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Hydraulic displacement pump as environmentally friendly tribosystem by PVD-coatings

Hydraulic systems are commonly used in agricultural engineering due to their high power density, various fields of application and the small required installation space. The use of hydraulic oil is connected to an ecological danger due to leakage. The Collaborative Research Centre (CRC) 442 of the German Research Foundation (DFG) has developed ecologically acceptable tribosystems which operate with lubricants compatible to the environment. The examinations within this context were conducted without additives. A hydraulic axial piston pump was examined and has shown good properties concerning friciton and wear. This has been realized by using synthetical esters and PVD-coatings (physical vapour deposition).

Keywords
Rolling bearings, hydraulic displacement pump, axial piston pump, PVD-coatings, biodegradability, ester lubricants, Collaborative Research Centre 442

Abstract
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The widespread use of hydraulic systems in agricultural engineering is always connected with a certain danger of leakage. A discharge of lubricants can occur when disconnecting hoses. Extreme leakage can occur when hoses are torn out. Particularly in agricultural engineering, a discharge of lubricants can cause huge damage to the environment. The bigger part of hydraulic fluids is based on mineral oil (80-90%) while only 5% of the hydraulic lubricants are synthetic and have a good biodegradability [1].

In recent years, universal tractor transmission oils (UTTO) have been developed. These lubricants are conjointly used for both gear box and hydraulic circuit of tractors. They are based on rapeseed-oil and have very good ecotoxicological properties as well as favourable chemical and physical properties [2]. Properties of the lubricants have a major influence on the biodegradability and the handling of contaminated soil. [3; 4; 5]

Alternative concepts

Tribology is the science of surfaces in relative motion and deals with friction and wear. Tribological systems consist of a base body and a counter body, the intermediate medium and the surrounding medium. Friction and wear are strongly influenced by the loading, the properties of the materials as well as the interactions between them. Especially lubricants and additives have a major impact on the tribological behaviour of the tribosystem [6].

Examinations of the CRC 442 have shown that many additivated mineral oils are ecotoxicologically harmful and have a poor biodegradability [7]. The aim of the CRC 442 was the development of environmentally friendly tribosystems without using additives. Instead, unadditivated ester lubricants from renewable basic materials were used. The developed lubricants were tested concerning their tribological performance as well as their ecotoxicity and biodegradability [8]. To improve the wear protection of the tribosystems without using additives, one surface of the contact bodies was coated by physical vapour deposition technique (PVD). The coatings deposited are very thin (in the range of micrometers) and have a high hardness and are chemically inert. One of the coating systems applied in the field of hydraulic components and rolling bearings is graded zirconium carbide (ZrC_g), which was developed at the Surface Engineering Institute of the RWTH Aachen University. Using coatings allows a renunciation of non-ferrous metal in hydraulic displacement pumps. The combination of surface coatings and the optimisation of the geometry of the components lead to a reduction of friction and wear [9]. It was shown that the coating was fully functional after the conducted tests. The coating system ZrCg was also applied to gear wheels [10].

Boundary conditions of the examinations

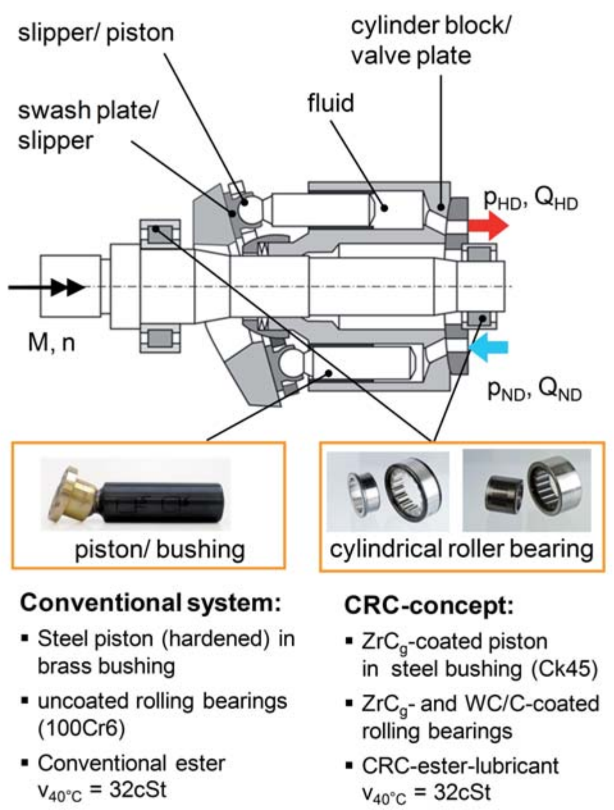
The developed lubricants and coating solutions were applied to a hydraulic displacement pump which is a central element in a hydraulic circuit. In the tests, the contact between piston and bushing as well as the rolling bearings were examined. The performance of the hydraulic displacement pump with coated components and lubricated by unadditivated synthetic ester lubricants developed within the CRC 442 was compared to a conventional system. The hydraulic displacement pump was tested close to real operation conditions with filtration units, cooling elements, valves and hydraulic resistances. **Figure 1** shows a cross section of the pump used for the examinations as well as the boundary conditions of the test.

The interpretation of the test results was conducted considering the results of the tests carried out in the test rig. It has been shown that PVD-coatings can give very good wear protection to rolling bearings and that they are able to replace additives for wear protection. Furthermore, the rolling contact fatigue lifetime of roller bearings was improved by the use of PVD-coatings depending on the boundary conditions [11].

Examination results

A comparison of the efficiencies indicates a slight improvement of the efficiency of the CRC 442 concept in comparison to the conventional hydraulic pump system [7]. This improvement depends on the speed as well as the system pressure. An increase in the particle emission of the pump was observed. An explanation for the higher concentration of particles is the material loss during running-in which takes place at the coated and uncoated components after a short period of time. The examination of the tested coated components after the experiment seems important for this reason, especially concerning the increase of emitted particles.

Fig. 1

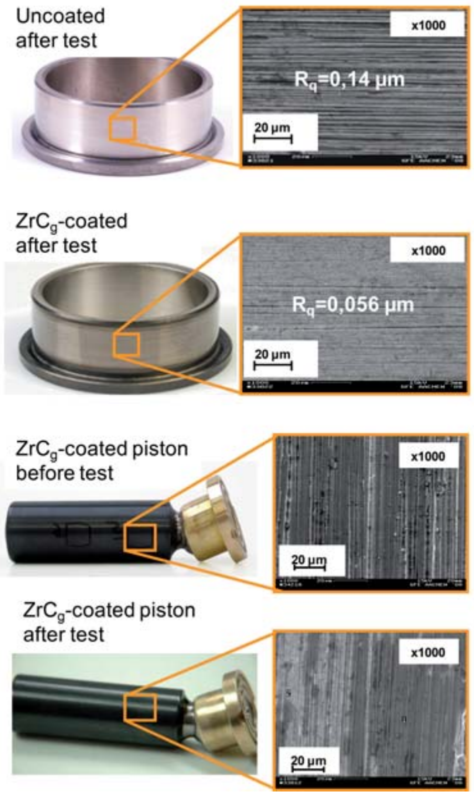


Hydraulic displacement pump; conventional and CRC-concept

The coated components have shown a running-in of the surfaces and a surface smoothing (**figure 2**). The roller bearings show significant material loss which is connected with a smoothing of the surface of the coated rolling bearing. The effect of the material loss as well as the smoothing had been observed in examinations in test rigs before. The test rig investigations have shown that the material removal depends on the contact pressure and the lubrication film thickness [7].

Coated pistons have shown a running-in behaviour connected with a removal of the roughness peaks. Due to the change to a hard-hard material pairing in terms of a coated piston and a steel bushing an increase in particles can be detected. Surface investigations showed no coating removal, but a running-in of the surfaces, resulting in good tribological properties [9]. Investigations of the metal content within the oil showed no significant values for the elements of the coating material, as zirconium (Zr) or tungsten (W). Instead, little wear of the counterbodies' elements were detected, as steel (Fe) or copper (Cu). These results underline the running-in behaviour of the used coating ZrC_g and show that the new design of the tribological system piston-bushing allows a reduction of friction.

Fig. 2



Rolling bearings after test (top), pistons before and after test (bottom)

Examinations concerning the lubricants after usage show that the change of the kinematic viscosity at 40°C is stronger for the reference lubricant in comparison to the CRC-ester lubricant. Both lubricants show an increase concerning ecotoxicity but the biodegradability was not affected. The biodegradation of the CRC 442 lubricant is rated as good according to the OECD-guideline (60% biodegradability within 28 days).

Conclusions

Environmentally friendly tribosystems can be realized by employing unadditivated synthetic ester lubricants and PVD-coatings. The efficiency of PVD-coated rolling bearings and hydraulic displacement pumps was shown in experiments close to reality. A surface smoothing as desired was found for the coated roller bearings and the coated pistons. The ester lubricant developed within the CRC 442 showed a good biodegradability even after usage.

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