Peter Pickel, Halle

Gear Concept with Power-splitting

Many construction and farm machines use fully hydrostatic power transmissions, which besides many big advantages have some evident drawbacks (poor energetic efficiency, high noise emission.) A multiple power split gear can compensate for these and other drawbacks from standard hydrostatic gears. Here several drives use a common mechanical gear as a main power transmission. Many functional characteristics can be almost infinitely adjusted to meet the needs of each individual application. Special benefits result from using adjustable motors. The gear concept can be transferred to (partial)-electrical drives, too.

Prof. Dr. Peter Pickel is the director of the Institute for Agricultural Machinery and Land Use Management of the Martin-Luther-University Halle-Wittenberg, Ludwig-Wucherer-Str. 81, 06108 Halle(Saale); e-mail: *peter.pickel@landw.uni-halle.de*

Keywords

Construction and farm machines, hydrostatic drives, power-split transmission

Literature

[1] *Pickel, P.*: Antriebssystem für mobile Arbeitsmaschinen. VDI-Max-Eyth-Gesellschaft, VDI-Berichte Nr. 1798. Vortrag, Tagung Landetechnik, Hannover, 2003, S. 245-250

A good concept for transmission on mobile machinery should combine the benefits of hydrostatics drives with the high efficiency of mechanical transmissions. For tractors, hydrostatic-mechanical power split transmissions have been established as a standard since about ten years ago. But this technical solution couldn't be applied to other mobile machines, which have additional high power drives besides their traction drives.

The Institute for Agricultural Machinery and Land Use Management at Halle/Saale and the Research Centre for Machine and Energy Systems (FBZ e.V.) at Merseburg have developed a new transmission concept, which can be applied to a lot of agricultural and construction machinery. The result of research and development is a multiple power split transmission. Here several drives use a common or main power transmission and several disaggregated continuously variable transmissions. At first the transmission concept was designed for a construction machine: an asphalt paver. It has several single drives. Amongst these, there are the crawlers, augers and conveyor belts. The lot of engine power is transmitted to these rotational drives. Generally, hydrostatic transmissions are state of the art for most of the drives of a paver.

Here, a diesel engine drives the hydraulic pumps using a standard transfer box (PVG). Final reduction transmissions are generally used on the output end for the traction drives. Often, final reduction transmissions are in use for augers and conveyor belts since this is cheaper than the use of slow-speed motors.

This design principle can be found on many agricultural machines especially on self-propelled machines. A modern drive concept must have a better efficiency for following reasons:

1. Lower fuel consumption
2. Smaller diesel engines for the same process performance
3. Lower manufacturing costs because of smaller hydrostatic components
4. Lower manufacturing costs because of fewer hydrostatic components
5. Better cooling
6. Reduction of noise emission
7. Free clearance space usable for:
8. Better noise insulation

The Design Idea

Figure 1 shows schematically the design concept for a paver, which uses the principle of power splitting. There is a common transmission shaft (AW) for traction drives, augers and conveyor belts on the rear part of the paver. The diesel engine drives the common transmission shaft over a central transfer box (ZVG) and a mechanical transmission (K). Additionally, the diesel engine drives the hydrostatic pumps over the central transfer box (ZVG). The mechanical transmission K can be a cardan shaft, a chain, or something similar. On each side of the paver, hydraulic motors and the common transmission shaft are connected to the crawler wheels and to the conveyor belts by planetary gears (S1 ... S4). The planetary gears (S1 ... S4) „sum up" the power of the continuously variable hydraulic transmissions and of the common transmission shaft. The augers can have a similar configuration using an additional mechanical transmission K2.

Figure 2 shows a modular mimic display of this basic idea. Principally, electric systems can replace the hydraulic components. The number of supported drives can be increased or decreased according to the needs of the individual application. The position of the main transmission HG can also be placed before the internal transfer box V. This transfer box V can have additional transmissions. Transfer box V and main transmission HG can be integrated into a central transfer box ZVG.

Many self propelled agricultural machines (especially self-propelled machines) could have this transmission design. As a basic demand, the different drives of the respective machine should have a limited working speed range.

For layout, it is necessary to fix the rotational speed of the common transmission shaft AW reasonably. One idea could be to choose a speed, which results in a typical or mainly used operational speed of the most power consuming drive i when its according continuously variable transmission SLW_i is set to a speed zero. This means, no power will be hydrostatically transmitted at typical working conditions.

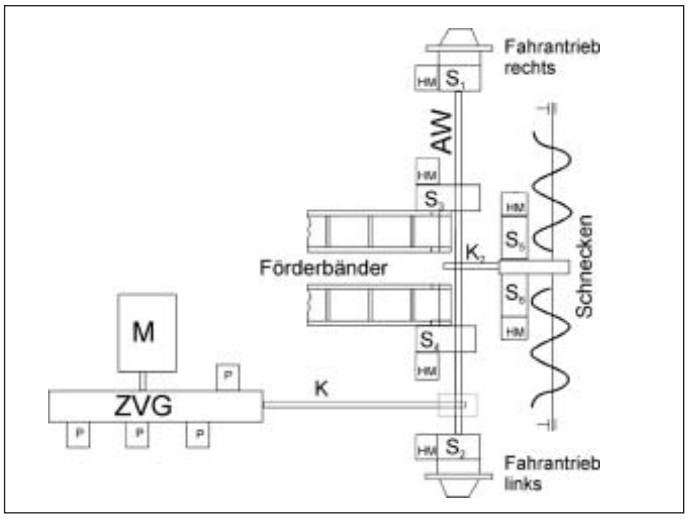

Fig. 1: Schematic diagram of a power-split drive for a road paver

This principle can theoretically be applied to all other drives. For this, the planetary gears must have a fitting basic gear ratio. This is the best solution with respect to efficiency. But there are several severe drawbacks. E.g., the system will invoke reactive power in certain conditions. To reduce or to avoid reactive power, the rotational speed of the common transmission shaft has to be decreased. This will lead to a transmission system with the following advantages:

1. Highest efficiency
2. Low cooling power
3. Lower noise emission due to the reduced power of hydraulics
4. Smaller and therefore cheaper hydraulic components
5. Standard hydraulic motors can replace adjustable motors since pump adjustment is sufficient
6. More clearance space due to smaller coolers
7. More clearance space due to smaller oil tank
8. Better noise insulation realisable
9. Good control of speed

But the drawbacks still are:

1. Additional mechanical transmission parts necessary (e.g. cardan shaft K, common shaft AW or a chain K2)
2. The central transfer box ZVG is more expensive than the old PVG (one more output shaft)
3. The mechanical gear path must be designed for full power transmission at very low speeds. This means highest torques and strength demands
4. The number of hydrostatic components still is the same
5. The hydrostatic drives must allow adjustment through speed zero (which of course is the same at the conventional paver)
6. Higher speed for transport demand a gearshift mechanism
7. End transmissions are more complex (planetary gears instead of standard gears needed)

Theoretically, it is possible to replace the adjustable pumps by constant pumps. For this, a reduction of the rotational speed of the common transmission shaft AW is necessary so that at zero speed of the transmission SLW_i the lowest operating speed of the respective drive will be achieved. Now, adjustable motors would be used for speed adjustment. The benefits would be:

1. Reactive power never occurs in the transmission in the total operating speed range (total power goes over the output shaft)
2. Characteristic curve corresponds to hyperbolic function
3. Hydrostatic braking is possible
4. Fewer hydraulic components needed (a single pump is sufficient instead of a single pump for each drive)
5. (Higher) transport speed without gearshift mechanism. For this, unused drives must be braked. The motors will act like pumps and the additional oil flow can support pump.
6. Lower driving speeds and backward driving by reversing the motors (this will result in a deadband for driving speed)
7. Good speed regulation at very low speeds

But still, the fundamental drawback will be the enormous torques in the common transmission shaft AW. For a compensation of this draw back, it is possible to increase the speed of the shaft AW up to a level so that at zero speed of the transmission SLW_i the highest operating speed or more of the respective drive will be achieved.

In this case, the transmission SLW_i always will act „against“ the common transmission shaft. In other words, the continuously variable transmission SLW_i will always transmit reactive power. This is a compromise and by far not the optimal but still a good solution, according to efficiency. The number of possible configurations is almost endless. So, there will always be a configuration to make the drive fit to the individual application.

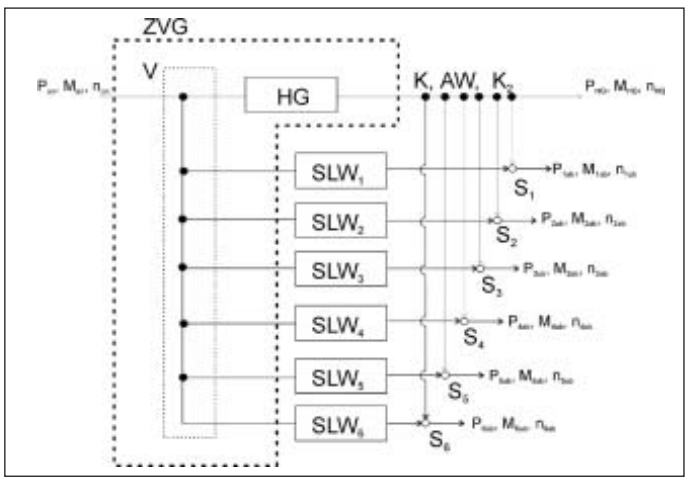

Fig. 2: Modular mimic display of a power-split transmission with several power drives and a common main transmission