# Analysis of Thermodynamic Performance of Jet Subcooling Refrigeration System

Yan Du

China University of Mining & Technology, Beijing, 100083, China

**Keywords:** Subcooling; Ejector; Thermodynamic Performance; Energy Efficiency Ratio

**Abstract:** An injection subcooling refrigeration system is proposed. By introducing an ejector and a subcooler, the ejector is driven by the high pressure working fluid at the compressor outlet to achieve the purpose of subcooling the remaining refrigerant after condensation. Using R134a as the refrigerant, a simulation model of the jet subcooling refrigeration system was established, and the thermodynamic performance optimization analysis of the system was carried out. The results showed that the ejector ratio (ER) is an important factor affecting the system performance [1]. The ejector ratio increases, and the system energy efficiency ratio is increasing When the ejector ejection ratio is 0.2, the system COP reaches 4.94, which is an increase of 12.9% compared with the system without subcooling. Adding ejectors to achieve subcooling is an effective way to improve system efficiency.

## 1. Introduction

At present, the vapor compression refrigeration cycle has been widely used in refrigeration, air conditioning and heat pump systems. Therefore, improving the efficiency of the vapor compression refrigeration cycle can effectively reduce energy consumption. At present, many scholars are trying to adopt different methods to improve the efficiency of the vapor compression refrigeration cycle, such as optimizing the structure of the refrigeration cycle. Among them, the method of increasing the cooling capacity per unit of refrigerant by increasing the degree of subcooling of the refrigerant at the inlet of the evaporator has attracted many scholars' attention [2].

In terms of subcooling research, domestic and foreign scholars have carried out research from the following aspects: (I) Subcooling technology using intermediate heat exchangers. Spain Scxnchez D et al. studied the performance of the system under three IHX connection modes. The three connection modes are: lOIHX at the condensing outlet; ② IHX at the outlet of the storage tank, before the expansion valve; ③ Using two IHXs, one at the condensation One is at the outlet of the storage tank. The experimental results show that the COP of the system can be improved under the three conditions. Among them, the use of two IHX can increase the efficiency by up to 15%, but this method increases the compressor outlet temperature by 20°C. Research by Llo-pis et al. showed that the IHX method is not suitable for subcritical refrigeration cycles, and in the CO2 cascade refrigeration cycle, the use conditions of lubricating oil should be ensured under the condition of low evaporation temperature. Zhang F Z and other studies also show that IHX is not suitable for carbon dioxide subcritical cycles, mainly because the compressor discharge pressure and condensation temperature in the transcritical cycle have a greater impact on system performance. (2) Adopt the supercooling technology that combines IHX and ejector or expander. Elhel SW et al [3]. conducted a theoretical comparison and analysis for four different refrigeration systems under the condition of air cooling temperature of 35°C. It is not recommended to use a system combining ejector and IHX under inverter compressor conditions. The experiment of Nakagawa M et al. 00 shows that IHX can improve the system efficiency in an ejector refrigeration system. When the compressor discharge temperature is higher, this promotion effect will be more obvious. Xu X et al. experimentally studied the impact of IHX on the performance of the CO2 transcritical injection refrigeration system. The results show that: after the introduction of IHX, the ejector's pressure rise capacity decreases, and the ejector expansion work recovery capacity decreases. Therefore, IHX weakens the injection The improvement effect of the cooling capacity of the system. The study by Zhang Z et al. showed that the introduction of IHX can improve the ejection ratio and ejection efficiency of the ejector. At the same time, it is believed that whether the introduction of IHX can improve the system efficiency lies in the isentropic efficiency of the ejector. IHX is suitable for isoentropic efficiency. Injection system.(3) Adopt independent mechanical supercooling or thermoelectric cooling technology. Llo-pis R and other experiments studied the performance of CO2 transcritical cycle combined with independent mechanical subcooling cycles. The results show that the COP of the CO2 transcritical cycle can be increased by 30.3%. Dai Baomin et al. combined the CO2 transcritical cycle with an independent mechanical subcooling cycle, which uses a non-azeotropic mixture of working fluids. Through analysis methods, the results show that the system COP is under the conditions of maximum exhaust pressure and optimal subcooling. The maximum value can be reached, and the conditions for reaching the maximum value are related to the temperature slip of the non-azeotropic mixing working fluid in the independent mechanical subcooling cycle.

## 2. Big Data and FAN PORTRAITS Marketing

### 2.1. System Principle

In this system, the refrigerant at the outlet of the liquid storage tank is divided into two paths. The main circuit circulates into the subcooler for subcooling, and then enters the evaporator after throttling; the auxiliary circulation enters the subcooler after throttling to cool the main circuit The agent is subcooled and then enters the ejector, where it is mixed with the high-pressure steam from the compressor, and then enters the condenser [4].

### 2.2. System Mathematical Model

According to the first law of thermodynamics, a mathematical model of the injection process refrigeration cycle is established. In order to simplify the calculation process, the following assumptions are made: (1) All components and processes in the refrigeration cycle are in a stable state and a stable process; (2) Pipes, evaporators and condensation The pressure loss in the device is negligible; (3) The fluid flow velocity at the inlet of the ejector is negligible; (4) The compressor is given an isentropic efficiency, and the ejector's efficiency is expressed by a given isentropic coefficient.

### 2.3. Visualization Research on Steam Condensation Process

Under different subcooling degrees, the vapor-liquid interface at the initial stage of vapor bubble growth is very smooth. As the bubble grows, tiny interface fluctuations (t=1. 8 ms) begin to appear locally on the bubble surface. Under low subcooling, the interfacial fluctuation develops very slowly. When t=10 ms, the bubble has already left the steam injection pipe. Because there is no new steam to supplement, the interface fluctuation is slightly stronger than before the bubble separation. When t=16 ms, the fluctuation has spread all over the bubble surface. Then the bubbles began to split gradually, and finally the condensation disappeared. At 30 K supercooling, not only will the bubble break during the condensation process, but also the bubble split will occur. The vapor bubble breaks away at t=5.7 ms, and then the bubble condenses quickly. At t=8 ms, there will be some small bubbles split from the large bubbles, and the size of these small bubbles is larger than the microbubbles formed by bubble breakage under high supercooling. Subsequently, the bubbles were broken at t=9.5 ms, and many small bubbles were formed. These small bubbles continue to condense and eventually disappear in the supercooled water. There is a significant difference between the condensation process of steam bubbles at high subcooling and low subcooling. At this time, the interfacial fluctuations on the bubble surface develop very rapidly, and the interfacial fluctuations have spread throughout the bubble before the bubble detaches. The higher the degree of subcooling, the shorter the time required for interface fluctuations to spread across the bubbles. When the steam bubbles leave the steam injection pipe, the interfacial fluctuations develop more intensely. When the fluctuation reaches a certain level, the bubbles suddenly break and a large number of microbubbles are formed. These microbubbles are ejected in all directions and eventually condense in the supercooled water. According to the condensation process of steam bubbles under different subcooling degrees, it can be found that the supercooling threshold for sudden bubble breakage is around 20-30 K, which is close to the supercooling threshold for MEB phenomenon [5].

## 3. Intelligent Recognition of Feature of Internet Celebrity Fan Portrait Based on Social Media

### 3.1. Analysis of the Effectiveness and Specificity of Primer Probes

The change curve of the system COP and subcooler outlet subcooling gas at different injection ratios ER and subcooler evaporation temperature t and conditions can be seen that when the condensing temperature is 30 0C and the evaporation temperature is constant at -10 0C When t in the subcooler changes within the range of 10~25℃, as the evaporation temperature in the subcooler increases, the system COP increases. The higher the evaporation temperature, the smaller the effect of ER on the COP. The evaporation temperature in the subcooler increases, the energy loss of the ejector is reduced, and the cooling capacity in the evaporator remains unchanged, so the system COP increases; when the evaporation temperature in the subcooler is constant, as the ER increases, the system COP increases, When t is 15°C and ER is 0.2, the system COP is 4.94, which is 12.9% higher than the system without subcooling [6].

When the evaporation temperature in the subcooler is constant, with the increase of ER, the supercooling degree of the outlet of the subcooler increases; when the ejector ER is constant, the evaporation temperature in the subcooler is increased, and the supercooling degree of the outlet of the subcooler increases. However, the increase is not obvious. The main reason is that when the ER is constant, the amount of refrigerant involved in the heat exchange in the subcooler is fixed. The main factor affecting the heat exchange is the unit system heat exchange, while R134a is a dry working fluid and is In a certain temperature range, the evaporation temperature in the subcooler increases, and the heat exchange per unit of working fluid increases. When the evaporation temperature in the subcooler is constant, the ER increases, and the subcooling degree of the refrigerant at the outlet of the subcooler increases. When t, is 15 0C, and ER is 0.2, the subcooling degree reaches 23.7 0C, which can effectively increase the refrigeration capacity per working fluid.

### 3.2. The Influence of Evaporating Temperature/Condensing Temperature on System Performance

When the condensing temperature is 30°C, when the evaporation temperature changes in the range of 20 to 0°C, as the evaporation temperature increases, the system COP increases. When the evaporation temperature is constant, as the ER increases, the system COP gradually increases. When the evaporating temperature is -10°C and ER is 0.3, the injection subcooling refrigeration system is compared with the non-subcooling system (ER=0), and the COP is increased by 18.7%.

## 4. The Effect of Ejector Internal Efficiency on System Performance

When the ER is constant, the internal efficiency of the ejector has a small effect on the system COP. The main reason is that the internal efficiency change will change the power consumption of the compressor, but the system cooling capacity does not change, and relative to the cooling capacity, the value of the power consumption change Smaller. In addition, when the efficiency in the injector is constant, the ER increases and the system COP increases, which is consistent with the results discussed above [7].

When the ER is constant and the internal efficiency of the ejector fluctuates in the range of 0.6 to 0.8, compared with the non-injected subcooling system, with the increase of internal efficiency, the increase rate of compressor power consumption gradually decreases, mainly due to the internal efficiency of the ejector Larger, under the same condensing pressure, the power consumption of the ejector to achieve the ejection function is reduced. When the internal efficiency of the ejector is constant, with the increase of ER, the power consumption of the system gradually increases. The main reason is that the flow rate of the primary fluid of the ejector is constant, the ER increases, and the flow rate of the secondary fluid increases. More work to draw more secondary fluid, thereby increasing power consumption. When the internal efficiency of the ejector is 0.75ER to 0.2, the compressor power consumption increase rate is 2.38%.

## 5. Conclusion

In this paper, an injection subcooling refrigeration system is proposed. By establishing an injection subcooling refrigeration system model, based on the internal efficiency of a fixed ejector and compressor, using R134a as the refrigerant, a thermodynamic analysis of the injection subcooling refrigeration cycle is carried out, and the evaporation is studied. The influence of temperature, condensing temperature, evaporation temperature in the subcooler, efficiency in the ejector and ejector injection ratio on the system COP and power consumption [8].

(1) Increasing the ejector injection ratio can effectively increase the refrigerant subcooling degree. Taking R134a as an example, when the evaporation temperature in the subcooler is 150C and the ER is 0.2, compared with the system without subcooling, the subcooling degree of the refrigerant at the outlet of the cooler can reach 23.7 0C, and the system COP has increased by 12.9%.

(2) In the jet subcooling refrigeration system, the system COP increases with the increase of the evaporation temperature and the decrease of the condensation temperature [9].

(3) The internal efficiency of the ejector is an important factor in the injection subcooling system. When the ejection ratio ER is constant, as the internal efficiency of the ejector increases, the system COP gradually increases, which is mainly due to the increase in internal efficiency leading to system power consumption. The increase ratio decreases. Although adding an ejector will increase the power consumption of the compressor, it also increases the cooling capacity of the system. Therefore, adding injectors to achieve subcooling to improve the efficiency of the system is an effective method [10].

## References

[1]. Metals Research; University of Lorraine Researchers Highlight Recent Research in Metals Research (Literature Review and Thermodynamic Modelling of Roasting Processes for Lithium Extraction from Spodumene)[J]. Mining & Minerals, 2020.

[2]. Conservation - Conservation Law; Keio University Researchers Report on Findings in Conservation Law (Development of phase-field model based on balance laws and thermodynamic discussion)[J]. Ecology Environment & Conservation, 2020.

[3]. Energy; New Findings from School of Energy Science and Engineering Describe Advances in Energy (Thermodynamic Analysis On the Combination of Supercritical Carbon Dioxide Power Cycle and Transcritical Carbon Dioxide Refrigeration Cycle for the Waste ...)[J]. Energy & Ecology, 2020.

[4]. Energy; Reports Outline Energy Study Findings from Institute of Engineering Thermodynamics (Reduced-order Models for Assessing Demand Response With Heat Pumps - Insights From the German Energy System)[J]. Energy & Ecology, 2020.

[5]. Energy - Oil and Gas Research; Studies from Ecole Polytechnique Have Provided New Data on Oil and Gas Research (Aspects of the Thermodynamic Behavior of Salt Caverns Used for Gas Storage)[J]. Energy & Ecology, 2020.

[6]. Energy; New Energy Findings from Kunming University Described (Thermodynamic, Exergoeconomic and Multi-objective Optimization Analysis of New Orc and Heat Pump System for Waste Heat Recovery In Waste-to-energy Combined Heat and Power Plant)[J]. Energy & Ecology, 2020.

[7]. Energy; Study Data from Urmia University Provide New Insights into Energy (A Comparative Analysis of Novel Combined Flash-binary Cycles for Sabalan Geothermal Wells: Thermodynamic and Exergoeconomic Viewpoints)[J]. Energy Weekly News, 2020.

[8]. Fuel Cells; New Fuel Cells Study Findings Have Been Reported by Investigators at Yunnan University (Thermodynamic Analysis of Organic Flash Cycle By R600a/r601a Mixtures)[J]. Energy Weekly News, 2020.

[9]. Fuel Research; New Fuel Research Findings from Qatar University Described (Thermodynamic Study of the Effect of Partial Thermal Reduction of Dysprosium Oxide On Solar-to-fuel Energy Conversion Efficiency)[J]. Energy Weekly News, 2020.

[10]. Energy; New Findings on Energy from Xi'an Jiaotong University Summarized (Thermodynamic Analysis and Optimization of Four Organic Flash Cycle Systems for Waste Heat Recovery)[J]. Energy Weekly News, 2020.