

Experiences and visions of an implement manufacturer

by Dr. Norbert Rauch

GERMANY

1. Introduction

The *sustainable* agricultural production of food, fiber and energy will be one of the biggest challenges in the coming years and decades [1]. Highly efficient energy use, carefully handled material resources, renewable energies and materials are the objectives and tasks.

Engineering of agricultural tractors, implements and mobile machinery is defining solutions to meet these requirements.

A considerable aspect of sustainable agricultural engineering is the farm's balance of incoming and outgoing energy. This balance has to incorporate the amount of energy required to produce operating goods, e.g. mineral fertilisers. A prime example are nitrogenous fertilisers, whose production induces high energy costs. Intending to apply such expensive supplies yield-efficiently, they should be metered and precisely distributed to the field. The challenge is to discover and exploit the potential advantages of new technologies alongside with the continuous refinement of proven fertiliser spreader designs.

2. Drives of fertilizer spreaders

To distribute mineral nitrogenous fertilizers in a highly accurate way, the plants' need of nitrogen is determined by different methods like nitrogen sensors or soil detection. Today the defined nitrogen rate is distributed in Europe with proven technologies such as twin-disc fertilizer spreaders.

Still today a common twin disc fertilizer spreader is driven mechanically. The power from the tractor PTO shaft is transferred to a gearbox, which distributes it to the right hand and the left hand disc and to the agitators in the hopper. Due to this drivetrain structure independent speed control of the two discs is not achievable.

Spreading widths of about 60m (respectively working width of 36m after overlapping) are getting more and more popular. Therefore an individual and precise control of each individual disc is key to precisely spread fertilizer in the field, of particular importance to avoid over-/under fertilization in the proximity of fieldborders and while working on complex field shapes.

Since more than 20 years RAUCH is successfully producing hydraulically driven twin disc fertilizer spreaders, for many years now with sensor-based closed loop mass-flow control. Their specific advantage is, that the rotation speed of each disc is controlled independently of the other. Limited system efficiency is one of the downsides of hydraulic drives, expensive sensor technologies are required to measure the torque and the latent potential for oil leakage and the respective environmental pollution is present.

Using the widely appreciated hydraulic drive system as a benchmark, the future potential and advantages of electrically driven twin-disc spreaders become obvious, particularly in combination with navigation and automation systems.

3. Potentials of electrically driven twin disc fertilizer spreaders.

Electric drives have become common in the industrial automation and today also for mobile applications. They simplify the precise drive control and efficient distribution of power to various consumers. The potentials of electric drives in agricultural machinery are:

- Sufficient power density with optimum controllability
- Simple power distribution across agricultural machines
- High efficiency even in complex power distribution systems
- Feedback of speed and torque
- Reliability and diagnosability in agricultural applications

At the Agritechnica 2007 John Deere has shown the first standard tractor with a high-voltage system on board, the 6030 E-Premium [2]. These tractors have an integrated system for the generation and distribution of 20 kW electric power. High voltage on board electric drives are applied for

- Reversible engine radiator fan
- A/C compressor
- Air brake compressor

The classical low efficient alternator is substituted by a highly efficient DC/DC converter providing enhanced 14 V power capability.

Independent studies have shown that controlled application of auxiliary drives with this technology allows to save a significant amount of fuel, in particular under part load conditions..

Besides these on board-systems, up to 5 kW are available for stationary loads with this first approach, the power generation system itself shows the potential to drive implements even in the field. In order to use the new electrical power source for implements, a cooperation by Rauch and John Deere has been presented by a prototype of a twin-disc fertilizer spreader with electric drives at the 2007 Agritechnica fair in Hannover (**Fig. 2** and **Fig.3**). This machine has three-phase electric drives (480 V AC) with adequate sensors and control components.

The power needed to drive a twin disc fertilizer spreader relates to the fertilizer mass flow, which itself results from 3 parameters: the application rate to be spread, the forward speed of the tractor and the spreading width. Maximum required power for extreme conditions is almost 20 kW of hydraulic power as shown by the following survey. For a spreading width of about 60m (respectively working width of 36m after overlapping) a circumferential speed for the disc of app. 50m/sec (900RPM, Disc diameter 110cm) is needed. A tractor speed of 20 km/h and an application rate of 400 kg/ha together with a working width of 36m leads to a mass flow of 480 kg/min! From our experience for this very high output demand app. 17 kW are needed. But the power demand can also be much lower in many cases.

Efficiencies of different fertilizer spreader systems are shown in **Fig 4**. Even a hydraulic energy saving power beyond-system (bypassing the tractor valves [4]) offers a relatively low efficiency level. The main reason is the cumulation of pressure losses within long tubes and the various connection elements with changing section areas. These pressure losses have a high weight because of the relatively low working pressure. The efficiency benefits of an electric three-phase drive with almost no “pressure losses” are obvious. A spreading pattern of a twin disc fertilizer spreader from a bird’s view shows the fertilizer layer on a quarter circle on the field surface behind the spreader. (**Fig. 5**). The throwing width is about 15-20m backwards and about 30m to the side right and left.

Within the spreading pattern the fertilizer amount has its maximum in the middle and falls down to zero right and left which requires an overlapping operation.

The electric drive of both spreading discs simplifies the control of their rotational speed with high dynamics and stability as well as the capability to quickly change of the distribution characteristics of the spreading pattern. The fertilizer distribution is also adapted to complex distribution duties, e.g. GPS-controlled optimization of overlapping on irregular field shapes

The hydraulically driven twin disc spreader offers a very important advantage: the-mass flow right and left can be controlled separately as the torque of the disc drive correlates well to the mass flow.

The torque T can be calculated by the basic equation of the mechanic-hydraulic balance [5] from the pressure difference Δp , the actual oil motor displacement V and the oil motor efficiency η as follows:

$$T = \frac{\Delta p \cdot V \cdot \eta}{2\pi}$$

With a pressure sensor based closed loop control the desired mass flow thus can be adjusted automatically and very precisely (<3%) to a given target. The recording of the actual fertilizer application is also simple.

However, the determination of the torque of an electric motor is very simple too. According to the similarity laws (analogy equations) of hydrostatic and electric drives [5] the current needed is equivalent to the pressure difference and thus can even easier be used to calculate the disc drives' torque, which correlates to the fertilizer mass flow.

Further criteria for twin-disc fertilizer spreaders with different drive systems are shown in **Table 1**.

4. Expected synergetic effects

The successful integration into the overall spreader design is particularly new and defines key parameters for the interaction between tractor and attached implements. A sophisticated design of the electric interface will allow simple and safe connection of power and controls.

The adjustment of the operation parameters of disc fertilizer spreaders are integrated to the tractor operation to a greater extent compared to conventional mechanically or hydraulically driven machines. This allows a high degree of automation and an optimized management of applied functions on the attached machine and the tractor – a perfect fit to the automation approach within the ISOBUS class III initiative. Like conventional systems the tractor provides the necessary power and control elements. Power electronics represent analogies to the hydraulic control valves. They can be used for a multitude of attached implements. The target of the tractor-implement system optimisation is minimizing fuel consumption and maximizing the overall system efficiency. The aim is to get an optimum result with minimized effort, considering material, machinery and labour related costs.

A further analogy (all-electric farm machinery) in comparison to conventional drive configurations is the possibility to locate the control elements on board the attachment. A current approach is to install two universal inverters onto tractors. If more than two independent control functions are needed, a fixed voltage is supplied and several inverters are situated on the implement. If the tractor is not able to supply high voltage: a PTO-shaft drives the implement's generator. This could be a transition scenario until all tractors have an electric power interface. The upcoming years will show how rapidly and to what extent the established power interfaces will be replaced by electric ones.

5. Conclusions regarding the first steps

On a twin disc fertilizer spreader the potential for optimized metering and distribution control of mineral fertilizer with electric drive systems has been shown. They also open up interesting perspectives for a multitude of other agricultural machines e.g. seed drills and pesticide sprayers. High voltage will make sense due to actual power requirements. In modern hybrid-technology vehicles 480 VAC are state of the art. High voltage is leading to components with adequate power density. Modern power electronics allow the precise control of the drives with very high efficiencies of, for example 98%, and become more competitive cost-wise. The integration of a communication interface will not only simplify the identification of the attached machine and its parameters but will also offer to identify the individual machine's electric drive and allow a real plug-and-play-design.

Other agricultural machinery with low power requirements (up to about 20 kW) like seed drills, precision drills and sprayers will be seen in the near future. Solutions for again higher power are under research. The machine concepts are not limited by geometrical or control related limits as sometimes is the case of mechanical or hydraulical drive.

6. Visions for future agricultural machine generations

- Self-sustaining, renewable power generation for every farmer by wind generators, photovoltaic`s, biomass etc. will be a common practice.
- Storage of energy by batteries will be improved, technology-driven by the automobile sector.
- The electrification of all agricultural machines and tractors ensures a reasonable load for the sustainable power generation and disburdens the agricultural holdings from the CO₂-producing fossil resources with probably permanently further increasing costs.
- Agriculture is the pioneer in production and use of renewable energies. Modern, foresighted maintenance, extended life-time of machines realized through updates and upgrades and finally their complete recycling will be important factors to save also conventionally not renewable materials.
- By modern electronic information- and sensor-based control systems agriculture demonstrates highly efficient and sustainable production chains for food, energy and raw materials.

6.1 Vision 2050:

What would be the remaining difference between an agricultural machine potentially working in a tramline on a field and a train on a rail system with conduction power supply (**Fig. 6**)?

Tramlines in the field could be used to add underground lines delivering energy for the vehicle, the vehicle`s battery and the agricultural process. The wireless electric power supply in the field with conducting paths between the tramlines via electromagnetic induction could be possible, particularly near available electric power supply nets like wind power plants.

In order to look for the potential of such a vision, an idea of Bombardier may be interesting as presented on the web-site of the company [6], see the following extract by table 2.. Being passionate pathfinders in agriculture it has to be our aim to identify all these potentials and to verify their future applicability in our industry.

Table 2: Extract from the WEB-site of Bombardier.com

PRIMOVE Catenary-Free Technology

Catenary-free tracks for trams and light rail vehicles enhance a city's attractiveness by providing unobstructed views.

Bombardier's new PRIMOVE system enables FLEXITY trams to operate catenary-free over varying distances, everywhere, including on underground lines.

Contactless Power Transfer – A World Premiere in Urban Rail Transport

The PRIMOVE system's outstanding feature is its safe and contactless power transfer. Its electric supply components are invisible, hidden under the vehicle and beneath the track. This is a key benefit in historic or environmentally protected areas of cities.

With its contactless power transfer, our unique PRIMOVE technology:

- ***Eliminates overhead wires and increases a city's attractiveness***
- ***Safely transfers inductive power***
- ***Eliminates wear on parts and components***
- ***Operates in all weather and ground conditions***
- ***Performance can be provides to vary from 100 to up to 500 kW, depending on the respective vehicles and system requirements***

7. Conclusions

A new system of electrical power transfer for tractor implements has been presented balancing the advantages versus mechanical and hydraulic systems. First results with a fertilizer prototype of Rauch company are very promising. Electrification of agricultural machines and tractors is still in a very early phase but the beginning of a new era of power supply will penetrate more and more the design of tractors, mobile machinery and implements in conjunction with state-of-the-art navigation and automation systems. This was also the result of several presentations on the recent international conference LAND. TECHNIK 2010 in Braunschweig. The question for me is not "will it come?", it's just but only "how fast will it be adapted broadly". Agriculture will become even more exciting.

References

- [1] Presentations on environmental sustainability of agricultural mechanisation. Club of Bologna, 20th Meeting, Hannover 8.11.2009 (free copies see home page Club of Bologna).
- [2] **Renius, K.Th. and H. Knechtges (2008)**. Agricultural Tractor Development. In: Yearbook Agricultural Engineering Vol. 20, 63-70 (bilingual German-English). Frankfurt/M.: DLG Verlag.
- [3] **Hahn, K. (2008)**. High Voltage Tractor Implement Interface. SAE Commercial Vehicle Engineering Congress 2008.
- [4] **ISO 17567 (2005)**. Agricultural and forestry tractors and implements – Hydraulic power beyond. International Standard.
- [5] **Matthies, H.J and K.Th. Renius (2008)**. Einführung in die Ölhydraulik (Introduction to oil hydraulics). 6th edition. Wiesbaden: Vieweg und Teubner.
- [6] **Bombardier**. Home Page. October 2010.

FIGURES

Fig 1 - Principle system of a simple electric drive

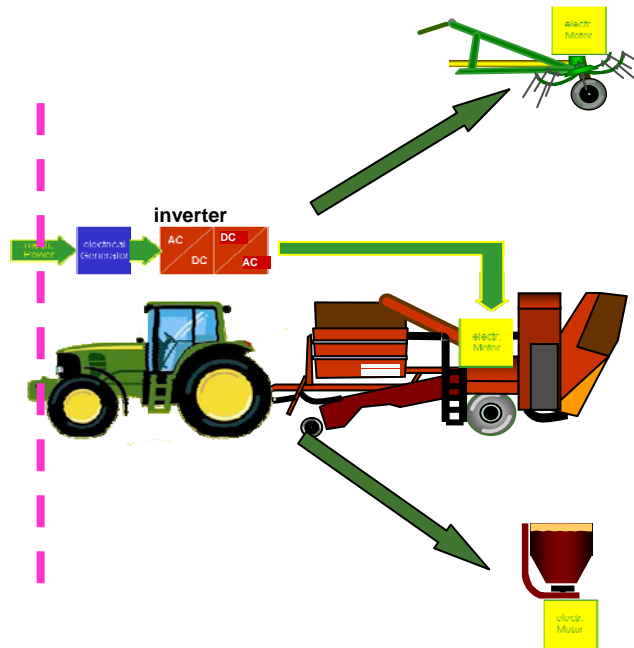


Fig. 2 - Prototype RAUCH fertilizer spreader AXIS EDR mounted on a JD 7530 E-Premium

Fig. 3 - Improved clearance between tractor and fertilizer spreader

Fig. 2



Fig 3

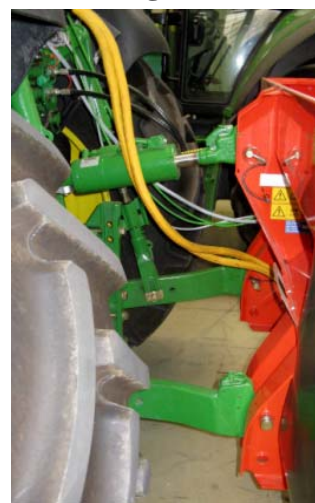


Fig.4 - Efficiency of various spreading disc drive systems of fertilizer spreaders [3]

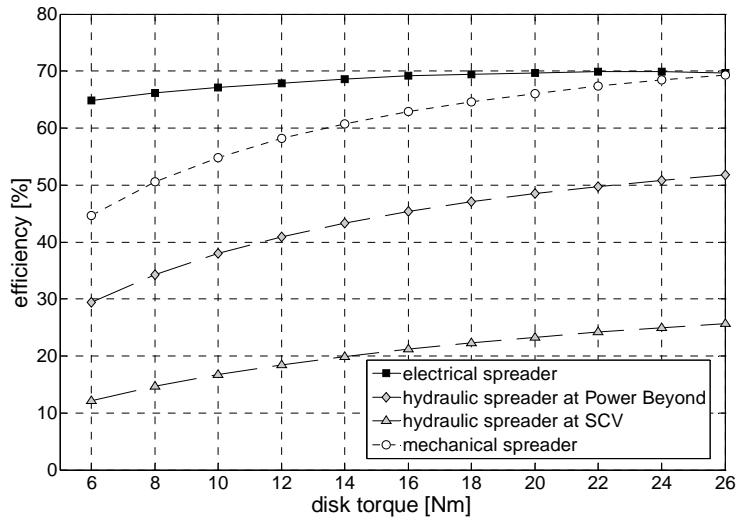


Fig. 5 - Examples of GPS-controlled optimization of overlapping on irregular field shapes

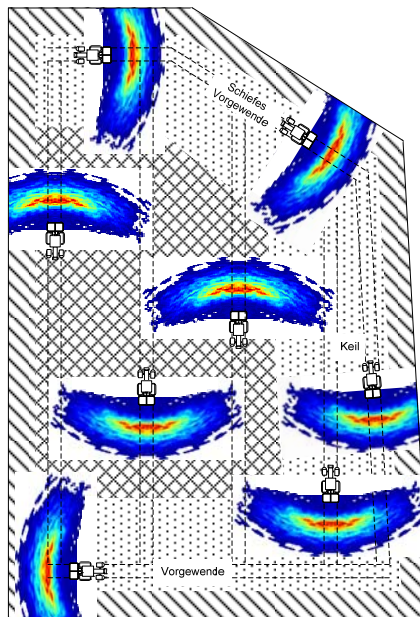


Fig. 6 - Electric power supply by conduction systems



TABLES**Table 1** - Comparison of the different drive systems on twin disc fertiliser spreaders

CRITERIA	CUSTOMERS ADVANTAGE	MECHANIC	HYDRAULIC	ELECTRIC
Separation of disc/agitator drive	operational safety	no	simple	simple
Stepless speed of disc drive on both sides	Adjustment of working width	no	good	very good
Various right/left revs of disc drive	limited and full border spreading	no	good	very good
Stepless speed of disc drive on one side	edge spreading	no	good	very good
Controlled adjustment of disc	operational safety /edge spreading	no	good (inert)	very good
Information about torque to drive right/left disc drive	automatic fertilizer flow adjustment	with sensors	with sensors	without sensors
Drive coupling to the tractor	Convenient coupling	telespace drive shaft	hydraulic plug	electric plug
Information data link to tractor	Identification of machine	no	no	simple
System efficiency factor	Fuel economy	high	low	high
Consumption of oil /fossil resources	Costs and sustainability	low	mean	none
Environmental hazard by oil losses	Oil losses - costs	low	high	none
Production costs	Purchase price	low	high	high
Compatibility with older tractors	Flexibility	yes	yes	no