

COLD CYLINDER COMPRESSION CYCLE FOR ROTOR TYPE COMPRESSOR

*A-ming Ji, Shanghai Qinchun Institute of Air-energy Thermodynamics
50/17/101, YunJinLu, Shanghai 200232, China*

Abstract: In existing compressor for air conditioning, steam compression process is nearly close to the adiabatic compression. The discharge temperature is far higher than the condensing temperature, may reach 150°C. Most electrical energy is transformed into the superheat discharge and wasted. But the $P_O \sim P_K$ pressure difference load required for cycle is small. In addition, compression exotherm is accumulated in the cylinder wall, which causes the expansion of suction and loses the displacement.

The cold cylinder compression cycle is that has the high-pressure discharge with the cylinder be cooled and the top and down cover of the cylinder carried on the gas phase and the adiabatic separation. The rotor surface is covered the adiabatic porcelain, and the compression exotherm is pushed to the cooled cylinder wall. In this paper, a mechanism and the realizing ways are discussed on a cold cylinder compression cycle for rotary compressor. Using Qingan YZG-48RCT1 and YZG-43RA as the prototype, through improving the running parameters of design, researching on effective restraint and elimination the formation of superheat discharge in the compression process, obtaining the temperature control region of the maximum displacement for the cold cylinder, and utilizing the motor exotherm, the paper shows the developing feasibility and necessity for heat pump rotor type two-cylinder and two-stage compressor $COP \geq 15W/W$.

Key Words: *compression exotherm, motor exotherm, cold cylinder, hot cylinder, cold harm, gas phase separation, adiabatic separation, absorbent, working substance pair, surface partial pressure, minus entropy compression*

1 INTRODUCTION

Compressors are widely used in refrigeration, air conditioning, heat pumps, air compression, and they use lots of electrical energy. Especially in summer, air-conditioning compressors take the main part of peak power value. As a result, improving compressor efficiency has a close relationship with best using energy and environment protection. In this paper, we take the cold cylinder compression cycle of the rotor type compressor (M_1) as an example to discuss how to effectively improve compressor efficiency.

In existing hermetic compressor (Inverse Carnot Cycle indicates that isentropic adiabatic compression brings the maximum compressor efficiency), steam compression process is close to the adiabatic compression. The discharge temperature T_2 may reach 150°C , which is far higher than the condensing temperature $T_K(50\sim 55^{\circ}\text{C})$. Most electrical energy is transformed into the superheat discharge and wasted. It also increases the condensing load. But the $P_O\sim P_K$ pressure difference load required for cycle is small, that can be proved by the test of different pressure with nitrogen or compressed air in M_1 . On the other hand, compression exotherm and motor exotherm are accumulated in the cylinder wall, then suction is heated up by the hot cylinder wall. Its cooling capacity loss from thermal expansion makes condensing load even large. Obviously, isentropic adiabatic compression isn't suitable for those compressors using refrigerants. The density of refrigerant stream molecule is much higher than ideal gas, so the calorific value of refrigerant steam compression process is far higher than ideal gas.

2 THE THERMODYNAMIC ADVANTAGE OF COLD CYLINDER COMPRESSION CYCLE

Cold cylinder wall effectively decreases the thermal expansion of suction, so it can have high air input efficiency and indeed get more cooling capacity.

Cold cylinder wall can eliminate compression exotherm. It can also restrain superheat discharge so as to decrease condensing load and compression net work. Exothermic compression of minus entropy can achieve the ideal isothermal (T_K) compression processes.

Motor exotherm and superheat discharge could be used to heat up the lubricating oil that can absorb gaseous refrigerants and make it concentrated. Concentrated absorbent has low surface partial pressure on cold cylinder wall, which may let the cooling capacity further improved and decrease compression net work. Thereby it forms a cold cylinder compression cycle full use of energy.

3 IMPLEMENTATION OF THE COLD CYLINDER COMPRESSION CYCLE

3.1 The separation of cold, hot cylinder and cooling of the hot cylinder

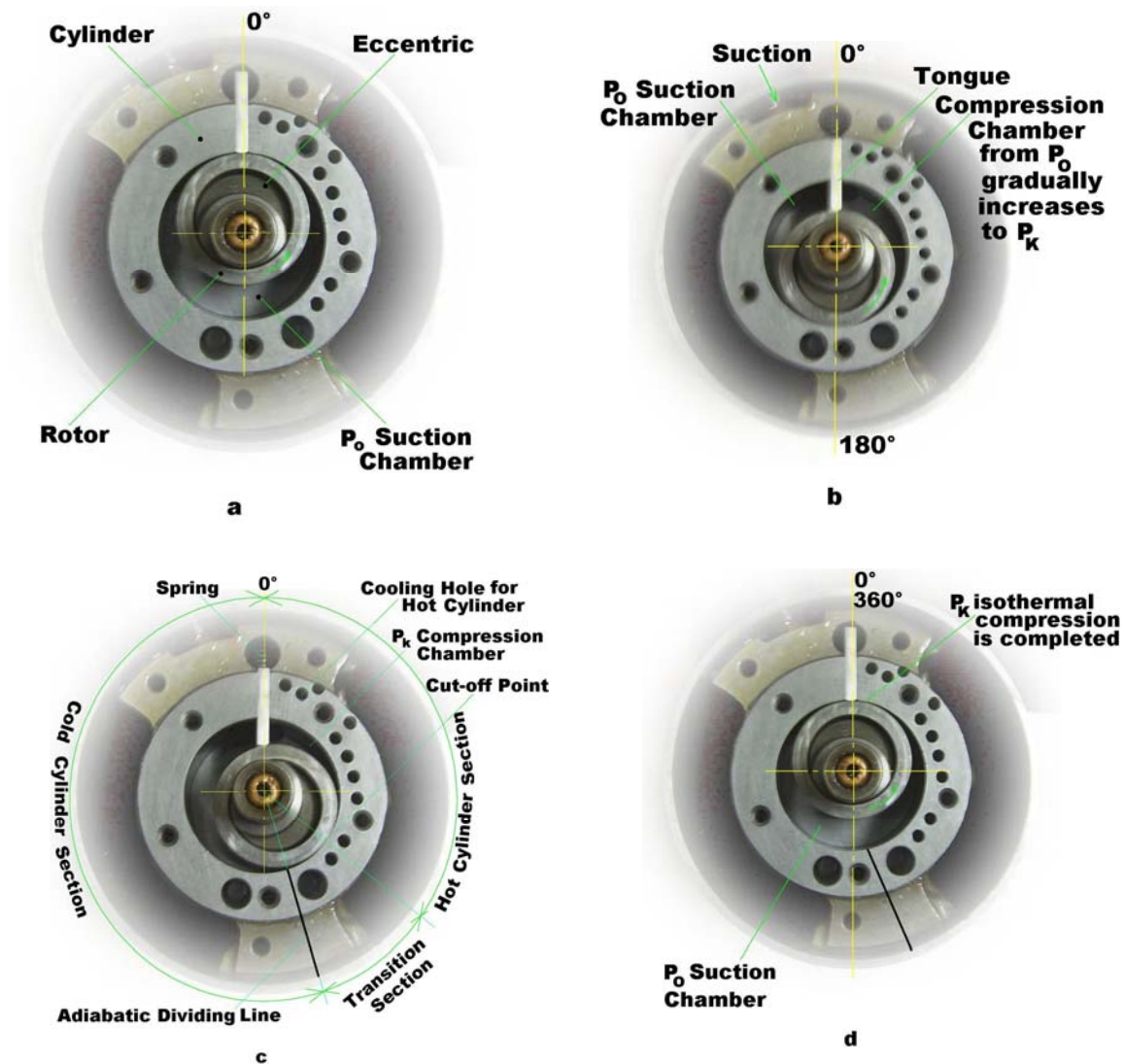


Fig.1: Gas Chamber Running Process Chart

In fig 1a: the eccentric wheel runs to the 0° position. P_0 suction chamber is in the maximum situation. Compression chamber is in the minimum situation. It continues to run after the discharge. P_0 suction chamber functions as the compression chamber and a new P_0 suction chamber begins to form.

In fig 1b: the eccentric wheel runs to the 180° position. The left P_0 suction gradually becomes bigger and the right $P_0 \sim P_k$ pressure increases. Compression chamber gradually becomes smaller. The temperature of the compressed gas refrigerants gets higher and displaces heat to the cylinder.

In fig 1c: the eccentric wheel runs to the cut-off point. (The closest point between rotor and cylinder is called cut-off point. The cut-off point could be distributed by the ratio of P_k to P_0). The compression chamber on the right increases its pressure to P_k . Then the valve piece opens. The compression chamber turns into the process of the isobaric compression discharge. And it is also the process of displacing heat to the cylinder.

According to the situation be heated:

The section from cut-off point to 0° position of the cylinder is defined as hot cylinder. Cooling holes are set to displace the heat from compression. The rotor surface is covered the adiabatic porcelain, and the compression exotherm is pushed to the cooled hot cylinder wall.

The left of the cylinder is defined as cold cylinder, keeping low temperature by suction continuously.

The cylinder between the hot cylinder and the cold cylinder is defined as transitional process. Its temperature is between the hot cylinder and the cold cylinder.

The cooling temperature of the hot cylinder should control P_K the compression discharge not enter the two-phase region. The too low cooling temperature will cause the working substance enter the two-phase region to form wet-compression and cold harm.

In fig 1d: the eccentric wheel runs to 360° back to 0° position. P_O suction chamber enlarges into largest then the suction is over. P_K compression chamber compress to the smallest then the discharge is over.

3.2 The definition and prevention of cold harm

The thermal expansion of the suction process should be decreased to gain more cooling capacity. So the cold cylinder temperature and the hot cylinder cooling temperature should be as low as possible.

The cold harm is explained as followed. When the P_K high-pressure discharge in the compressor chamber contacts the low temperature object (e.g. cylinder, the lateral of the cooled hot cylinder, cooling pipes...) below T_K , the discharge will displace heat and condense into liquid refrigerant then dilutes lubricating oil. This part of P_K high-pressure discharge isn't able to enter the condenser. After the diluted lubricating oil is sucked into the cylinder, it will absorb heat to evaporate and lost the amount of the suction. It will also make the cooling temperature of the hot cylinder too low and form the two-phase region wet-compression in the compression chamber. The lubricating oil will be diluted further more and the cycle will be worse. More cooling capacity will lost.

In order to prevent the formation of the cold harm, the cold cylinder, the lateral of the cooled hot cylinder, hot cylinder cooling pipe, low temperature suction pipe etc should be separate from P_K high pressure discharge by the gas phase or the adiabatic separation.

3.3 The utilizing of the discharge superheat and the motor exotherm and structure of the cold cylinder compression cycle

P_K compression discharge temperature rise further after absorb the motor exotherm. It can be

introduced into the bottom of the chamber and heat the lubricating oil to eliminate the cold harm. After the improvement of the M_1 circulation system, the hot cylinder with lower cooling temperature can be used to increase the cooling capacity. Meanwhile the cold cylinder temperature will decrease with the evaporation temperature decreasing and increase the cooling capacity. Compression work will decrease with the P_O return air temperature decreasing. So the cycle becomes the virtuous circulation with the cooling capacity increasing and compression work decreasing. It is useful for the implement of the maximum cooling capacity operation. Using working substance pair combined by the lubricating oil with strong absorption to refrigerant and the concentrated lubricating oil heated by the superheat discharge and the motor exotherm to form low surface partial pressure on the surface of cooling cylinder, which has strong absorbability to gaseous refrigerant. It increases further the cooling capacity and decreases the compression work to optimize the circulation system.

4 Control of power and progress of M_1

The power control ability in the fast rotating type of the motor 2 poles is not good. The process of the compression strong exotherm is between 1/100 and 1/150 second. (50Hz)

Using Qingan YZG-43RA as the prototype of air conditing compressor, through improving the M_1 running parameters of design is followed: M_1 consumption electric power $N=1050W$, the cooling capacity $Q=7000\sim 7500W$ (according to the unit match). Using YZG-48RCT1 as the prototype, COP of the M_1 operation is close to $Q/N=6.5\sim 7W/W$.

M_1 is developed recently, and the fast rotating type M_1 is also under development. The slow rotating type of the motor 4 poles has not matched the motor, so it is a shame that there is no statistic here.

The rotational speed is to be declined to reduce the relaxation time of the gaseous working substance compression process. Enlarging the exotherm area of the cylinder, fully decreasing the cooling temperature of the hot cylinder (control it out of the forming cold harm range) to displace the compression exotherm and effective restraint the formation of superheat discharge. It can realize the ideal compression process of the T_K isothermal.

$$N = \dot{m} [(h_2 - h_1) + Q_1]$$

$\dot{m}$: mass flow ; N : power of M_1 ; h_2 : enthalpy of the discharge ; h_1 : enthalpy of the suction ; Q_1 : compression exotherm.

h_2 and h_1 can be closed to saturated state to decrease N and the cold cylinder temperature. Q_1 is small but it must be eliminated, or it will have greatly bad effect on the cycle system.

Cold cylinder compression cycle applying in two-cylinder and two-stage rotor compressor (for short

M₂) can create higher COP. It is feasible according to the existing M₁ theory and experiment. And it is essential to supply higher efficient compression to the market. The cost of making a rotor type compressor is cheap and the craft is not complicate. The rotor type compressor production cost is low and the craft is not complex, but the key is its using cost. It used so much energy.