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# Analysis of the overlaying cut in rotary mowers

Disc mowers play an important role in green forage harvesting due to their specific application benefits. Their cutting principle is based upon using the inertia and bending forces of the grass blades. The established technology is reliable but others provide potential for reducing the power requirements.
At the Institute of Mobile Machines and Commercial Vehicles an overlaying cut as an alternative cutting principle in a disc mower has to be proven. Therefore, a modified cutting unit is designed with two cutting discs. The aims of the project are to improve the cutting quality, to reduce the power requirements and to build up a simulation model of the process.

**Keywords**
Disc mower, power reduction, cutting quality

**Abstract**
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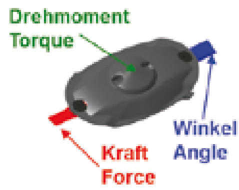
Green forage harvesting is one of the most important processes in agriculture due to the fact that high quality requirements and time limits must be met during several crop phases per year. Machines with performances of approximately 20 ha/h are available for private contractors and large farms providing high productivity and cost effectiveness. These modern, partly self-propelled, mower combinations can have working widths from 10 to 15 m with a power requirement of 350 kW. Machines with such a performance are designed as cylinder or disc mowers. Their cutting principle is based upon using the inertia and bending forces of the grass blades as counterforces for the cut. The blades need to be accelerated up to 80 m/s to cut grass under demanding conditions like with blunt knives.

## Pre tests

This cutting principle is analysed in a previous project of the institute by Niemoeller [1]. A conventional disc mower is equipped with sensors to measure the cutting force of a mower blade, the torque and the speed of a disc (**Figure 1**). In addition the power take off (pto) torque and the rotational speed of the pto drive shaft are gauged. With these measurements the overall driving power, the power of the mower disc and the power of the blade are calculated.

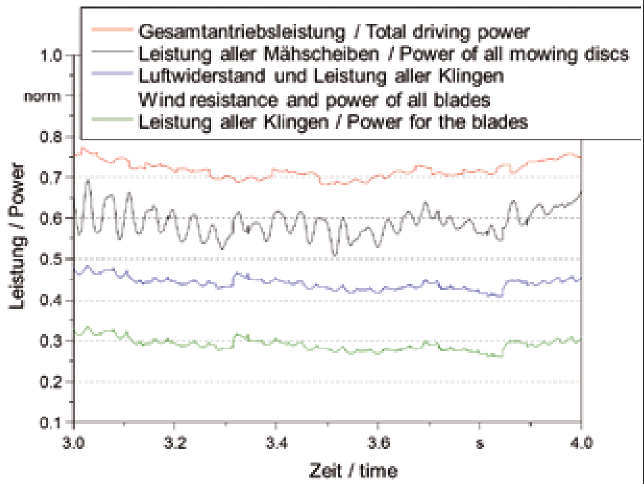
**Figure 2** shows the total driving power, the power of the seven discs with and without wind resistance and the power of the 14 blades for a driving speed of 10 km/h and a rotational disc speed of 3200 rpm. The power of the blades is the primary power required to cut grass. The difference between the black and green line shows power losses due to friction of the crop flow on the discs and to the wind resistance. Additionally included is the power needed to transport the grass over the mower bar. These power percentages can reach 20 to 45 % of the driving power. The area between the red and the black line describes losses in the drive train. They can amount to approxi-

Fig. 1




*Measuring points on the cutting disc [1]*

Fig. 2



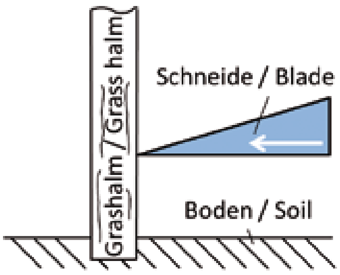

*Power analysis of a disc mower [1]*

mately 20 % of the driving power so that only approximately 35 % of the total drive power are effectively used for the cutting process. In this point of operation 40 to 65 % of the total driving power are losses. An optimization of the drive train increases the efficiency but an improvement of the cutting process must be considered to reduce the power requirements. [1]

Suller et al. (1983) patented a cutting method with one rotating disc and a static counter blade and a variant with two rotating discs for a lawn mower. The results show that the energy consumption of the concept could be reduced with two rotating discs. This principle has not yet been tested in agricultural applications.

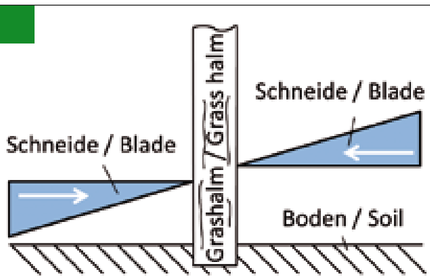
At the institute Wiedermann (2011) analysed the precision cut of a chopper in a combine. The results show that the required cutting power decreases with reduced rotational speed of the chopper while improving or keeping the chopping quality constant. The analyses of Suller [2] and Wiedermann [3] are the base for the following project.

Fig. 3



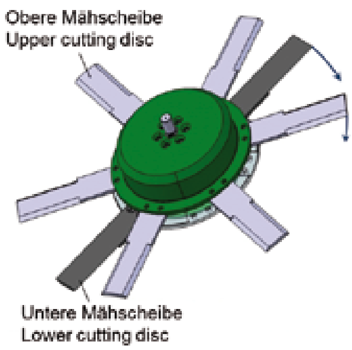

*Scheme of the conventional cut*

Fig. 4




*Scheme of the overlaying cut*

Fig. 5




*Cutting unit consisting of two cutting discs*

## Project description

In this project, sponsored by the German Research Foundation (DFG) for two years, an overlaying cut will be researched as an alternative cutting principle. The primary aims of the project are reducing the required machine power, improving the cutting quality and building up a simulation model of the process. The crop flow should not be negatively affected.

**Figures 3** and **4** show the two cutting principles. For a conventional cut only one blade is needed to cut the grass halm, whereas an additional cutting blade is necessary for the overlaying cut. This principle is similar to a double knife mower.

For an optimal cut the grass halms need to be held by the upper blade and the soil. In the case of accordantly rotating discs the lower one rotates faster than the upper one. With counter rotating discs the absolute rotational speeds of the discs could be decreased without changing the relative speeds. A decrease of the rotational speed of the discs will be expected as a reduction of the required cutting power (see [2]).

## First tests

Therefore a special cutting unit is developed consisting of two cutting discs (**Figure 5**). The upper disc is equipped with six blades and the lower one is equipped with two blades. The lower of the two accordant rotating discs has a speed of 1800 rpm. Both discs are coupled by a fixed gear ratio with i = 3 so that the upper disc rotates with 600 rpm. Because of the different revolution speeds a relative cutting speed of 30 m/s is generated to allow an overlaying cut. The shear cut occurs more often with increased blade number and higher rotational speeds (relative cutting speeds). Grass halms which are not cut by an upper and lower blade at the same time are still cut by the conventional cutting principle.

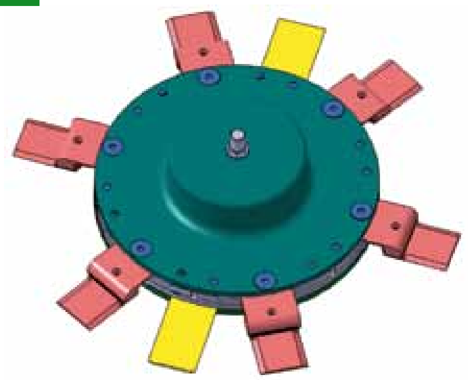
For the first test a conventional disc mower with a working width of 3 m is used. The cutting unit is placed in the middle of the mower bar (**Figure 6**). All standard discs are removed to eliminate their influence.

Fig. 6

*Cutting unit mounted on the mower bar*

The results of the first test show that firm grass halms can be optimally cut due to their stiffness. Thin grass halms with very low stiffness are just turned over without being cut. High speed videos show that this effect can be explained by the air turbulences caused by the two cutting discs, which push the grass halms out of the cutting zone. The crop flow is hardly affected because of the two accordant rotating discs.

Fig. 7

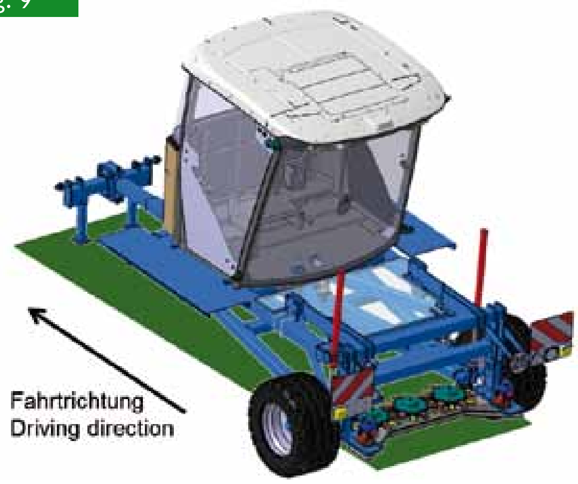


*Modified cutting unit with two decoupled cutting discs*

Fig. 8

*Mower with three cutting units*

Fig. 9




*Experimental machine with modified mower*

## Description of the experimental machine

Requirements regarding an enhanced test machine can be derived from the results of the first tests. Hence a cutting unit with counter rotating cutting discs is developed. The rotational speeds and the direction of speed of the two discs as well as the blade distance are variable.

**Figure 7** shows the modified cutting unit with the same amount of blades like the cutting unit of the first tests. The motions of the blade levels are decoupled. There is no fixed gear ratio between the discs so that absolute and relative cutting speeds are adjustable.

On the modified mower bar (**Figure 8**) three cutting units are mounted side by side. The upper and the lower discs are driven by two hydraulic motors. With speed sensors in the hydraulic motors and pressure sensors in the flow and return line the hydraulic power can be calculated. These values are used for a relative comparison of the different test configurations. To evaluate the crop flow a normal video and a high-speed camera document the process.

The mower is mounted on a universal test machine (**Figure 9**) which is being moved and supplied with hydraulic power by a tractor.

## Test phase

Tests with three blades on the upper and three on the lower discs show that a power reduction is possible but further steps must be considered to keep the cutting quality constant. In various tests the speeds of the discs, the blade distance, the amount of blades on upper and lower discs and the driving speed of the tractor will be varied. The aim of the variation is to find an optimal configuration (amount of blades, rotational speed of the disc) with the lowest power requirement and the best cutting quality.

## Conclusions

First tests with a modified cutting unit show potential for power reduction. For further investigations one of the mower units will be equipped with sensors to measure the cutting forces of an upper and a lower blade as well as the pendulum motion of an upper blade. With these data the power of blade can be calculated. To compare these results with the analysis from Niemoeller [1] a reference test with only two blades on each lower disc will be carried out, since geometric dimensions (disc diameter, blade length) have changed.

Besides these tests a discrete element method simulation model of the cutting process will be built up which should allow detailed analyses of the cutting process. The cutting unit equipped with sensors will be used to validate the simulation model.

## Literature

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