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Conceptual Comparison of Electrical and Hydrostatic Propulsion in Combine Harvesters

The necessity of putting increasing machine capacity into a space limited by Road Traffic Regulations, the considerable progress in recent years in electrical drive development and the accompanying power electronics make new propulsion concepts, based on electro-mechanical energy conversion, possible or even demand them. This paper compares the pros and the cons of current propulsion solutions with new systems, which replace the mechanic and hydraulic power splitting with their respective disadvantages in efficiency, construction space and flexibility with the consistent exploitation of the advantages of electrical drives.

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Over the last decades, development efforts in the area of self-propelled harvesting machines were concentrated on increasing productivity and efficiency. As a consequence of wider cutter bars and threshing and separation channels as well of functional improvements for increasing throughput and overall capacity, energy demand and engine power increased.

The driveline of a combine harvester combine is very complex. Depending on the power demand, component location or speed variability, machines have mechanical or hydraulic drive systems to distribute power. *Figure 1* shows the schematic power distribution of a harvesting combine.

Mechanical and hydraulic drives are currently used to supply power to high-power consumers. Gear boxes and actuators adjust the various speeds and torques generated by the power source to the consumer needs. Besides the high power hydraulic transmission in general, hydraulic drives are used for medium power in decentralised systems. Actuators and low-power consumers are electrically driven.

Electrical drives offer an alternative. Hydraulic drives offer a flexible spatial power distribution, but generally reduce the efficiency of the machine. The number of transmission elements as a measure of the complexity of the harvesting machine can be reduced by 60 % [1] using electrical drive technology. Additional advantages are higher efficiency and better controllability. The electrical drives facilitate new management strategies. With the available information, like torque and speed, the power flow within the driveline is known. Individual and continuous speed and torque settings enable a flexible dimensioning of the drive units. *Figure 2* shows an example of an electrical powertrain.

A generator consumes the engine output and converts mechanical into electrical energy. A rectifier supplies the DC link that feeds all electrical drive units with the necessary power.

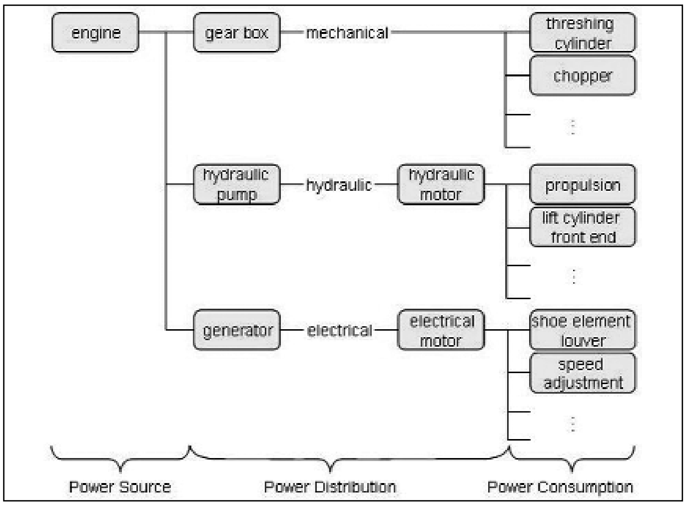

Fig. 1: Schematic power split in a combine harvester

Propulsion systems of combines

The propulsion of large combines is realised with hydrostatic drives to be able to vary continuously the vehicle speed in accordance with the mass flow. *Figure 3* left shows the typical layout of the hydrostatic propulsion system in the combine.

The diesel engine drives the variable hydraulic pump via the main gear box. The generated volume flow is directed towards the hydraulic motor that is connected to the driving wheels by gear boxes, differential and final drives. Oil is a medium with two functions: power transmission and cooling. It is impossible to extend closed hydraulic systems. However, the decentralisation in electric propulsion systems has the additional benefit of extendibility. Additional electrical motors can be integrated into the entire system at low costs.

Electric propulsion systems as efficient alternatives

Figure 3 right shows the configuration for a combine with electric drives. The generator is directly connected to the engine. The rectifier feeds the provided power into the DC link. The inverters generate an AC voltage for the electric drive motors which supply their power through the final drive to the wheels. The integral design contains permanently excited synchronous motors and inverters in one unit [2, 3].

Since electric power transmission requires fewer gear boxes, the number of active parts in the powertrain is reduced by 57 % compared to a hydraulic alternative [1]. The flexible arrangements of the transmission elements create new potential for the machine design. A limiting factor in the design of self-propelled harvesting machines is their total width. Integration of electric drives inside the rims can provide additional space. The performance of standard electric motors, however, is not sufficient to fulfil the necessary parameters [4]. *Table 1* gives a quantitative comparison of mass, cost and efficiency for a 150 kW combine with electrical and hydrostatic propulsion. The given values depend on the degree of integration, production volume and future technical development.

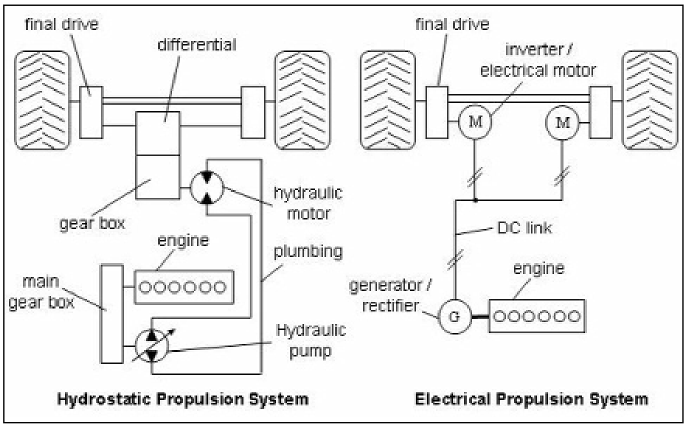

Fig. 3: Hydrostatic and electrical propulsion in a combine harvester

The efficiency of an electric propulsion system is higher compared to a hydrostatic drive. Mass and purchase costs of currently used propulsion systems in combines are lower. The higher costs of electric propulsion systems, which may be reduced by 10 to 20 % soon, can be over compensated by new customer benefits [5] taking life-cycle costs into consideration. Users will accept a higher purchase price if it is justified by reduced specific fuel consumption, less maintenance, increased reliability and productivity.

Summary and prospects

Mechanical, hydraulic and electric transmission elements distribute the mechanical output from the source to the consumer over long distances. Task-specific, decentralised electric propulsion systems with a modular design could be a promising alternative; an electric power system could provide them with the power they need [6, 7].

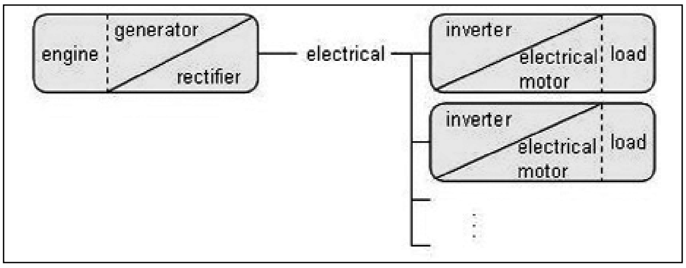

Fig. 2: Electrical powertrain in a combine harvester

Table 1: Comparing of mass, costs and efficiency of an electrical and a hydrostatic propulsion in a combine harvester

	electrical propulsion				**hydrostatic propulsion [1]**		
	mass [kg]	costs [€]	η [-]		mass [kg]	costs [€]	η [-]
generator	250	5000	0.92-0.96	hydro pump	60	1500	0.70-0.87
rectifier	80	2500	0.95-0.97	main gear box	200	3000	0.96-0.98
wiring	100	1800	0.99	wiring	30	500	0.93-0.98
motor-inverter	2x80	2x2500	0.95-0.97	differential gear	160	6000	0.95-0.97
				drive shaft	2x20	2x250	0.99
final drive	2x280	2x3500	0.97-0.98	final drive	2x280	2x2500	0.97-0.98
drive motor	2x300	2x4000	0.90-0.94	hydro motor	40	1200	0.70-0.87
radiator	150	600	-	radiator	20	600	-
cooling pipes	90	600	-	oil tank	20	100	-
total	***1990***	***30500***	***0.72-0.82***		***1130***	***17800***	***0.40-0.68***

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