ENERGETIC OPTIMIZATION OF AN EXISTING CLAMPING POWERPACK BY SYSTEM AND CONTROL CONCEPT ANALYSIS AND ADAPTION OF THE HYDRAULIC FLUID VISCOSITY

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ABSTRACT

Many hydraulic systems that have been in operation for several years are planned to be used further on some time. As nowadays the design objectives and possibilities are a lot more focused on energy efficiency than at the time these machines were build, retrofit activities such as energetic optimization are often useful in existing installations.

The clamping powerpack of an automated milling station is examined according to the control strategy of the pump motor by systematic measuring and recording of all relevant system parameters like operating status of the motor, activation status of control valves and pressure switches as well as the different hydraulic pressures in the system.

The system evaluation showed that the motor is driven at constant speed on demand by the controller of the milling station but with a time limited switch-on time, which leads to high losses due to oil flow over the systems relief valve. By improving the hydraulic system design, due to the addition of a pressure accumulator, and changing the control signal of the motor to a separate pressure switch, the energy consumption of the clamping powerpack is reduced by 89 %. In addition, the hydraulic oil viscosity was found to have no significant influence on the efficiency of the powerpack, which was presumed because of the specific application, where pressure, not flow, is the predominant parameter.

Keywords: clamping, power unit, efficiency, system, control concept

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1. INTRODUCTION

Major advantages of hydraulic systems are their very high reliability and durability which leads to very long machinery lifetimes. Therefore, much machinery installed years ago is planned to be used further on for some more time. Nowadays, energy efficiency is a much more important design parameter then it was at the time these machines were planed and manufactured. The potential of systematically energetic optimization of existing installations is significant and some measures can be realized with manageable effort. [1]

This study focusses on the optimization of the control concept and system architecture of a clamping powerpack of a milling machine where high amount of wasted energy was assumed.

2. METHODS

The investigations were done with a hydraulic powerpack of an automated milling station which consists of three combined production cells that were fed with workpieces by a robot. The production cells are initially 3-axis milling machines which were upgraded with a fourth axis and a hydraulic clamping unit. The hydraulic oil supply for the clamping and the locking of the fourth axis is realized via three separate powerpacks (one for each production cell). The hydraulic circuit diagram of the powerpacks is shown in **Figure 1**. For the evaluation of the control logic and understanding of the system behavior pressure sensors (Trafag 8252.34.2517) were installed at A and B ports of the clamping and the locking section and at the port MP for the pump pressure. Additionally, all signals of the pressure switches, the voltage of the valve solenoids and the voltage signal from the motor contactor are recorded with the DAQ system USB-AD16f (bmcm). For the investigation of the efficiency the power consumption was measured with the energy meter EASTRON SDM72D-M. The pulse output of the active energy from the energy meter was count on the digital input channel of the AD16f. The oiltemperature is recorded with a Parker SCT-150-0-02, connected to the DAQ via a SCM-200.

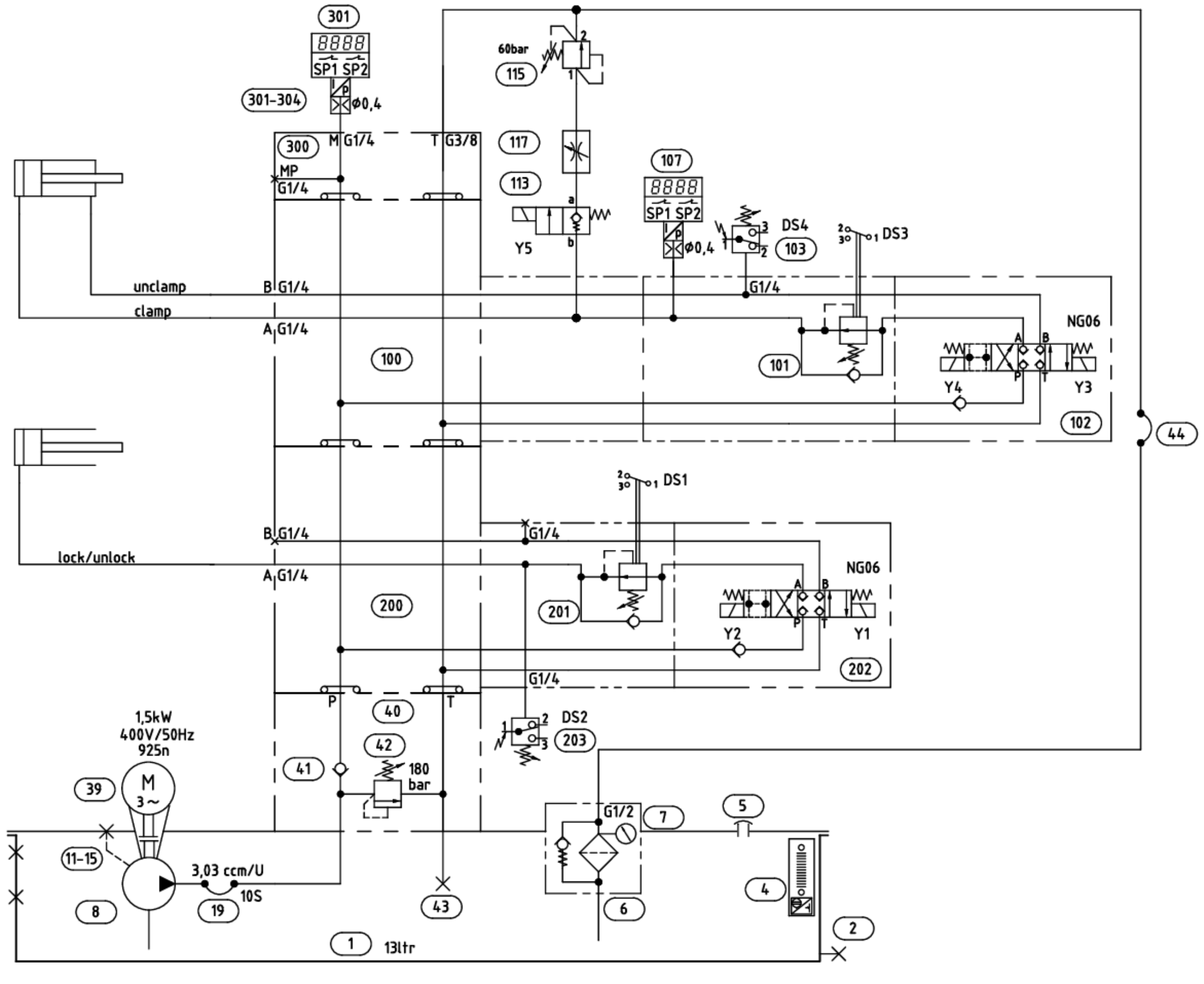

Figure 1: hydraulic circuit diagram of the powerpack

The first step of the evaluation was to record a typical cycle at the powerpack. This is absolutely necessary to understand the machine process and the logic of the higher-level machine control. In **Figure 2** a recording of the original cycle is shown. A cycle starts/ends with unclamping of the workpiece followed by a clamping and rotating the fourth axis to rinse the clamping jaw before clamping the new workpiece. The clamping pressure is adjustet to nearly 80 bar. The pressure to lock the rotation of the fourth axis is set to 65 bar. The main pressure relieve valve is set to 175 bar. At every clamping/unclamping and locking/unlocking operation the motor starts by request of the machine controller for providing required hydraulic energy. To ensure immediate availability of the pressure the motor is started 500 ms before the valve is activated. The motor stop is time-based after

5 s. This control concept leads to a calculated hydraulic energy consumption of 1,4 Wh ($E = \frac{p \cdot Q}{0,8} \cdot \Delta t$) [2] at every clamp or lock operation regardless of the actual energy demand. The motor is running 60 % of the cycle time of 483 s. while lot of energy is dissipated by the flow over the pressure relieve valve the oil temperature reaches a static value of 90 °C.

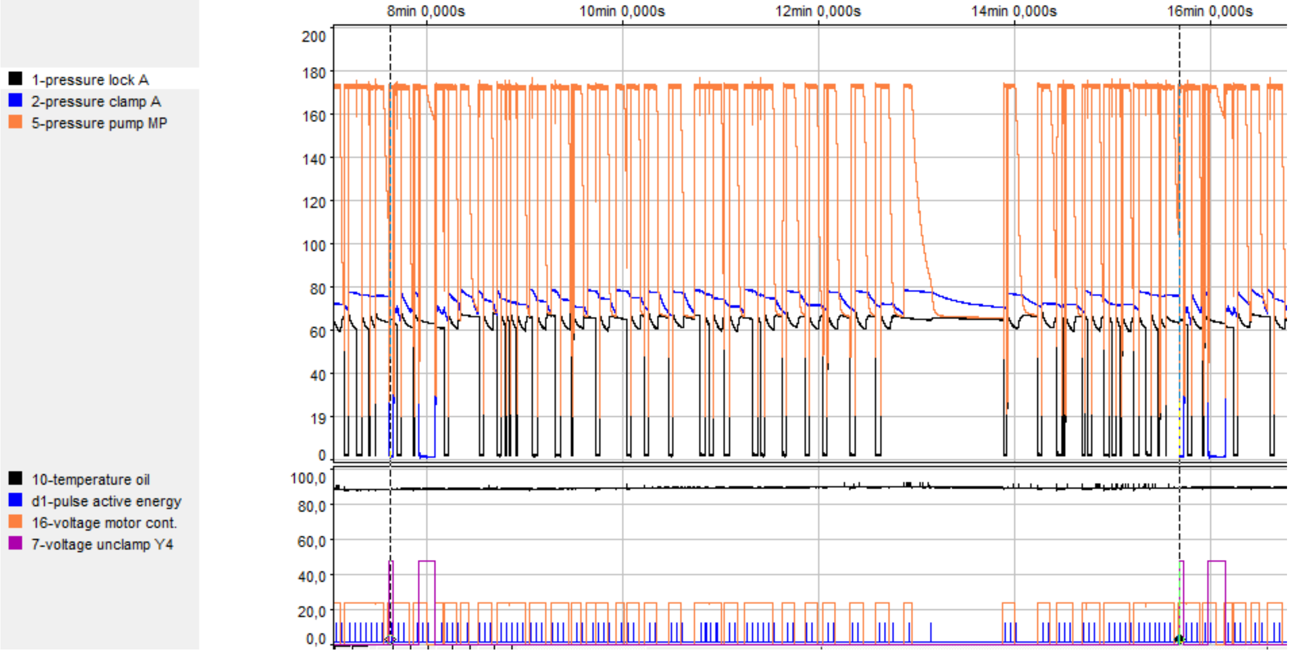

Figure 2: recording of powerpack cycle before optimization

By knowing the behaviour of the powerpack respectively the control logic from the recordings of the relevant system parameters it is totally clear that there hast to be found a solution to prevent the motor from pumping most of the time just over the system pressure relief valve. Several solutions would be possible but one of the easiest in this application is to integrate a small accumulator (0,75 l) at the port MP. The clamping and locking pressure are fed from the accumulator which just needs a few reloads within a cycle because the cylinders make very little stroke. Besides the modification of the hydraulic system a little modification on the electric side has to be done to realize the proper function of the higher-level machine control and the reload function for the accumulator. The higher-level machine control gives an output to the motor contactor every time a state of clamp/unclamp or lock/unlock should change. With no change in the motor control logic the pump would run almost the same duration over the relief valve than before. To solve that issue, without changing the control software, a separate pressure switch is installed at MP and the switching output is connected to the motor contactor replacing the signal line from the machine controller. These modifications are done with little effort on the hydraulic and electric system and without changes of the higher-level machine control logic. The control signals and software that are related to the functional safety of the machine (e. g. the signals of the pressure switches) are not changed.

The optimization results in a reduction of the oil temperature and thus the chance to select a lower oil viscosity to enable further savings through ideal oil selection. Two different tests are carried out to check the influence of viscosity on the efficiency of the power pack. In the first test, the temperature dependence of the viscosity is utilized and the power consumption is determined as a function of the oil temperature in order to make the influence of the viscosity visible. This test is done with the initial system design, where a temperature range from room temperature to 90 degrees can be examined. With the used oil AVIA FLUID HLPD 32 in this temperature range a viscosity range of 76 mm²/s – 6,7 mm²/s is tested. The second test is done with the optimized system and two different oils with the viscosity grades 32 and 10 (AVIA FLUID HLPD 32 and AVIA FLUID RSL 10), which leads to the viscosities of 76 mm²/s and 19 mm²/s at room temperature. The viscosities as a function of the temperature are calculated with the formulas of Ubbelohde and Walter respectively DIN 51563 [3, 4, 5].

3. RESULTS

A recording of a cycle of the optimized system is shown in **Figure 3**. The motor runs an average of 2,5 times per cycle to reload the accumulator whereas clamp/unclamp operation needs most of the stored hydraulic energy. To realize the lock/unlock operations within the cycle only one reload per cycle is necessary. The oil temperature remains at 22 °C, which corresponds to the room temperature.

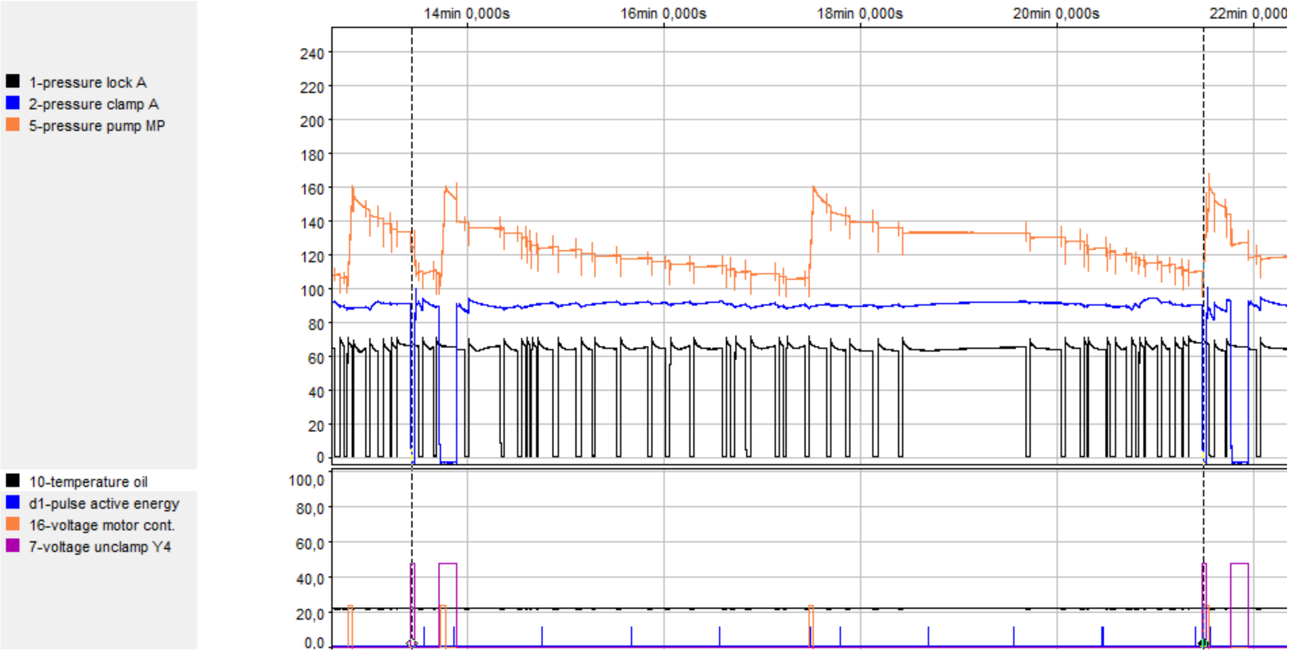

Figure 3: recording of powerpack cycle after optimization

The overall energy consumption of the powerpack is reduced from 96 Wh to 11 Wh per cycle which corresponds to a power reduction from 693 W to 79 W in relation to the cycle time. By analysing the period when the motor is not running the power requirement of the solenoid valves is determined to 66,5 W. That means that the power requirement of the motor in the optimized system is only 12,5 W on average.

The evaluation of the measurements to check the influence of viscosity on the power requirement did not show any significant effect. **Figure 4** shows the results of the first test with the original system at increasing temperature. There seems to be a slight reduction in power consumption with increased temperature, but the coefficient of determination is very low. With the conversion of temperature into viscosity there is also no significant dependency on the power consumption identifiable.

The overall effect of the optimization is shown in **Figure 5**. A huge decrease of the power consumption is realized by the optimization of the hydraulic system and the control strategy. The change of the hydraulic oil to a lower viscosity grade at the optimized system shows no significant influence on the power consumption. The chart includes measured values at different temperatures which is acceptable because no significant effect of the temperature was observed. By reducing the number of measured values in the chart of the optimized system with HLPD32 to a temperature of 24 °C the result is qualitatively equal. The only difference would be the omission of the lower whisker, due to the omission of the minimum measured value, which was measured at 36 °C. It should be noted that the energy meter used cannot resolve more precisely than 1 Wh and the values measured on the optimized system vary between 10-12 Wh per cycle regardless of the temperature (viscosity).

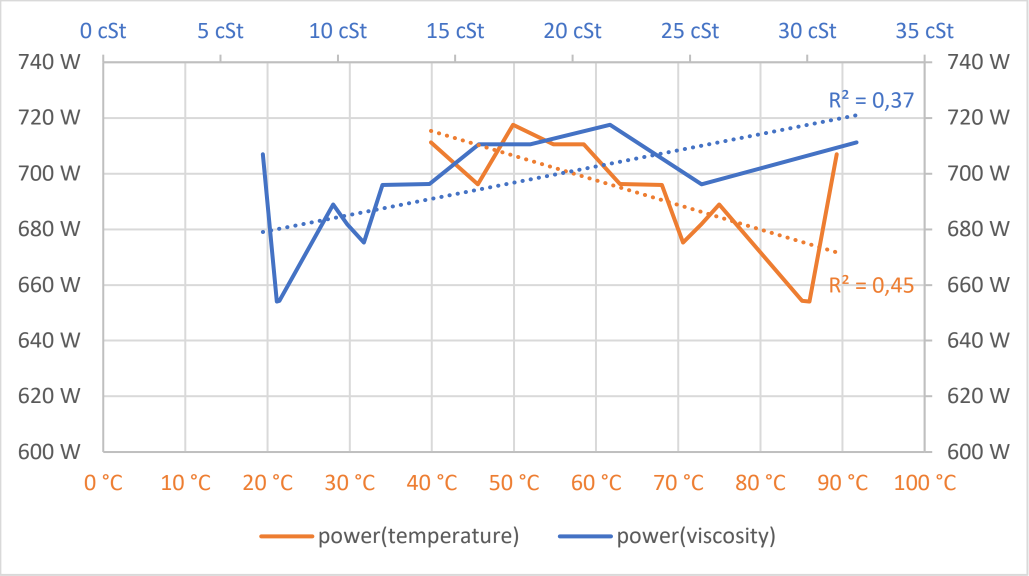

Figure 4: influence of fluid viscosity on the power consumption of the clamping system.

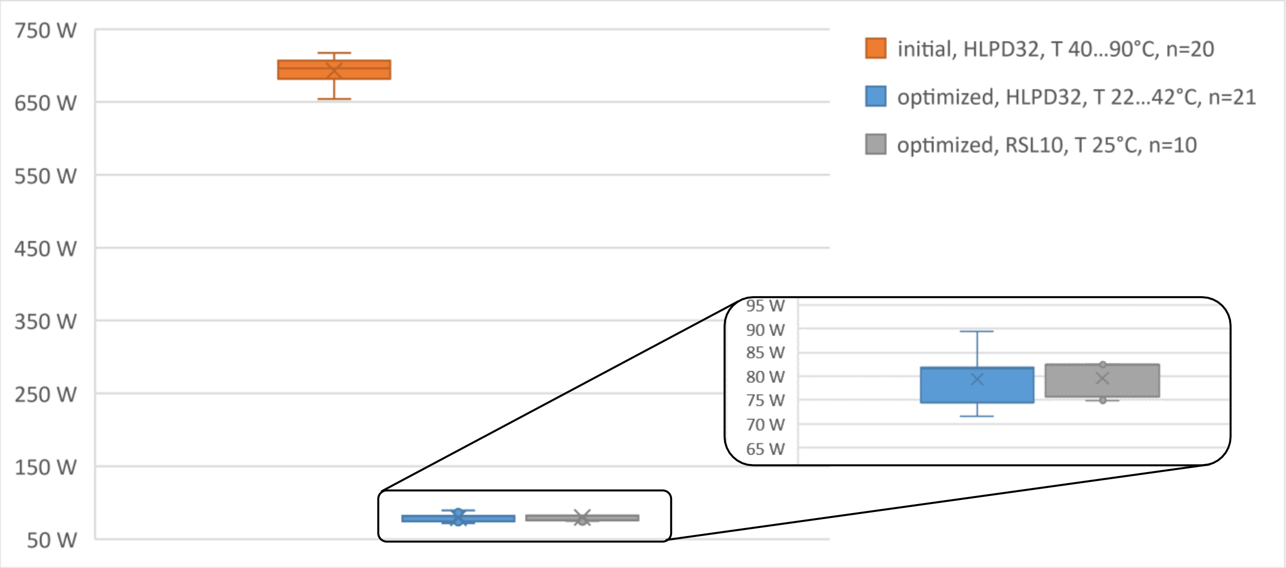

Figure 5: power consumption of the initial clamping system, the optimized system and the optimized system with a lower viscosity grade oil.

4. CONCLUSION AND OUTLOOK

A comprehensive analysis of the work process of the clamping unit and a critical examination of the implemented control strategy made it possible to identify considerable energy-saving potential. The power requirement was reduced by 89 % by making minor changes to the hydraulic system and the control of the clamping unit. The resulting reduction of the oil temperature from 90 °C to room temperature also extends the service life of the seals and the hydraulic oil, thereby increasing machine availability through reduced maintenance and repair times. The number of motor starts and the operating time of the motor were also reduced, which increases the service life of the motor, the relay and the contactor.

Unfortunately, no significant results were obtained for the influence of oil viscosity on energy efficiency. The reasons for this include the fact that the hydraulic performance of the clamping system in question is mainly defined by the required pressure and less by the volume flow and therefore the viscosity induced flow losses in the hydraulic lines are relatively low. It may be possible to prove an influence of viscosity with a higher number of measurements and the use of an energy meter with higher measurement accuracy. However, the present results show that any additional energy savings due to oil viscosity in this specific case are negligible, since the motor's average remaining power requirement is only 12,5 W.

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