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Electric Tractor: Vision or Future?

Electric drives will be used in mobile machines in the future. Due to their good efficiency factors and the possibility of integrating them into the entire vehicle management, electric motors offer numerous positive characteristics for utilisation in mobile machinery. Outstanding are the short term overload with a multiple of the rated torque and maximum torque availability at low rpm's. This paper deals with previous and current developments in electric drives in mobile machinery.

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Keywords

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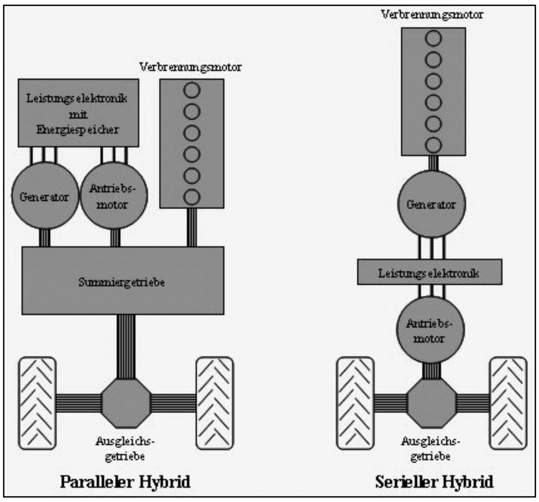

Fig. 1: Schematic diagram of hybrid drives

Due to improved handling characteristics and the reduction of fuel consumption, electric drives will become more important for application in mobile working machines. The Agritechnica 2007 has shown many innovations in the field of electric drives in agricultural machines. Nearly all known manufacturers of tractors and of self propelled harvesting machines and many research facilities are working on new powertrain concepts. Using this technology allows to substitute all existing drives by electric components. The parallel hybrid concept is widespread in the automotive industry whereas the serial hybrid concept is applied to tractors and working machines (*Fig. 1*).

The integration level of electric drives and power electronics into the mechanical powertrain indicate the degree of hybridisation. They can be classified into soft-, mild- and full-hybrid [1]. The complete decoupling of combustion engine and wheel drive is only achieved by the full-hybrid, similar to the hydrostatic drive. By using this approach, complex gearbox arrangements within the powertrain can be saved. However, the double conversion of energy requires enormous electro-technical input and and is cost-intensive. A straightforward serial hybrid drive system is the central drive. An electric motor drives front and rear axle by a transfer gearbox. In an axle drive, each axle is driven by an individual electric motor (*Fig. 2*).

Electric motors are characterised by:

- Temporary overload capability up to multiples of their nominal torque
- High torque at low revolutions
- Good controllability
- High efficiency

Historical development of electric drives

In 1900 the first car with electric drive was presented by Lohner-Porsche on the world exhibition in Paris. Since 1961 the Soviet tractor factory in Tscheljabinsk has built the diesel-electric crawler DET-250. The tractor is powered by a 220 kW combustion engine which drives a generator and a direct current motor. In 1999 a serial hybrid with single wheel drives has been developed by EvoBus (Mercedes-Benz - commercial vehicles). Daimler Trucks is going to place a hybrid truck on the market this year. This truck will be a parallel-hybrid design, which will provide up to 30 % fuel reduction. However, the price of the product is much higher compared to a standard truck [2].

Alternative drive concept

The University of Technology in Dresden has analysed the requirements of an electric drive for tractors [3, 4]. For a continuous drive with electric-mechanical power split, the electric drives can be smaller in dimension but with a small range between the nominal and the maximum speed, the parallel hybrid has an increased efficiency compared to serial hybrids [5].

The electric wheel drive allows adjusting the motor torque, depending on wheel slip

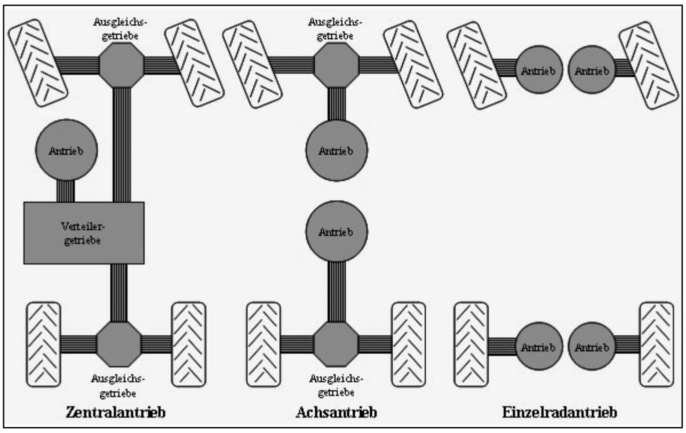

Fig. 2: Schematic configuration of vehicle power trains

[6]. By using an electric drive, a reduced turning radius for cornering can be achieved with the full tractive power. The design advantage results in a maximum utilisation of the available space within the wheel rim of the tractor. Further development and analysis are necessary concerning the power density and the increase of torque for electric drives. For example, such developments are taking place in the project „Mobil-elektrische Leistungs- und Antriebstechnik" (MELA) [7]. To attain a very high power density of the permanent-excited synchronous machine, special cooling oil must be used. The power converter is directly mounted onto the electric motor and makes use of the cooling circuit of the combustion engine. *Table 1* gives a comparison of electric, mechanic and hydraulic drives.

Actual developments in electric auxiliary drives

For an experimental comparison between hydraulic and electric auxiliary drives, the intake and the front attachment of a forage harvester have been equipped with reluctance motors [8]. As a result, the efficiency of the electric drive was increased by about 15 %. A disadvantage is the higher weight to power ratio of the electric motors compared to the hydraulic components. The first hybrid wheel loader was presented as a mild-hybrid at the Trade Fair for Construction Machinery in 2007 [9]. A 10 kW starter generator with a lithium ion battery pack absorbs the system peak power in the "Power Boost" mode. In addition, a start/stop automatic function and the recuperation of the kinetic braking energy provide high ease of handling and operation. The manufacturer of this system predicts a fuel saving of 10 to 20 %. The 7530 E Premium tractor developed by John Deere, executed as mild-hybrid, was awarded a gold medal by the DLG at the Agritechnica in 2007 [10]. This concept provides electric energy using an integrated crankshaft generator (20 kW) for providing independent power for the fan, coolant pump, air conditioning and pressurized air compressor. Beside a fuel saving up to 5 % there is a standard power socket for external consumers with 230 V and 400 V.

RAUCH and AMAZONE apply this approach by integrating electric drives into their products. A further step is the implement e.g. a rotary harrow with electric drives. The aim for achieving high system efficiency is to operate the generator independently from the consumer load. The combustion engine generates a permanent constant power. This energy is stored by a storage system and can be utilized according to the demand. Power peaks of the electric motors are compensated by an accumulator in the intermediate direct current link, which ensures that the combustion engine is operated in the favourable working point with the highest efficiency. In principle flywheel energy storage systems, accumulators and supercaps are suited for such short energy storage systems. Beside the actual developments [11], further efforts concerning the cost-benefit analysis are required.

	electric	mechanic	hydraulic
Weight to power ratio	good	good	low
Density to power ratio	low	good	best
Energy transmission	best	good	good
Energy storage	best	good	good
Controllability	best	low	good
Efficiency	best	good	low
Design flexibility	best	good	best
Cost	partially high	high	low

Table 1: Comparing electrical, mechanical and hydraulic drives

Summary and prospect

Due to their advantages electric drives will become more important in agricultural machines. However, further research and development are necessary in order to reduce the power to weight ratio and other disadvantages. The listed developments and trends demonstrate that electric drives for agricultural machines are not a vision, but in fact the future of the agricultural machines.

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