1992

Scroll Compressor Operating Envelope Considerations

M. J. Maertens
Tecumseh Products Company

H. Richardson
Tecumseh Products Company

Scroll Compressor Operating Envelope Considerations

Michael J. Maertens — Project Engineer
Hubert Richardson — Manager

Development Engineering Department
Tecumseh Products Company
Tecumseh, Michigan, USA

ABSTRACT

The scroll compressor design is unique, it can truly be optimized for a specific set of running conditions, however, when operating at conditions other than the design point, performance can suffer. This study will investigate the performance of a scroll compressor designed for the traditional design point and other points. It also evaluates how each of these designs affects the operating envelope performance of the compressor.

INTRODUCTION

The scroll compressor concept was originated in the early part of this century, however, the technology to mass produce the scroll wraps did not exist until approximately twenty years ago. Even then, it was necessary to have a mechanism to seal the pockets in the scroll wraps and prevent leakage between the scroll pockets. Many methods of sealing the leakage areas have been used in different scroll designs. The most obvious method of preventing leakage would be to make perfect scroll wraps and hold them in perfect alignment during operation. However, this is not a practical solution. Other methods of sealing leak areas include; the use of tip seals, intermediate pressure, swing links, and differential pressure force mechanisms. In recent years many scroll compressor designs have been produced by different manufacturers using various combinations of these methods. For the purpose of this study, a high side design has been chosen. A scroll computer simulation was used to analyze this design and predict compressor performance. The computer model was used to evaluate the effects of compression ratio, compressor operating envelope, and system operating envelope on compressor efficiency.

HIGH SIDE SCROLL COMPRESSOR

The operation of the high side compressor is as follows: The suction gas enters the compressor directly into the suction cavity of the scroll set. The gas is compressed by the wraps and discharged out a port in the center of the fixed scroll. The gas proceeds out and around the fixed scroll into the lower cavity of the compressor containing the running gear and the motor. Oil is separated from the gas and drains into the oil sump while the high pressure gas leaves the housing through the discharge tube. In this particular design, leakage between the scroll pockets is prevented by using discharge pressure on the back of the orbiting scroll to force the wraps together and minimize the leak area.

COMPUTER MODEL

The scroll compressor simulation model was used to evaluate the effects of compression ratio, compressor operating envelope, and system operating envelope on compressor efficiency. It models the scroll wrap geometry and takes into account the bearing forces, gas dynamics, leakage, and operating conditions. The computer data from the program was compared to actual test data from the compressor and system testing. When the results from the program matched the actual test data, additional runs were made to predict the performance at other operating conditions. The operating conditions were determined using the data from the system test, changes were then made to the computer model data sets to evaluate performance at the conditions, see Table 1. New scroll set geometries were created to optimize the compressor at each of the chosen test conditions. The number of wraps and the radius of the wrap circle were changed while holding the wrap height constant. This changed the design compression ratio of the scroll wraps to match test conditions.

COMPRESSOR OPERATING ENVELOPE

The traditional compressor operating envelope is limited by minimum and maximum evaporator and condensing temperatures. These are often determined by the application of the motor and overload to the particular compressor design as shown in Figure 1.

Scroll compressors use the operating conditions to determine the clamping forces between the wraps. The compression ratio is the absolute discharge pressure divided by the absolute suction pressure. The forces pressing the wraps together increase for high compression ratio conditions and decrease for low compression ratio conditions.

The design compression ratio of scroll compressors is determined by the number of wraps. For different operating conditions, traditional hermetic reciprocating and rotary compressor mechanisms use the discharge valve to exhaust the compressed gas only when the cylinder pressure is greater than the high side pressure. The scroll set geometry determines the pressure of the gas exhausted into the high pressure area instead of the discharge valve. The compressor has higher compression efficiency at the design point than at other operating conditions.

This characteristic is common to all scroll compressors and is caused by the fact that the scroll wraps will compress the gas to the design compression ratio regardless of the operating pressures. If the operating pressure ratio is at the design compression ratio, optimum compression efficiency is achieved. If the operating pressure ratio is lower than the design compression ratio, the gas is over compressed, causing extra power consumption which reduces efficiency. If the operating conditions are higher than the design compression ratio, then the gas will not have achieved a pressure greater than the discharge pressure. High pressure gas will flood back into the scroll pockets from the discharge port until the pressures equalize. While this is happening, the volume of the pocket is still decreasing and discharge of the gas from the pocket will not occur until the pocket pressure is greater than the discharge pressure. This process is less efficient than the compression process because some of gas is being compressed twice, lowering compression efficiency.

SYSTEM OPERATING ENVELOPE

In the compressor operating envelope shown in Figure 1, the Air-Conditioning and Refrigeration Institute (ARI) rating point would be toward the upper right corner and the heat pump operating conditions, would be toward the lower left corner. Normal operating conditions will occur along a wide diagonal between these two points. The upper left corner (letter A in Figure 1) has the characteristics of having a low evaporator temperature and a high condensing temperature. In a residential application, these conditions would occur when the compressor is operating in heat pump mode and the air flow across the evaporator becomes restricted. The compressor would see a high load with minimum gas flow to cool the components, and in this case, the compressor could experience high discharge gas temperatures causing the motor overload protector to trip. The lower right corner (letter B in Figure 1) is represented by a high evaporator temperature and a low condensing temperature. This could occur when the air conditioning unit is turned on when the home has been warmed on a sunny day but the outdoor ambient temperature is low. In this case the compressor operates with a low load and high mass flow.

To investigate the system operating envelope of the scroll compressor, it was applied to a typical high efficiency air conditioning-heat pump unit. The system was tested using the Department of Energy (DOE) test procedures and the Seasonal Energy Efficiency Ratio (S.E.E.R.) was calculated. Table 1 summarizes the system operating conditions during the (DOE) testing and the compressor operating envelope test conditions.

COMPUTER ANALYSIS

Using the high side compressor design, the computer simulation, compressor operating envelope, and the system operating conditions, a series of computer data sets were evaluated using the following sequence:

1. Optimize the compressor design for each of the operating conditions from Table 1.

2. Run the other operating conditions from Table 1 with that design configuration.

3. Repeat the process for each of the conditions.

The results of this analysis are shown in Figure 2.

CONCLUSIONS

The graph in Figure 2 represents the percentage difference between the standard designs and the modified designs. When the design was changed for lower compression ratio conditions, the efficiency improved at those conditions. But the efficiency was lowered for the higher compression ratio conditions. In a similar manner, the design for the higher compression ratio conditions had higher efficiency at those conditions and lower efficiency at the lower compression ratio points.

To achieve the best overall compressor efficiency, the application conditions should be considered when the scroll set geometry is designed. Since different units operate at different conditions, the wrap designs could also change. For this reason, the compressor manufacturer should work closely with the system designer during the design phase so that the compressor and system can both achieve maximum efficiency.

The scroll compressor represents a new technology for compressor and system designers. Achievement of the maximum benefits of this technology requires an integrated effort between compressor and system manufacturers.

Rating Points and Application Testing Conditions

Test point	Discharge Pressure	Suction Pressure	Compression Ratio
ARI Rating point	311.5 PSIA	90.72 PSIA	3.43
Cheer point	210.6 PSIA	90.72 PSIA	2.32
DOE "A" point	274.6 PSIA	90.72 PSIA	3.03
DOE "B" point	241.0 PSIA	90.72 PSIA	2.66
DOE "C" point	210.6 PSIA	83.21 PSIA	2.53
Heat Pump "A" point	241.0 PSIA	69.59 PSIA	3.46
Heat Pump "B" point	196.5 PSIA	38.66 PSIA	5.08

Table 1

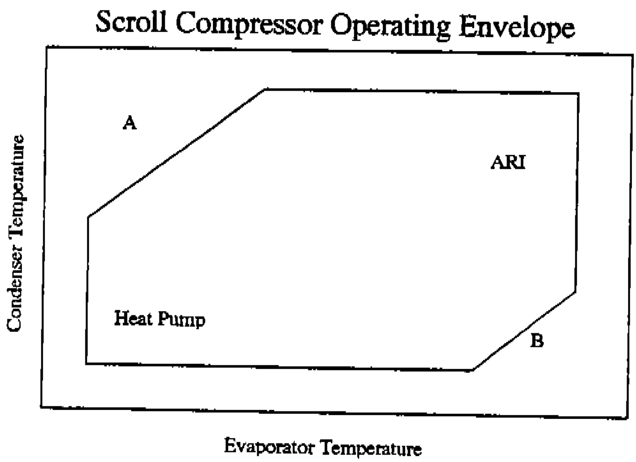

Figure 1

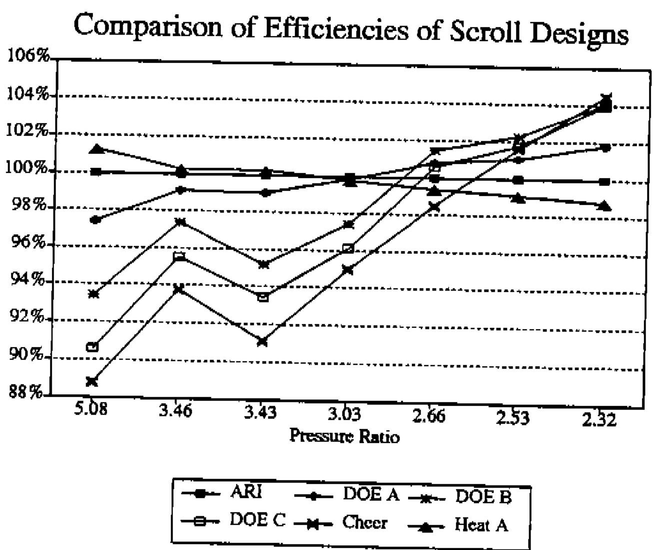

Figure 2