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Low Cost Level Sensing for Receivers in Small Sized Refrigeration Systems with Natural Refrigerants

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Summary: Natural refrigerants, such as porpane (R290), are increasingly being used in refrigeration systems and heat pumps due to their positive environmental properties in comparison to other refrigerants. This applies in particular to small refrigeration systems. Due to the flammability potential, sensors that monitor the refrigerant charge are of interest. In this work we study the feasibility of low cost level switch using ultra sound transducers. The detection of the refrigerant is based on a de-tuning effect, which allows a low cost implementation.

Keywords:
level sensing, vessel, natural refrigerants, refrigeration systems, heat pumps

Introduction

Compression refrigeration systems and heat pumps have become a main system component for the cooling and heating of buildings [1]. Due to their environmental impact and international regulations, previously used refrigerants such as hydrofluorocarbons (HFCs) should no longer be used in new systems. To replace these conventional refrigerants, natural refrigerants such as hydrocarbons, e.g. R290 (propane), or R717 (ammonia), are to be used [2]. Due to the potential flammability of some of these refrigerants, new regulations have been introduced for their application [3], e.g. a maximum refrigerant charge. Therefore, the use of natural refrigerants is particularly relevant in small refrigeration systems. To minimize the risks due to the refrigerants, leakage detection systems are also of interest. In the case of small refrigeration systems, the implementation of a leak detection system is of further interest, as it is able to detect minor losses of refrigerant before they compromise the system's efficiency.

The need for such sensors either level sensors, or level switches, has been addressed by various researchers [3, 4]. In this work we investigate the feasibility of low cost ultrasound (US) level sensing based on a de-tuning effect of small vessels. Figure 1 sketches the scheme. A US transducer is mounted on the outside of the refrigerante receiver. A photography of a typical refrigerante receiver is depicted in the small inset in Figure 1. For the sensing task a pulse signal is used as excitation signal for the US transducer. The resonance behavior of the transducer is influenced by the refrigerant level within the refrigerante receiver, where the presence of a liquid refrigerant will lead to a dampening effect for the oscillation of the transducer. A simple way to sense this is evaluating the peak magnitude of the oscillation after the excitation. In the following procedure, a test bed and measurements are presented to show the feasibility of the approach.

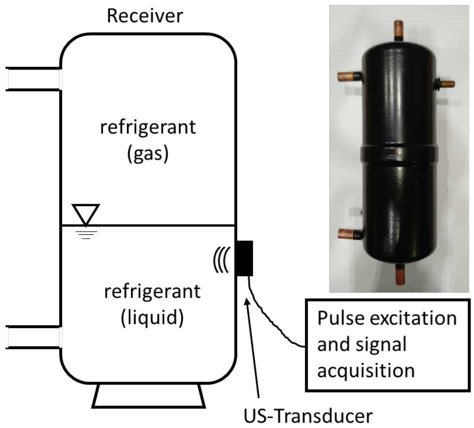

Fig. 1: Photography of an receiver for small compression refrigeration systems and sketch of the proposed level sensing approach using an US transducer.

Test Bed and Measurements

In this section, the test bed for the experiments and the proposed measurement procedure are addressed and results are presented. Figure 2 shows a photography of a test bed for the evaluation of the proposed sensing approach. It consists of a receiver and a second tank to adjust the fill level via height adjustment. For reference measurements a sight glass is installed. The experiments are performed with propane (R290) as refrigerant.

To test the proposed sensing principle a US-transducer was mounted on the wall of the receiver. Figure 3 depicts two measured signals

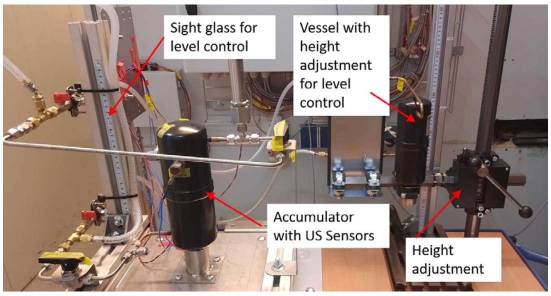

Fig. 2: Test bed for the evaluation of the sensing approach. The central element of the test bed is an refrigerant receiver, where the US transducers are applied. The level of the refrigerant is controlled by the height of a second vessel. A sight glass is used for the level control.

and a sketch of the measurement circuitry to apply a high voltage pulse to the transducer. The voltage signals show the pulse excitation at $t = 10\,\mu s$, which are followed by some oscillations with a high frequency, which are due to electrical parasitics. Afterwards, at about $t = 15\,\mu s$, the voltage signal is dominated by the mechanical oscillations of the transducer, which are influenced by the liquid level of the refrigerant. For the sensing of the refrigerant, the negative peak of the transducer signal is evaluated as marked in Figure 3.

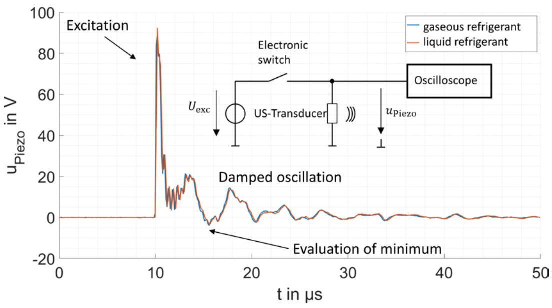

Fig. 3: Scheme of the measurement circuitry and measurement signals from the US transducer with gaseous refrigerant (blue) and liquid refrigerant (red).

Figure 4 depicts a statistical evaluation of the minimum voltage level of the oscillation over a series of experiments. The inset inside the figure shows the relevant sequence of the signal. The evaluation of the signals shows a separation of the minimum values, which can be used to detect the liquid refrigerant in the vessel. In the presence of the liquid refrigerant at sensor hight, the negative peak value is smaller, which corresponds to the increased dampening due to the liquid fluid inside the vessel. The raw data shows an overlap between the states. Here, detection can be improved by averaging [5]. While all experiments have been performed with lab equipment, the procedure can be realized with low hardware effort.

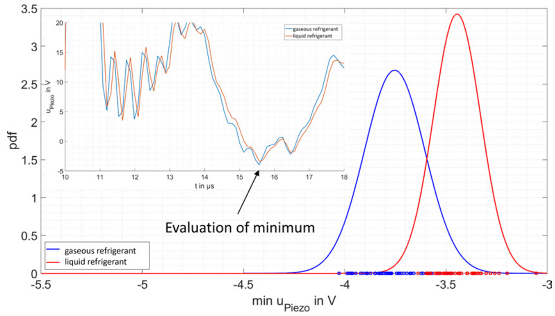

Fig. 4: Statistical evaluation of the minimum voltage level of the US resonance with gaseous refrigerant (blue) and liquid refrigerant (red).

Conclusion

In this work the feasibility of a low cost ultrasound (US) based level sensing based on a de-tuning effect on small refrigerant vessels was demonstrated. The final paper will include a more detailed study, addressing application specific details and an analysis of cross sensitivities.

Acknowledgement

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