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H. H. Cho
*Korea University*

Y. Kim
*Korea University*

# EXPERIMENTAL STUDY ON AN INVERTER-DRIVEN SCROLL COMPRESSOR WITH AN INJECTION SYSTEM

**Hong-Hyun Cho*, Yongchan Kim****

* Graduate Student ** Associate Professor

Dept. of Mechanical Engineering, Korea University, Sungbuk-Gu, Seoul, 136-701, KOREA

Fax: 82-2-921-5439, Phone: 82-2-3290-3366, E-mail: yongckim@mail.korea.ac.kr

## ABSTRACT

For an inverter-driven compressor, the discharge temperature increased with a rise of frequency. Therefore, it is necessary to control the discharge temperature at high frequencies in order to obtain system reliability and efficiency. This paper describes the effects of an injection system on the performance of an inverter-driven scroll compressor. As results of the present work, the refrigerant discharge temperature for the injection system dropped approximately 10~20°C as compared to those for the non-injection system. The COP of the compressor was improved approximately 0.8~9.3% at high frequencies (75, 90, and 105 Hz). The injection port at 180° showed a lower discharge temperature and a higher COP as compared to those at 90°.

## INTRODUCTION

When an inverter-driven compressor operates at low outdoor temperature conditions, high compression ratios and high frequencies are required to compensate a shortage of heating capacity. The increase of the frequency results in a higher discharge temperature. The reliability and efficiency of the compressor decrease with an increase of the discharge temperature due to its detrimental effects on oil and compressor elements. Recently, several techniques for discharge temperature control were introduced in the open literature. One of them is the injection technique. The benefits of using the injection technique are a decrease of the discharge temperature and an enhancement of the heating capacity at high compression ratios.

The most important factor in the development of an energy efficient heat pump system is the performance of a compressor because approximately 90% of the total power was consumed in a compressor. The scroll compressor was adopted in the present study, because it has advantages of high efficiency, low-vibration and low-noise. The less power is also required due to small change of starting and operating torque for the compressor. Lots of research has been performed on the scroll compressor, but the research on the scroll compressor with the injection system is very limited. The objective of the present work is to provide the performance data of the scroll compressor with the injection system. The present paper describes the effects of the injection system on the performance and discharge temperature of the inverter-driven scroll compressor.

## EXPERIMENTAL APPARATUS AND TEST METHOD

The test compressor used in this experiment has a rated capacity of 3.5 kW. It has a back-pressure chamber on the fixed scroll. The injection port was precisely manufactured passing through outer shell and fixed scroll. Two injection ports were installed at 90° and 180° from the suction position with a diameter of 1.0 mm. However, one injection port was used for the series of tests by blocking the other port located at different orbit angle.

Fig. 1 shows the refrigerated compressor calorimeter used in the experiment of the inverter-driven scroll compressor with the injection system. Refrigerant leaving the condenser was divided into two lines: one is the main stream entering into expansion device and the other is the bypass stream entering into the subcooler that adjusts the state of injected refrigerant. The needle valve controls injected mass flow and pressure in a large range, and the capillary tube allows the precise control of their values. The heating unit keeps the refrigerant entering the test compressor at superheated vapor state. The experiment was performed under ASHRAE-T conditions. The injection pressure varied from 900 kPa to 1200 kPa, and frequency altered from 45 Hz to 105 Hz. The mass flow rate of the injected refrigerant was measured using the mass flow meter before the expansion device in the bypass line. Temperature and pressure of the injected refrigerant were measured at the inlet of the injection port.

## RESULTS

### Comparison of the performance of the injection with the non-injection system.

Fig. 2 shows the comparison of the discharge temperature of the injection with the non-injection system. Except the injection conditions of 45 Hz and 900 kPa, the discharge temperature of the injection system drops approximately 10~20°C as compared to those of the non-injection system. Since the injected mass flow increases with the injection pressure, the discharge temperature drops. The discharge temperature at a frequency of 45Hz is higher than that at a frequency of 60 Hz due to a large amount of leakage in the compression process. The discharge temperature of the injection system at 900 kPa and 45 Hz is higher than that of the non-injection system because of back-flow caused by a lower injection pressure.

Fig. 3 shows the effects of the injection on the power input to the compressor. Generally, the power input to the compressor can be determined from total mass flow rate and enthalpy difference across the compressor. The total mass increases and the enthalpy difference across the compressor decreases with an addition of injected mass. The power input either decreases or increases depended on the difference in relative effects of these factors. The compressor power input with the injection is higher than that of the non-injection system at 45 Hz. It was due to that the effects of an increment of total mass were relatively higher than those for inter-cooling with the injection at low frequencies. However, the trend was reversed as the frequency increased over 90 Hz. For high frequencies, the inter-cooling effects from the injected mass were relatively significant.

Fig. 4 shows the cooling capacity for the injection and non-injection system. Generally, the injection system shows higher cooling capacity than that for the non-injection system due to an increase of mass during the compression process. However, the cooling capacity at a frequency of 45 Hz is not raised with the injection due to an increase of leakage in the compression process. For high frequencies, the discharge mass flow rate increases with the injection due to relatively low leakage in the compression process. The difference in the cooling capacity between the injection and non-injection system becomes larger as the frequency increases.

Fig. 5 shows the comparison of COP of the injection with that of the non-injection system at each frequency. The COP of the compressor was improved by injection at a frequency over 75 Hz, but it was reduced at low frequencies such as 45 and 60 Hz. For low frequencies, the compression power increases due to a rise of injected mass, but the cooling capacity does not increase due to an increase of leakage. However, for high frequencies, the COP enhanced due to a drop of the compression power and an improvement of the cooling capacity.

## Effects of the location of injection port on the performance

Since the pressure during the compression process varied with the location of injection port, the injected mass significantly altered with a variation of injection position. Fig. 6 shows the injected mass flow rate vs. injection pressure with a variation of injection position. The injected mass increases with a rise of the injection pressure. The injected mass at an orbit angle of 90° is larger than that at an orbit angle of 180° because the injection port at 90° is located near suction ports. The pressure at 90° is lower than that at 180°. For low frequencies, the difference in the injected mass between at 90° and 180° is considerable, while for high frequencies it is negligible.

Fig. 7 shows the discharge temperature vs. injection pressure with a variation of injection position. Generally the discharge temperature decreases as the injection pressure increases. The compressor has a lower discharge temperature at 90° with 45 and 60 Hz, and at 180° with 105 Hz. When the injected masses are the same for both positions, the discharge temperature at 180° is lower than that at 90°. Therefore, refrigerant injection at 180° is more effective to reduce the discharge temperature and enhance inter-cooling effects. Fig. 8 shows the COP vs. injection pressure with a variation of injection position. The COP decreases as the injection pressure increases. The COP of the compressor injected at 180° is higher than that at 90°. A higher volumetric efficiency is observed at 180° due to a longer compression period.

## CONCLUSIONS

The experiment was performed on the inverter-driven scroll compressor with the injection system. The characteristics of the scroll compressor were analyzed in terms of discharge temperature, power consumption, cooling capacity, and COP of compressor. As a result of the present work, the refrigerant discharge temperature for the injection system dropped approximately 10~20°C as compared to those for the non-injection system. The COP of the compressor was improved approximately 0.8~9.3% at high frequencies (75, 90, and 105 Hz) because the compressor power decreased by means of inter-cooling and the cooling capacity enhanced with injection. The COP of the compressor with the injection system was not improved at low frequencies due to an increase of the compressor power and leakage. In addition, the injected mass increased and the discharge temperature decreased when the injection port was located near the suction ports.


## ACKNOWLEDGMENTS

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## REFERENCES


1. Diab, T. A. R. and Gephart, J, Compressor technologies for low temperature applications of R-22, International Journal of Refrigeration, Vol. 14, pp.5-9, 1991.
2. Hickman, C., et al, Implications of cooling rotary sliding vane heat-pump compressors, International Journal of Ambient Energy, Vol. 5, Num. 4, pp. 207-212, 1984.
3. Morishita, E., et al., Scroll compressor dynamics, Bulletin of JSME, Vol .29, No. 248, pp. 476-482. , 1986.
4. Tojo, K., et al., Computer modeling of scroll compressor with self-adjusting back-pressure mechanism, Proceeding of 1986 International Compressor Engineering Conference at Purdue, pp. 872-886, 1986.
5. Dong-hyeon Kim, Dong-koo Shin, Sung-Oug Cho, An experimental analysis on the flow rate in scroll compressors, Proceeding of 1998 International Compressor Engineering Conference at Purdue, pp. 872-886, 1998.


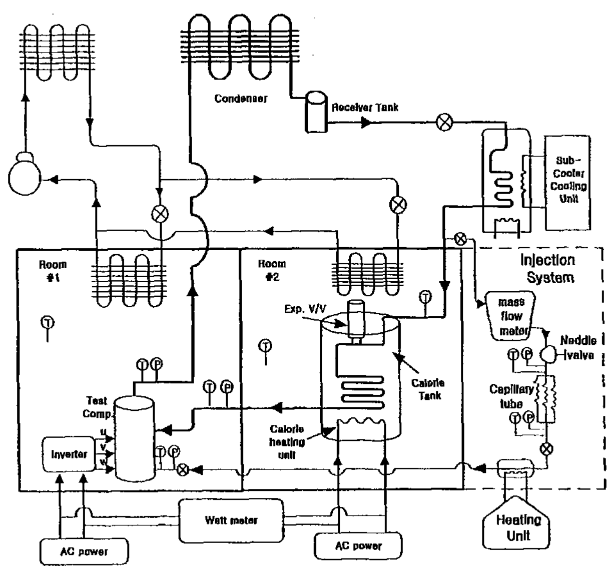


Fig. 1 Schematic diagram of compressor calorimeter.

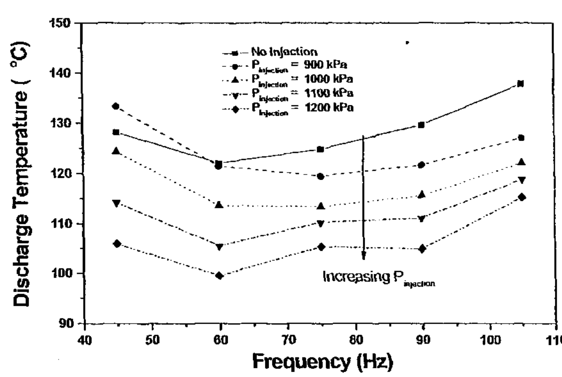


Fig. 2 Comparison of discharge temperature for injection with non-injection system.

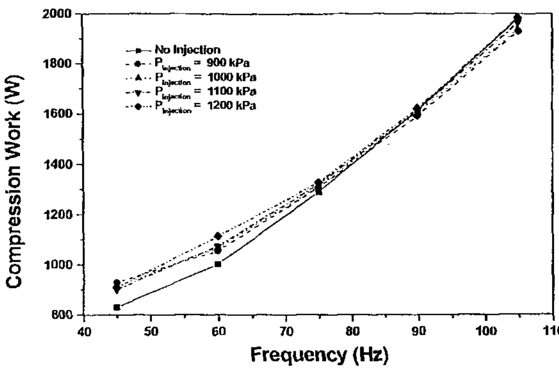


Fig. 3 Comparison of compressor power for injection with non-injection system.

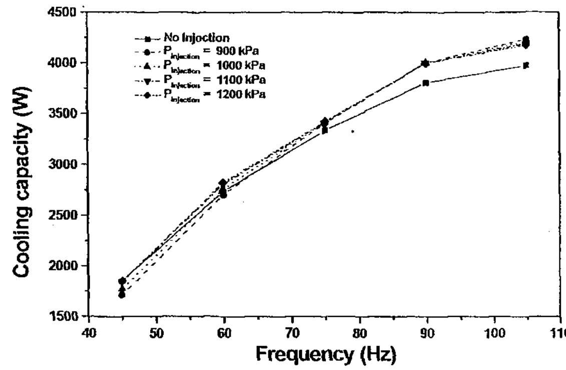


Fig. 4 Comparison of cooling capacity for injection with non-injection system.

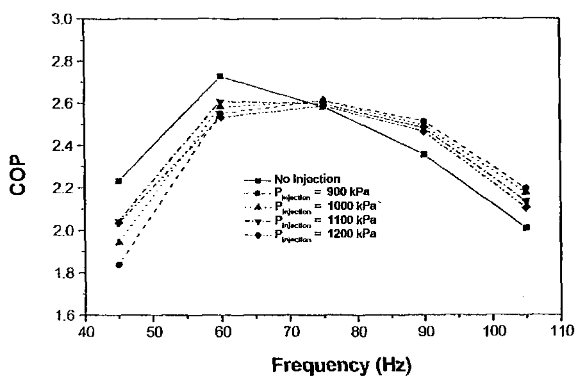


Fig. 5 Comparison of COP for injection with non-injection system.

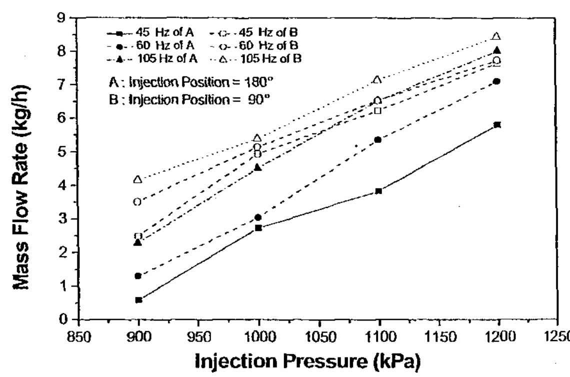


Fig. 6 Injected mass flow rate vs. injection pressure with injection position.

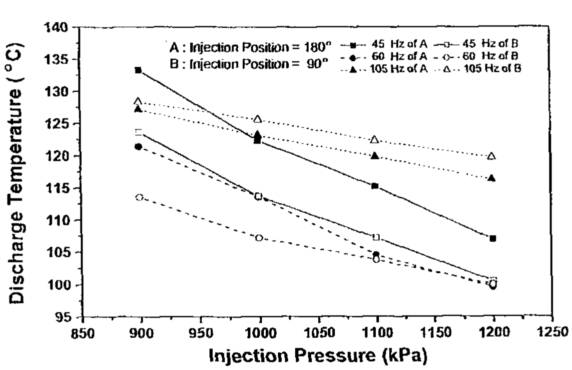


Fig. 7 Discharge temperature vs. injection pressure with injection position.

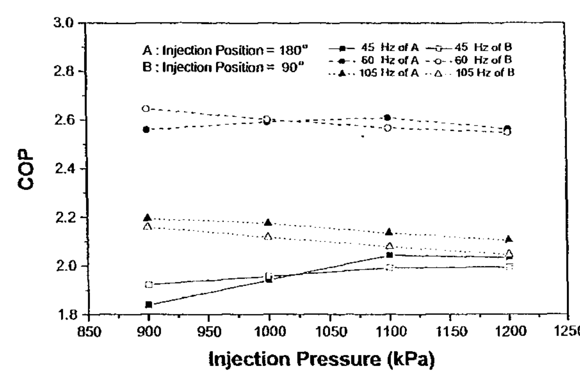


Fig. 8 COP vs. injection pressure with injection position.