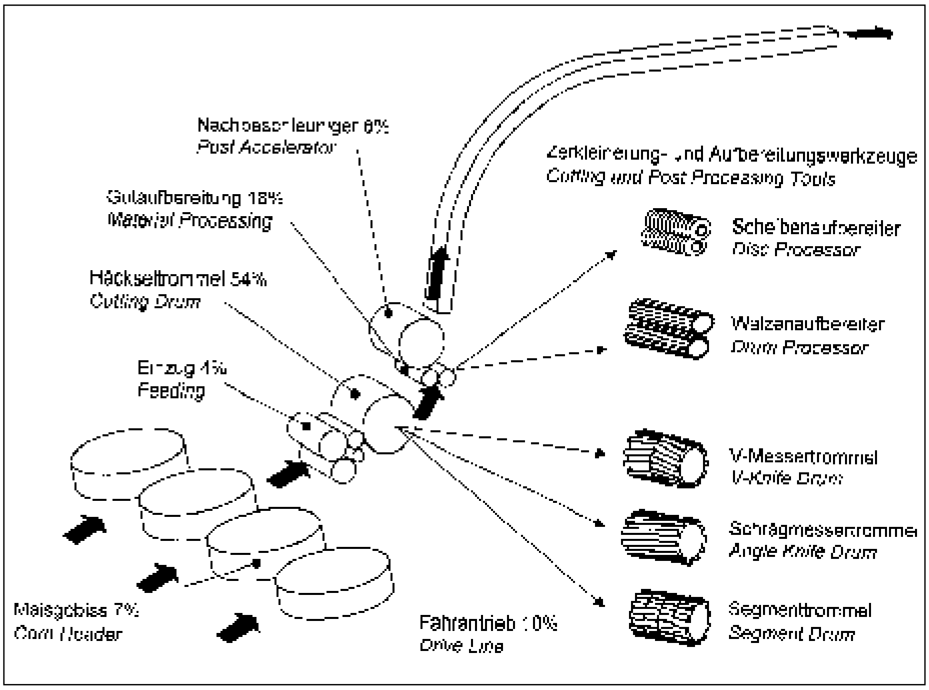

Fig. 2: Chopping process with material flow, design of cutting and post processing tools and power distribution (forage maize)

In order to be able to use most efficiently the installed power in the machines within the silage making chain, and for the forage harvester to utilise the conditioning processes as efficiently as possible, many control and regulation techniques have appeared in association with ergonomic operation. The actual level of this technology is summarised in [7]. In order to meet requirements for spatially-specific management in forage harvesting too, the throughput of the SFH will have to be field-map compatible for yield mapping in the foreseeable future. It is known that many manufacturers and institutes are working on many solutional concepts. It has yet to be demonstrated how great the requirement and use of such systems is for the forage harvester and whether the technology can meet customer requirements.

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