Flexible Hydraulic Controls

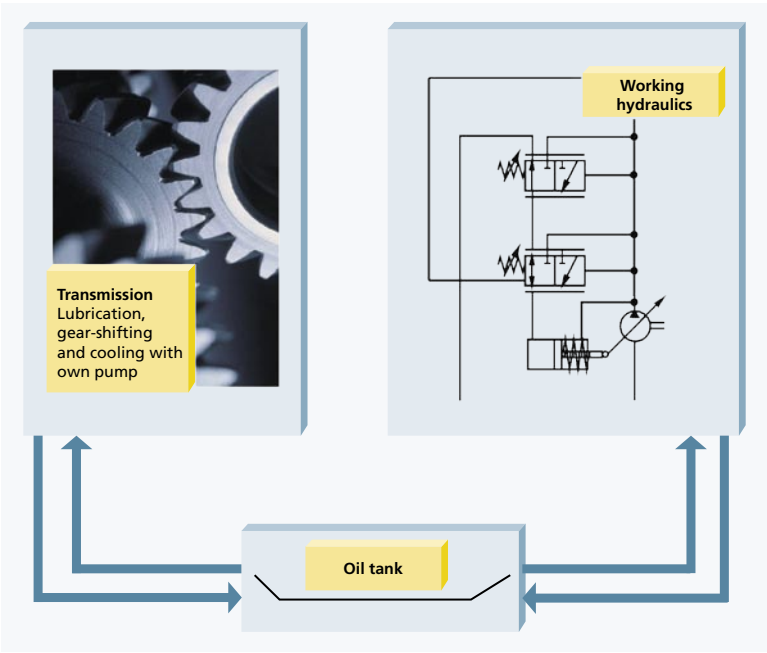
- **Air in Hydraulic Oil: Research topic at the Technische Universität Braunschweig**
- **Extensive measurement data capture combined with dynamic control tasks**
- **DS1103 PPC Controller Board as universal measurement technology hardware**

The Institute of Agricultural Machinery Sciences and Fluid Power at the Technische Universität Braunschweig, Germany has installed the DS1103 PPC Controller Board on several test benches used in research and teaching. An experimental hydraulic test bench is currently being used for research into "Air in Hydraulic Oil". Control models based on MATLAB®/Simulink® are being programmed, compiled, and with the aid of the ControlDesk experiment software, executed and monitored.

One major research area at the Institute of Agricultural Machinery Sciences and Fluid Power is concerned with the subject of "Air in Hydraulic Oil". We already carried out several research and development projects on "Foaming Behavior of Mineral Oils" for Volkswagen AG and for the fluid power division of the Verband Deutscher Maschinen- und Anlagenbau (VDMA, German Engineering Federation).

Transmission and Hydraulics Share Oil Resources

Many tractors have a single oil resource that is shared by the transmission and the hydraulics, so the institute is investigating whether shared use of oil by the two subsystems increases the problems caused by dispersion and surface foam, both due to free air in the mineral oil.



▲ *Mobile working machines like tractors often have a shared oil resource for transmission and working hydraulics.*

The Effect of Air in Hydraulic Oil

The oil is used for the hydraulics, transmission lubrication, and cooling. If air penetrates the oil circulation system, it causes a series of operating problems throughout the entire system. These include efficiency losses in energy utilization, malfunctions such as gear-changing problems, increased noise, and a shorter useful life for the oil. Additional air is pushed into the hydraulic oil by intermeshing gearwheels, for example, and then sucked in via the hydraulic pumps. The oil-air mix can get into the hydraulic circulation system by this route, and then cause the above problems as an air-in-oil dispersion. In the transmission sump (between the gearwheels and the oil collection points), dispersion can cause surface foaming, which in extreme cases can lead to oil losses due to oil foaming over.

Transmission and Hydraulics in an Experimental Setup

As part of the research on "Air in Hydraulic Oil" carried out at the institute, we set up a state-of-the-art experimental bench. This consists of the transmission of a standard tractor, a complete working hydraulic system, a load unit with hydraulic pump, and a load cylinder that runs via a second hydraulic cycle. The transmission gears and the hydraulics share the same oil resource, with the transmission serving as the tank for the hydraulic system. We equipped the transmission and the working hydraulics with sensors and actuators that are controlled via the various output modules of the dSPACE hardware. Actions such as gear shifts, which in a real tractor would be performed by a tractor ECU, were implemented by means of

◀ *The stationary test bench: The research team analyzes the effect of air in a working hydraulic system in a mobile working machine. From the left: Björn Grösbrink, Julia Leichnitz, Thomas Fedde.*

a dSPACE prototyping system based on the DS1103 PPC Controller Board. Thus, we can easily control different gear shifts from the host computer. The signals generated in the computer are transferred to electric magnets which switch various gear valves. We implemented the gear shifts under safe operating conditions using a logic circuit that was mapped in MATLAB®/Simulink® and that includes user prompts.

Measuring Dynamic Movements of a Hydraulic Cylinder

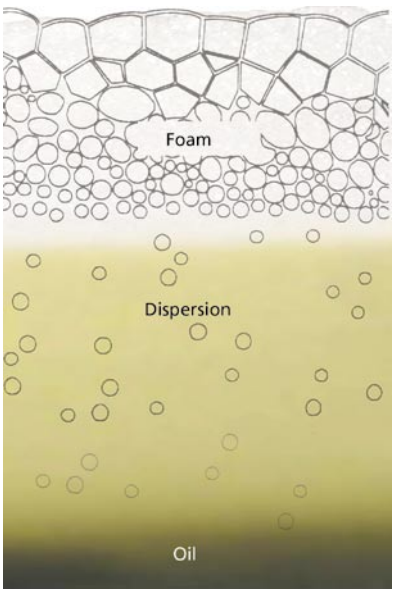
We established a defined, increased air content in the hydraulic oil for our experiments, and then measured the dynamics of the working hydraulics with the aerated oil. The load states of a real tractor working with a hydraulic cylinder (load equivalent from 0 to 6 tonnes) are mimicked by targeted loading of the differential cylinder,

> *"We use dSPACE systems for controlling our experimental hydraulic test benches at the institute, because they allow numerous sensor and actuator signals, and CAN bus messages, to be processed simply and flexibly."*
> ***Dipl.-Ing. Julia Leichnitz, TU Braunschweig***

and the changes due to the increased free air content are analyzed. To define the effects of the air in the system, we installed more than 30 different sensors and recorded numerous analog signals, frequencies, and CAN bus messages at a high sampling rate. All the components from different manufacturers interacted smoothly, for example, the control of the frequency converter producing the input values for the electric motor that drives the hydraulic pumps; the control inputs for the tractor's CAN-controlled mobile hydraulic valves and the switching signals for the black-and-white valves (simple solenoid-controlled valves that are either open or closed and do not allow any position in between) for electrohydraulic gear-shifting, and the control inputs for the highly dynamic servovalves that provide fast load changes via the load hydraulics cylinder.

The Next Research Stage

The results of the experiments show that as expected, an increased quantity of free air in the system has a considerable effect on how the working hydraulics operate. Pressure losses and operating states with strong pressure fluctuations occur, as well as a high noise level. In the next stage of research, we will be looking at the material properties of the hydraulic oil to help us interpret the effects we have observed and evaluate the effect of free air in the system in greater detail.



▲ *Free air in hydraulic oil takes the form of air-in-oil dispersion or surface foaming. This can cause operational problems in the working hydraulics and the transmission.*

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