Summary

In the context of energy saving, including cost reduction, Fontijne Grotnes (FG) has increased its attention to improve existing machines that use too much energy. They prefer to start optimizing these machines by using simulation models, in order to have a good understanding before it is implemented in practice. This will increase the cost reduction in a positive way. The "pipe expander" is analyzed in this report. This machine is able to expand pipes to obtain a precise sizing of their internal diameter.

FG has commissioned to simulate a part of the hydraulic system of the pipe expander in 20-sim. The simulation contains several subsystems of the machine; "power cylinder" and "main hydraulic system". Before a simulation model of the pipe expander can be modeled, a short literature research about the working of the machine has been conducted. An important subsystem of the machine is the hydraulic cylinder. This part ensures the translation of the cylinder rod. To move the cylinder rod according to the position setting, a required pressure and flow rate is needed in the cylinder. This pressure depends on the flow rate in the system, which is provided by the hydraulic pump. This force depends on the dynamic force and the expand force from the expander head. When the force that is needed to expand the pipe is known, the power of the cylinder can be determined. After that, the pressure and the flow rate of the cylinder can be calculated, which leads to the understanding how the pumps system affects the output power of the cylinder.

This first simulation model approaches the machine which can only displace a mass in one direction. With some assumptions for different components, three situations of the model is investigated, each with its own assumptions on the components of the system. In the first situation where the rear rod diameter is increased, it shows that the flow rate and the pressure of the system is changed. In the second situation where the pump pressure is set higher, the system responds faster. And in the last situation, where the rod diameter of both cylinder sides is equal, it shows that the maximum pressure in the system can still be lower than the verified model, while the pump pressure is higher. This simulation model has shown that there is a start to simulate a part of the pipe expander. A next step is an implementation of the external force, which comes from the cylinder head, when it expands the pipe.

In the second simulation model, the model is improved with an external force component. The external force is simulated as a standard 20-sim LuGre friction model, which approaches the real expand force well. This model can translate a mass with a external force in only one direction. To see if the assumptions remains the same as in the first simulation model, a number of situations is considered in order to confirm this. After verification of the improved simulation model, three other situations are described; increasing the pump pressure, changing the rod diameter and setting the rod diameter equal at both cylinder sides.

When the pump pressure is set higher, the system responds faster and therefore the setting position profile can be approached in a more accurate way. A disadvantage when increasing the pump pressure is the high acceleration peaks in the system. When increasing the rear rod diameter, the acceleration peaks of the cylinder will increase and therefore the velocity peaks will be higher as well. This behavior occurs during the transition from the “slow expanding” state (when the cylinder has almost reached the setting position) to the “dwelling” state (when the cylinder has reached the position and does not move). In the situation, when the cylinder rod is set equal for both cylinder sides, the system responds slower, and so the accuracy of the reference will decrease. However, the required position setting of the cylinder (XXX [mm]) can still be achieved. Moreover, the starting pressure at both cylinder sides will increase, which causes a higher pump pressure. Also the maximum cylinder pressure is higher as well at the front side of the cylinder and at the state “dwelling”.

In the third simulation model, the pump model has been improved with a more realistic pump model. When the pump model is simulated as the variable displacement pump model, including leakage, the needed flow rate is not achieved and therefore the setting position cannot be reached in time. The positive point of this model is that, there is almost no counter pressure between both cylinder sides at the state when the cylinder is pulling, so the needed pump pressure is not high for that part of the simulation. When increasing the rotation speed of the motor higher than 400 [rad/s], the system becomes unstable. When using the ideal displacement pump model instead of the variable displacement pump model, the pump can deliver the required flow and pressure. Therefore, the needed output power of the cylinder can be reached. When the external force model is changed from a function of the time to a function of the position, the system pressure will be higher and so the power of the pump is larger. When the external force is a function of the position, the system approaches the real external force better.