Jasper Forche and Hans-Heinrich Harms, Brunswick

Management of Hydraulic Drives in Mobile Machines

Drive power requirements of mobile machines varies strongly during the work process. The diesel engine, as the drive source, is often operated with constantly high rpm's. For this reason this operating point frequently has a high specific fuel consumption. At the Institute of Farm Machinery and Fluid Technology, exemplary for mobile machines, a driveline management system for hydraulic excavators was developed. Tests demonstrated that with a partial-load mode considerable energy savings potentials exist.

Dipl.-Ing. Jasper Forche is a scientist, Prof. Dr.-Ing. Dr. h.c. H.-H. Harms is the director of the Institute of Agricultural Machinery Sciences and Fluid Power at the Technical University at Brunswick, Institut für Landmaschinen und Fluidtechnik, Langer Kamp 19a, 38106 Braunschweig;
e-mail: *ilf@tu-braunschweig.de.*

Keywords

Mobile machine, powertrain management, saving energy

Mobile machines can be characterised by two facts. Firstly, they do not work stationary and carry their energy source with them. Secondly, next to the task of driving, they have to fulfil a working task.

Initial Situation

The feature of mobility results in the need of a construction that is optimised in points of weight and volume. Both parameters are limited by legal or process aspects. Because of their good power to weight ratio, hydraulic drives are widely implemented.

The power demand of mobile machines varies significantly during a working period, whereas the diesel engine is run at a constant high speed. It is therefore often working at a point with high specific fuel consumption and the whole system runs at a poor level of efficiency.

A powertrain management optimises the interaction of the diesel engine and the hydraulic powertrain. A hydraulic excavator was used for the research work, representing a mobile machine with exclusive hydraulic powertrain.

A research project concerned with the powertrain management of agricultural tractors has been carried out at the Institute of Agricultural Machinery Sciences and Fluid Power, bringing excellent results regarding the improvement of efficiency [1].

Objectives

A main objective of the project was the reduction of fuel consumption. If diesel engine and variable displacement pump are run at optimum duty point, fuel consumption can be reduced, thereby it is possible to increase the efficiency level of the whole system.

A second aim was to improve the ease of use. The operator is to be relieved of the necessity to choose the right settings for each individual working task.

The objective of reducing noise emission was to be addressed by reducing the engine speed to the level needed. Consequently, the power for cooling would be automatically reduced as well.

Test Rig

A test rig was constructed at the Institute of Agricultural Machinery Sciences and Fluid Power, being built inside a sound insulating cabinet. The components used resemble an mid-class excavator The test rig consisted of an electronically controlled diesel engine as

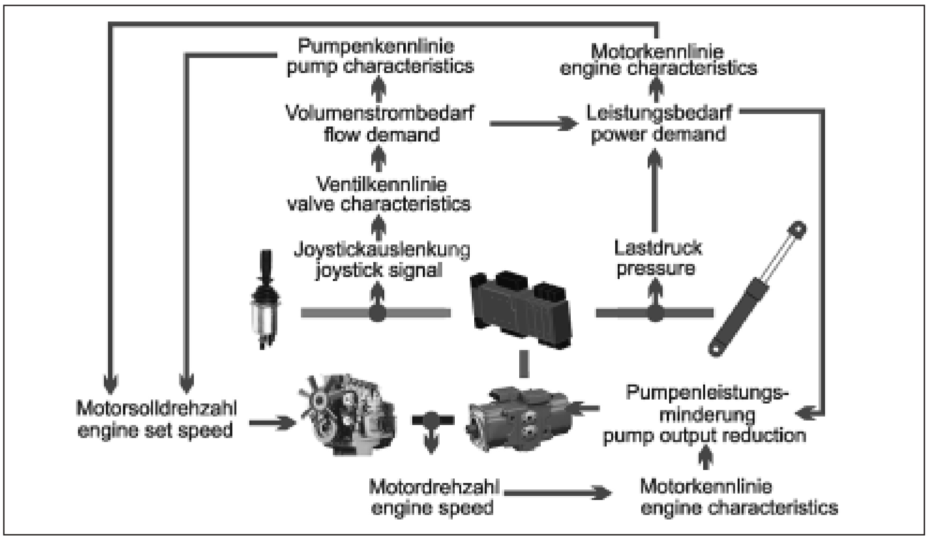

Fig. 1: Information flow in powertrain management of excavators

power source. The engine drives a variable displacement double pump, which is connected to a control block with load independent flow distribution system. The pressure built up by the four actuators, being boom, stick, bucket and swing drive for an excavator, is set by electronically controlled pressure relief valves. The flow and the pressure is recorded for all four actuators.

Flow of information

In order to illustrate the flow of information, *Figure 1* shows a hydraulic powertrain of an excavator schematically. Many mobile machines are driven by the same or very similar devices. The powertrain consists of an electronically controlled diesel engine, a pump and a control block. A joystick is used to control the electro-hydraulic valves, the actuators are resembled by the cylinder.

The joystick signal and the pressure are picked up as they enter the system. The joystick signal can be transformed into signal that resembles the flow demand using the valve characteristics. Multiplying flow by pressure, the power demand can be estimated. Using the pump and the engine characteristics, a engine speed set point can be determined.

If the engine works in a duty point near to the maximum torque, the engine does not have the ability to accelerate in case of higher power needed. In this case, the output power of the pump has to be reduced by decreasing the swash plate angle. The required signal is calculated from the engine speed and the estimated power demand.

Tests

In order to test the powertrain management system, realistic load progressions for different working tasks are available. These load progressions have been recorded by Holländer [2] using a real excavator at the Institute of Agricultural Machinery Sciences and Fluid Power. With this data it is possible to produce identical conditions for every test, making the development of a powertrain management practical.

The reduction in engine speed regularly results in lower system dynamics. In reality, the reduced dynamics lead to a prolonged working cycle time. This prolonged cycle time could not be simulated with the test rig. Therefore a dimensionless term "dynamical aberration" was introduced. It is calculated using the flow deficit at each sampling point and the available flow at each sampling point.

Figure 2 shows the normalised fuel consumption per working cycle in relation to the dynamical aberration. The results for fixed modes are joined by a line. With a reduction in engine speed, the dynamical aberration increases, as expected.

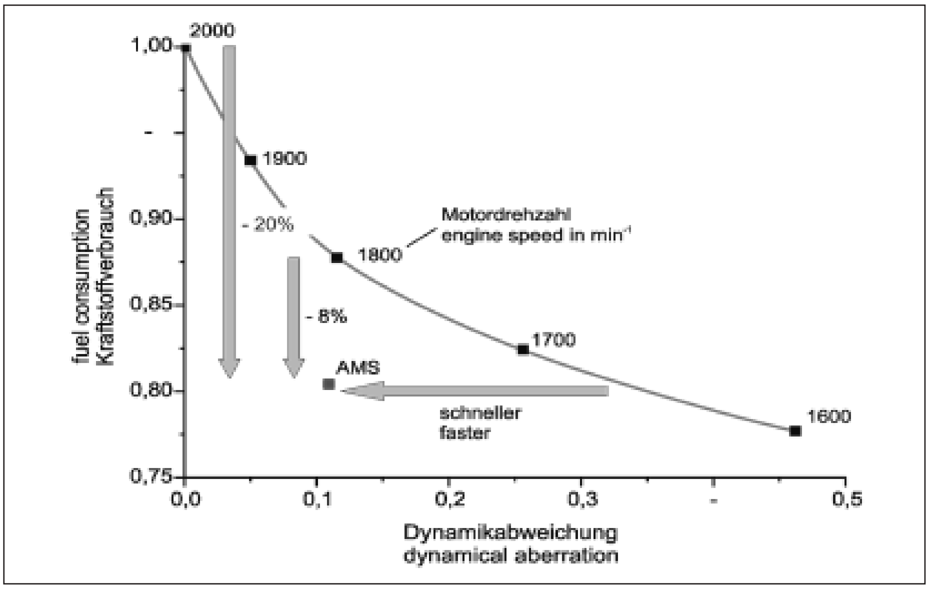

Fig. 2: Fuel consumption and dynamical aberration at partial load

The result for the powertrain management (AMS) shows a fuel-saving of about 20 % in relation to the pass with a speed of 2000 rpm. In relation to a engine speed with the same dynamical aberration, about 8 % of fuel could be saved. Comparing to the results with the same fuel consumption, the powertrain management system shows a much lower dynamical aberration.

Conclusions

It was shown, that a powertrain management is able to save a significant amount of fuel at partial load by adapting the engine speed to the actual power output. Compared to a conventional system with fixed power-modes, the new system achieves higher system dynamics. The more the task moved from partial load to full load, the lesser is the fuel-saving being achieved.

The ease of use is being increased using the management system. The operator does not have to adjust the powertrain parameters to the individual task. He can fully concentrate on machine operation and control.

The average noise emission is reduced by the powertrain management system. The acceleration of the engine, depending on the operation commands, results in a new "sound" to which the driver needs to get used to.

Outlook

The results from the test rig are to be verified by tests with a real excavator. The subjective effects of a powertrain management system can not be assessed at with the test rig. To achieve that, the subjective perception would have to be put into relation to measured results.

With repeating working cycles a cycle identification could lead to better system dynamics. A cycle identification would be a glance into the near future, surely an ideal condition for every control system.

Literature

Books are identified by •

[1] • *Seeger, J.*: Antriebsstrangstrategien eines Traktors bei schwerer Zugarbeit. Forschungsberichte des Instituts für Landmaschinen und Fluidtechnik, Shaker Verlag, Aachen, 2001

[2] • *Holländer, C.*: Untersuchungen zur Beurteilung und Optimierung von Baggerhydrauliksystemen. Fortschr.-Ber. VDI Reihe 1, Nr. 307, VDI Verlag, Düsseldorf, 1998