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INFLUENCE OF EXTERNAL PROCESS FLUID INJECTION ON THE CONVEYING BEHAVIOUR OF SCREW PUMPS WITH DECREASING SPINDLE PITCH

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1. ABSTRACT

External process fluid injection into the screw pump with a progressive spindle pitch counteracts the decrease in delivery rate at high gas volume fractions (GVF) and increases both the volumetric and isothermal efficiency. In experiments with a progressive spindle, the injection position, injection volume flow, rotational speed, differential pressure and gas content are varied to determine the impact of process fluid injection on the conveying behaviour. Pressure-side injection shows the highest improvement potential in the experimental investigations. This result is confirmed by measured local state variables (p, T).

2. INTRODUCTION

In many energy conversion and process engineering applications, multiphase fluids must be conveyed. Conventional pumps or compressors are not capable of handling this, necessitating the complex thermal separation of multiphase systems. To avoid this and thereby increase energy efficiency as well as conserve resources, multiphase screw pumps are utilized to convey multiphase gas/liquid mixtures. This particular type of positive displacement pump can convey not only multiphase systems but also those with high GVF of up to 90 % and, for short periods, 100 %. They are used, among other applications, to enhance the efficiency of low-temperature steam processes, as the pressure increase can be adapted to the respective refrigerant, eliminating the need for high superheat. Screw pumps consist of axially parallel, intermeshing spindles that, in combination with the housing, form a series of closed chambers. These chambers are moved from inlet to outlet by the rotational movement of the spindles. In the case of a progressive spindle pitch, the chamber volume continuously decreases towards the pressure side. The gaps between the spindles and the housing, inherent to the design, are sealed by the conveyed liquid. When the gas content increases, the remaining liquid no longer adequately seals the gaps, leading to a decrease in delivery performance and an increase in thermal load. The external injection of process fluid regulates the thermal management of the multiphase pump (cooling) and improves the gap sealing in the delivery chamber (efficiency). At the department of Technical Thermodynamics, a pilot-scale facility has been set up to optimize multiphase conveying, e.g., through external fluid supply. Inside the machine, numerous pressure and temperature sensors are installed to analyse the thermo- and fluid dynamics. These sensors are used to resolve the pressure and temperature profiles along the compression process both axially and azimuthally.

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3. METHDOLOGY

The experimental apparatus is depicted schematically in *Figure 1*. The system utilizes paraffinic white oil and air as working fluid. The mixture of oil and air is separated in a pre-separator (1) into gas and liquid phases. Pump (2) and compressor (3) move the liquid and gas phases, respectively, mass and volumetric flow rates are measured (4). Heat exchangers (5, 9) control fluid temperatures. The oil tank (6) serves as a reservoir, and a static mixer (7) recombines the phases before the multiphase screw pump (MPP) (8) circulates the mixture. An additional oil pump (10) injects the liquid directly to the MPP. The system allows for both suction-side (VAR1) and discharge-side (VAR2) injections, each with four injection ports, monitored by a volumetric flow sensor. Needle valves adjust the injection rates precisely. Temperature and pressure sensors are installed within the pump housing to capture local data during the multiphase compression process.

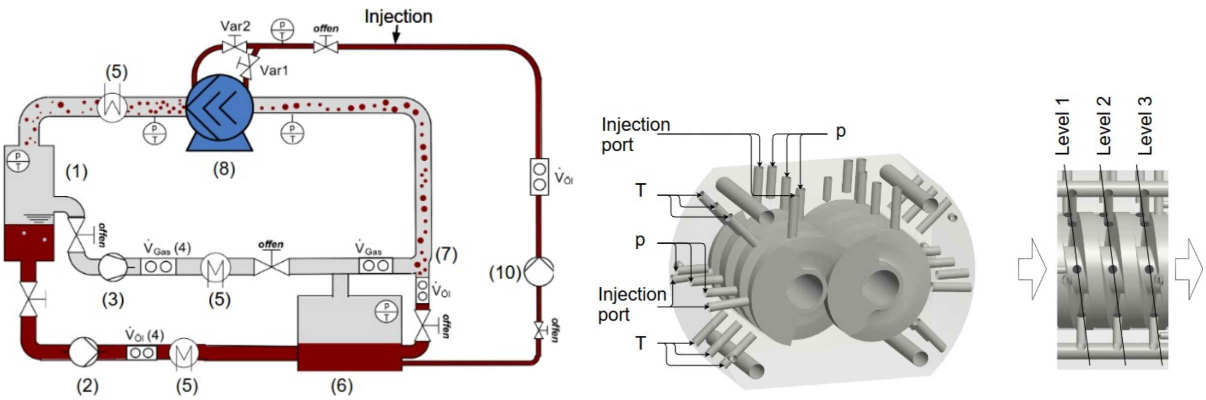
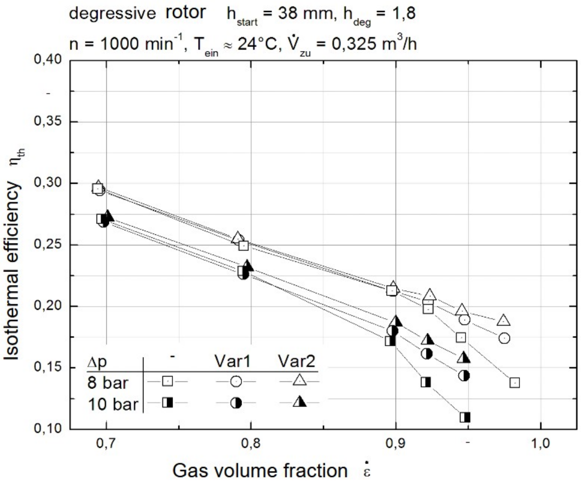


Figure 1: Experimental setup (left) and instrumentation of the multiphase pump (right)

4. RESULTS

Figure 2 (left) presents the isothermal efficiency plotted over the GVF for 8 and 10 bar differential pressure. Square icons indicate no external process fluid injection, while a circle represents the suction side injection and a triangle the discharge side injection. In general, the efficiency drops linearly until GVF of 0.9 before declining further. It can be seen that for both differential pressures the efficiency drops after GVF of 0.9 can be mitigated by injecting process fluid. Here the discharge side injection shows the best improvement especially at high GVF. A similar result is depicted for the volumetric efficiency *Figure 2* (right). While the efficiency without injection drops significantly over GVF of 0.9 the fluid injection is able to seal the gaps between rotor casing and spindle much better, hence the efficiency does not drop as significantly. Once more the discharge side injection yields a higher efficiency at very high GVF. This is due to the pressure built up along the spindle axis within the pump. The pressure difference between two neighbouring chambers increases in direction of the discharge side. Hence sealing chambers close to the discharge side results in a better conveying behaviour than injecting into the suction side where the pressure difference is less.



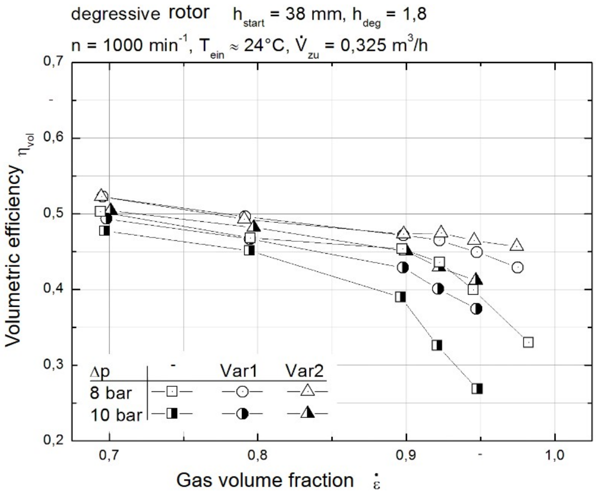


Figure 2: Isothermal (left) and volumetric (right) efficiency over GVF for n = 1000 min^{-1} and different differential pressures

At high GVF the discharge temperature starts rising rapidly due to compression heat. External fluid injection counteracts the temperature increase by sealing gaps, between housing and spindle, through which already compressed high temperature gas would flow back to the suction side. *Figure 3* shows the temperature differentials for the reference measurement without fluid injection as well as with suction and discharge injection of process fluid.

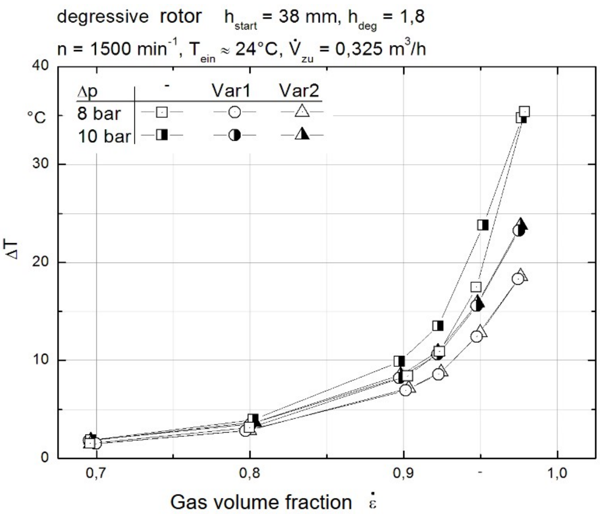


Figure 3: Temperature difference between suction and discharge over GVF

For GVF below 0.8 there is no observable impact for process fluid injection. At very high GVF both injection variants show significant improvement regarding the thermal load as well as isothermal and volumetric efficiency compared to a conventional operation.

5. CONCLUSIONS

Pumping multiphase mixtures efficiently at high GVF is of great interest and screw pumps are able to convey such mixtures. To increase efficiency at high GVF external process fluid injection is utilized. The discharge side injection achieves the biggest efficiency improvement compared to the baseline without injection.

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