Numerical investigation of refrigerant outgassing in the screw pump of a hermetic reciprocating compressor oil supply system

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Introduction and Modelling
Proper lubrication plays a major role in assuring compressor reliability and energetic efficiency, particularly in variable capacity compressors adopted in household refrigerators. In order to achieve that, the understanding of the complex two-phase flow of oil-refrigerant mixtures in the oil supply system is required.

In hermetic compressors the oil and the gas are in contact with each other, exchanging mass, momentum and heat. When dissolved in the oil, the gas alters the mixture properties, reducing its viscosity when compared to the pure oil, which is detrimental to the oil lubricity. The solubility of the gas in the oil depends on pressure and temperature, so when pressure decreases in the oil supply system the refrigerant comes out of solution, giving rise to bubbles that may lead to noise generation.

Although several models have been presented to investigate the oil supply system of hermetic compressors, none of them have accounted for the interactions between the lubricating oil and the refrigerant gas. All the available models consider both fluids to be immiscible, with constant properties and no mass transfer (refrigerant absorption and outgassing).

This paper executive summary reports the analysis of refrigerant outgassing in the screw pump of a hermetic reciprocating compressor oil supply system by using a CFD two-phase model. The interfacial mass transfer between the refrigerant and the lubricating oil is modelled by means of a cavitation model based on the Rayleigh-Plesset equation, considering the mass fraction of refrigerant dissolved in the lubricant oil constant, corresponding to the solubility of refrigerant in oil at the crankcase pressure and temperature. The effects of (i) the empirical calibration coefficients required by the cavitation model, (ii) compressor speed and (iii) compressor crankcase pressure are assessed by comparing the oil mass flow rate and the oil volumetric fraction field for each simulation.

Results
Simulations were carried out to investigate the influence of empirical calibration coefficients, compressor speed and reference pressure on the refrigerant desorption phenomenon. The effects of the parameters were evaluated based on the oil mass flow rate and the oil volumetric fraction field in the center cross section of the screw pump. The main results are:

- The empirical calibration coefficients proved to strongly affect the refrigerant outgassing, as the values of the coefficients increase, the oil flow rate decreases, due to more refrigerant outgassing. In the most detrimental case, the oil flow rate is 47% smaller than the case in which
no cavitation model is employed. In this case, a stratified flow pattern is established within the screw pump.

- The increase of the compressor speed intensified the refrigerant outgassing, reducing the oil volumetric flow rate. This reduction increases with the compressor speed, reaching 50% when the rotation speed was set to 3000 rpm.
- On the other hand, the model predicted a very small effect of the pressure inside the compressor environment on the refrigerant outgassing, which is probably related to its limitation of assuming a fixed mass fraction of refrigerant dissolved in the oil regardless of the pressure value.

**Conclusion**

The results reveal that significant outgassing of refrigerant may take place in the oil pump. Although the presented model is relatively simple, the findings of the present study highlight the importance of further analysis since refrigerant outgassing may lead to several issues. In future work, the adoption of a model that calculates the gas mass fraction in the oil via a transport equation should address the main limitation of the model proposed herein. It would also be important to develop an experimental rig to investigate the two-phase flow and generate data to validate the model.