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Optimization of a mowing conditioner using electric drives

The optimal power adaptation of agricultural processes and the associated increase of efficiency require high demands on drives for the agricultural machinery. In a sense the adaption of the speed of a mowing conditioner gives new chances for process optimization. Due to their advantageous properties electrical drives provide good speed variability. The following article describes the development of an integrated tubular drive.

Keywords
Mowing conditioner, electric drives

Abstract
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In order to increase the efficiency in the process of the fodder-harvest process an optimal power adaption to the process-requirements is necessary. This in turn demands the use of new and innovative drive-concepts [1]. Through the application of electric drives some requirements on implements can be met which have been hard to achieve in the past.

The mower-conditioner of disc- and drum-mowers specifically damages the plant's fibers and results in a significant reduction of drying time, but demands high power. The effect depends on the rotational speed of the conditioner drum. At low revolution speed the influence is close to be neglected, high revs do increase the power-demand and particle-losses.

Electric drives have the advantage to be precisely speed-operated. From zero to nominal speed the maximum torque is provided. The conditioner therefore can be operated with any speed when using electric drives. The drying process can be optimized and losses be reduced with respect to the kind of crop, the yield density or any other parameters using an electric drive.

Development of the electric drive

Within the research project „FFT – Future Farm Technology“ a drive was developed by Vienna University of Technology in cooperation with Josephinum Research, BLT Wieselburg and the companies Alois Pöttinger Maschinenfabrik, High Tech Drives and Egston. The advantages of electric motors regarding design opportunities have been utilized: The motor is designed as an outer-runner motor and integrated directly into the conditioner's tube. For the operation a specific power-electronics was developed and installed.

Figure 1 shows the electric motor with flange for fixation onto the tube. On top the stator's coils are visible. **In Figure 2** the cross-section of sheet-metal of the rotor and the stator are illustrated. Technical data of the electromotor are collected in **Table 1**.

During the development of the motor the design-requirements of appropriate power-data and the diameter of the motor, which was defined by the conventional conditioner-tube, have been considered.

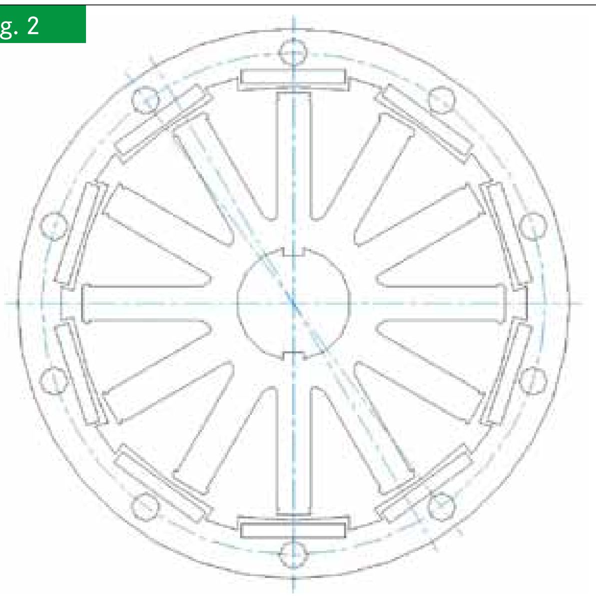
A permanent-magnet-synchronous motor was chosen. It is of low-maintenance due to permanent magnets inside the tube and has high efficiency compared with other motors.

The motor is fitted into the tube and screwed with it on the front face. The stator in the center of the motor is fixed with

Fig. 1

Electric drive with flange (Photo: TU Wien)

Fig. 2



Profile of stator and rotor

Table 1

Motor specifications

Motorart *Type of Engine*	Permanentmagneterregte Synchronmaschine (PSM) *Permanent magnet synchronous machine (PMSM)*
Bauart *Construction type*	Außenläufer mit Oberflächenmagneten *Outer rotor with surface magnets*
Polpaare *Pole pairs*	5
Nuten *Slots*	12
Wicklung *Winding*	konzentriert, einschichtig *concentrated single layer*
Nenndrehzahl *Nominal speed*	1000 rpm

the frame. The rotor is rigidly connected with the tube and supported on the stator. So the principle of an outer-runner without gearbox can be realized, while the tube rotates directly with the rotor. **Figure 3** shows the schematic design of the conditioner tube.

For measurements on the test-bench the length of the conditioner-rotor was divided in half and supported correspondingly (Right side in the figure). The static parts of the conditioner-rotor were fixed by two supports onto the machine bed. On the opposite side of the motor (blue) the moment of a load-machine can be applied via two belts. On the right side an encoder (orange) is shown which is in use on the test bench. In normal operation the PMSM is controlled sensorless [2].

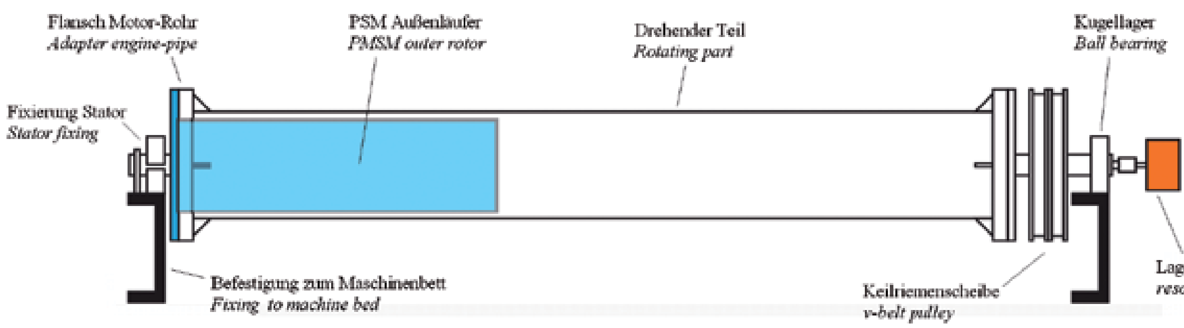
Measurement results

The system dynamics were in focus at the test bench measurements. The conditioner-rotor was driven with different rotational speeds and the coupled load-machine provided a load-moment according a pre-defined load-profile. The load-profiles reflect the average moments of a conditioner during field operation. Figure 4 shows the measured actual moment of the rotor in comparison to the target-value from the load-profile. The enlarged detail illustrates that the dynamic requirements of the motor are fulfilled.

Electric drives are not just easy to control, but they feature high efficiency. **Figure 5** shows an efficiency map of the conditioner-rotor at 80 °C stator temperature. Remarkably, in a wide range efficiency from 90 to 95 % could be reached, what is typical for an electric motor in that size.

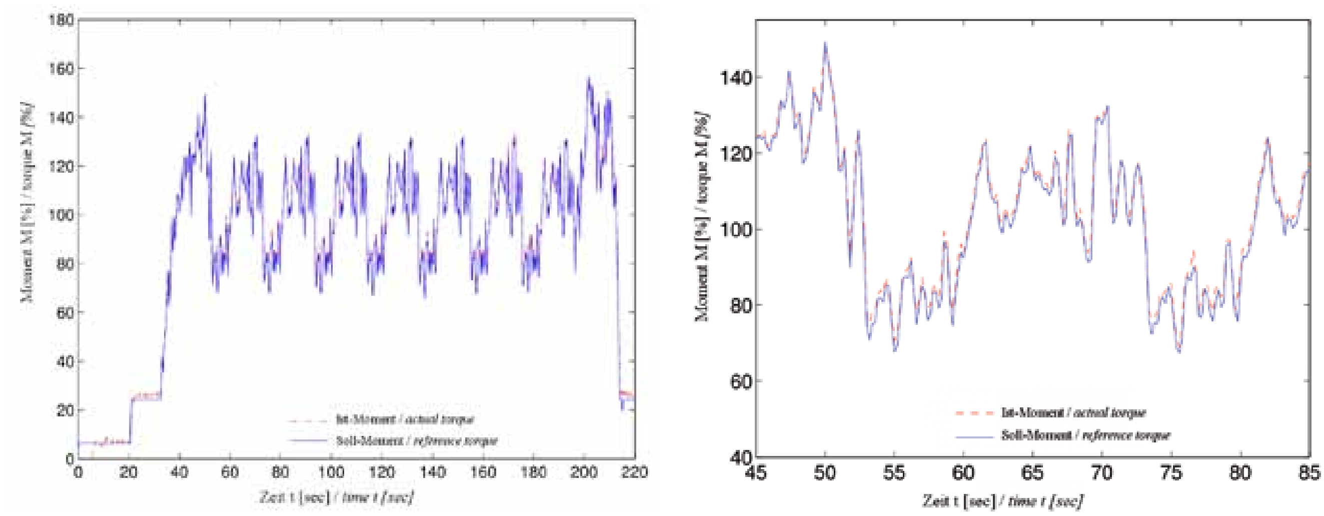
It has to be mentioned, that in some operating conditions power-losses up to 10 % can be emerged, which equals a thermal load of more than 1 kW of machines in that size. During continuous test-bench operations of several hours a water-cooling system was used. A thermal optimization is necessary if the heat shall be discharged by convection only. With a appropriate thermal contact between rotor and conditioner-tube, which has a gap due to tolerances, a quite big surface of the conditioner can be used for thermal reasons.

Fig. 3



Sketch of the mowing conditioner on the test bench

Fig. 4

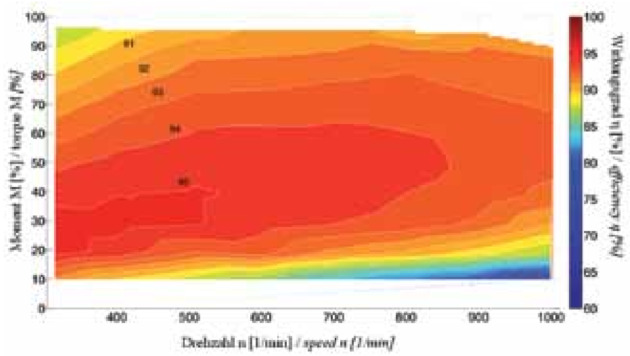


Defined load profile, left side: overview, right side: detail

The power inverter

The concept of the electronics comprises a robust and reliable solution, which meets the high demands of mobile agricultural machinery. The power electronics is designed for power of 30 kVA and comprises a converter for voltage up to 700 VDC with an IGBT-module (Insulated Gate Bipolar Transistor) for 150 A peak. The electronics is equipped with a separate cooling-system. The power inverter is designed for sensorless operation [2] of a permanentmagnet synchronous motor. The prototypes were driven on the test-bench and in field operation. **Figure 6** shows a power inverter. At the bottom side the cooling-device is shown with its interfaces on the right. On top of the cooling-device the power-inverter with DC-link capacitors and voltage- and amperemeters is situated. The control unit is based upon the power-inverter with digital signal processors (DSP). Technical data are shown in **table 2**.

Fig. 5



Efficiency map of the conditioner at 80 °C)

Conclusions

Through co-operation between research institutes and industry a genuine drive concept of a mower-conditioner could be realized. The integrated PMSM as direct drive and the designed power inverter operates the conditioner with the required

Fig. 6

30 kVA high power inverter for agricultural applications (Photo: TU Wien)

Table 2

Inverter specifications

Eingangsspannung *Input voltage*	3 x 400 V AC
Zwischenkreisspannung *DC Voltage*	700 V DC
Phasenstrom *Phase current*	70 A_{peak}
Schnittstellen *Interfaces*	2 Temperatursensoreingänge / *temperature in* 4 digitale Ausgänge / *digital out* 4 digitale Eingänge / *digital in* 3 analoge Eingänge / *analog in* CAN 2.0B RS232

speed. Therefore the whole process can be optimized and the power-requirements can be reduced and field-drying accelerated. In coming field tests the potential will further be analyzed. In order to open perspectives of this new technology for agriculture some basic features as increased flexibility, robustness or potentials of energy-saving will be investigated.

Literature

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