Performance tests of a vapor injected scroll compressor in an economized vapor compression cycle

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Introduction

Vapor injected (VI) scroll compressors have an extended operating range due to their reduced discharge temperature. Combined with an economizer cycle as represented by the internal heat exchanger (IHX) the VI compressor may also increase the specific cooling capacity of a refrigeration machine and thus improve its coefficient of performance (COP).

![Figure 1: (A) Economized vapor compression cycle with a VI compressor and (B) its qualitative p-h diagram](image)

In this study the performance of a VI compressor was tested at different operation conditions and injection conditions using a modified compressor calorimeter.

Performance test setup

The utilized compressor calorimeter as shown in Fig. 2 is a regular vapor compression cycle. It allows the control of the condensing and evaporation temperatures $T_C$ and $T_D$, the suction superheat $\Delta T_{SH}$, and the compressor chamber temperature $T_{cham}$, and enables the measurement of the cooling capacity $Q_0$ and the compressor power $P_{el}$.

![Figure 2: FI diagram of the modified compressor calorimeter](image)

The modification (green) represents the economizer cycle and enables a control of the injection mass flow rate using an electronic expansion valve (EXV). This leads to different injection pressures $p_{inj}$ and different injection superheat values $\Delta T_{SH,inj}$, respectively

Test Matrix and Results

The performance tests were carried out for a 67cc VI scroll compressor with R-407C. The suction superheat and the compressor chamber temperature were kept constant at $\Delta T_{SH} = 11.1$ K and $T_{cham} = 35$ °C. The scroll compressor was tested with and without vapor injection at the operating condition $T_D = 4.5$ °C and $T_C = 48.9$ °C.

The results of the injection tests are shown in Fig. 3 which represents each value relative to its baseline test value (BL) as defined by the following equations.

$$Y^{rel} = \frac{Y - Y^{BL}}{Y^{BL}} \quad \text{for} \quad Y \in \{Q_0, P_{el}, \text{COP}, \lambda, \eta\}$$

$$T^{rel} = T - T^{BL}$$

The results indicate an increase of $Q_0$ by 10 to 20 %, a reduction of $T_{cham}$ by up to $-2.5$ K, and an improved cooling COP (up to 2.5 %) during vapor injection. For two phase injection $T_{cham}$ is reduced even further (here by $-20$ K). However, this also leads to a declined cooling COP and compressor efficiency $\eta$. During injection the volumetric efficiency $\lambda$ and $\eta$ are reduced, which indicates increased internal losses.

![Figure 3: Relative performance data of the tested VI compressor](image)

Conclusions

The tested unit (VI compressor and economizer cycle) can be used to reduce the discharge temperature and improve the COP of a vapor compression cycle. In regard to COP and cooling capacity optimization, saturated vapor injection seems favorable. For a proper characterization of a VI compressor the injection pressure needs to be included in future performance test matrices.