

Optimization of operation parameters of refrigeration cycle using particle swarm and NLP techniques



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ABSTRACT

In this paper, the two mixed refrigerant refrigeration cycles were proposed to be replaced by pure ethylene cycle in the olefin plant of the Tabriz petrochemical complex. Both these components composition of refrigerant and the compressor operations pressures are the key design parameters in the mixed refrigerant refrigeration systems. The purpose of the paper is to present a systematic method based on a combination of mathematical methods and thermodynamic viewpoint to optimize mixed refrigerant cycles parameters. Particle swarm optimization and non-linear programming techniques were employed to optimize the parameters of cycles. Results show that the particle swarm optimization is superior to the NLP optimization techniques in finding the values of optimizing variables.

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1. Introduction

Due to increases of energy prices, the restrictions of production resources and preservation of environment, the necessity of energy consumption reduction as well as its consumption optimization in energy intensive industries, has been revealed. Olefin plants are one of the petrochemical industries with high energy consumption. Ethylene and propylene, which are the raw material of most downstream petrochemical industries, are produced during thermal cracking of hydrocarbons in the furnaces of the olefin plant.

One of the defects of the common cascade systems in different petrochemical industries is high temperature difference between refrigeration system pure working fluid and cooled streams in refrigeration system's evaporator. By appropriate using of mixed refrigerant, this defect can be avoided to a large extent. In recent years, many studies in order to develop refrigeration systems with mixed refrigerant have been conducted in LNG. Results of these studies show that if mixed refrigerant have been used properly, axial work of cascade refrigeration systems would decrease in

liquefaction of natural gas. Moreover, low-temperature separation processes design is affected by amount of axial work and refrigeration system consumption power more than anything else. Many researches are being conducted in order to decrease axial work in low-temperature refrigeration systems and diverse systems for cooling supply in low-temperature processes (Wang et al., 2013; Cao et al., 2006; Becdelieuer et al., 1978; Finn et al., 1999). Having investigated the performance diagnosis mechanism for SMR process they proposed a control strategy to control the changes in working refrigerant composition under different working conditions, and this strategy separates the working refrigerant flow in the SMR process into three flows through two phase separators before it flows into the cold box. The approach was validated by process simulation and shown to be highly adaptive and exergy efficient in response to changing working conditions (Xu et al., 2014). Also energy efficiency is dependent on refrigerant composition and size of heat exchangers (Aspelund et al., 2010; Alabdulkarem et al., 2011; Castillo and Dorao., 2013).

Several approaches have been developed for optimizing mixed refrigerant systems (Nogal et al., 2008) developed a thermodynamic model for a mixed refrigerant cycle and optimized it using Genetic algorithm (GA). Single mixed refrigerant natural gas liquefaction process was improved using the PSP algorithm coded in MATLAB to reduce compression energy requirement (Khan and

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Lee, 2013). The use of HYSYS as the thermodynamic model and Matlab as the optimizer is explored, in order to optimize the verified APCI LNG plant model (Alabdulkarem et al., 2011). Genetic algorithm (GA) was also used for optimization of liquefaction process in peak shaving plant with building mathematical mode in MATLAB. Having combined all chosen variables such as: condensation, evaporation and intermediate pressures, flow rate, and composition of MR in the objective function, they concluded that the compressors and LNG heat exchanger contribute to the main energy losses of the liquefaction process (Mokarizadeh Haghighi Shirazi and Mowla, 2010). NLP was also used to minimize the power consumption of a cascade MR cycle. Refrigerant composition (C1, C2, C3 and n-butane), vaporization fraction in flash tanks as well as compressor pressure ratios were used as optimization variables (Vaidyaramana et al., 2002; Vaidyaraman and Maranas, 2002). Systematic method was conducted on the optimal design of a PRICO cycle, using non-linear programming (NLP) to find the optimal operating conditions. The NLP techniques are used to optimize the refrigerant composition at given refrigerant flow rate and pressures (Lee et al., 2002).

The purpose of this paper is to develop usage of mixed refrigerants in low-temperature refrigeration systems in petrochemical industries. Two low-temperature cycles with mixed refrigerant, which are employed to replace with pure refrigerant refrigeration cycle have been introduced and simulated. Design and optimization of mixed refrigerants refrigeration cycles operation parameters is one of the objects of this research. Furthermore, after identifying effective parameters on the mixed refrigerant refrigeration cycles behavior, a systematic method for design and

optimization of these cycles parameters have been developed. Particle swarm optimization and NLP optimization techniques has been employed in presented systematic method. The ability of presented method in thermal integration and optimization, which is used in proposed mixed refrigerant refrigeration cycles, has been investigated, and the optimization results were also reported.

2. Low-temperature refrigeration cycles description

Low-temperature refrigeration system of olefin plant in Tabriz petrochemical complex is composed of two separate closed refrigeration cycles with pure refrigerants, which are propylene for the first cascade, ethylene for the second cascade, and also an open loop methane cycle. Propylene cycle not only provides cooling for process streams of olefin plant to -35°C , also it has external cooling role as a condenser for ethylene cycle (second cascade cycle). Fig. 1 shows the second cascade cycle in refrigeration system of Tabriz olefin plant. Pure ethylene is compressed to 20.2 bar in this cycle. As exited superheated vapor of ethylene from compressor passes through heat exchanger (E504), its temperature decrease to approximately 33°C ; it is then condensed by passing through heat exchangers E505, E506 and E507. The condensed ethylene after passing through throttle valve, its temperature and pressure is reduced, so it can supply required cooling for feed and reflux streams. In order to help to supply required cooling for feed and reflux streams in the olefin plant; cooling potential of tail gas, regeneration gas, and hydrogen rich gas, which are obtained from demethanizer tower upstream products, are employed.

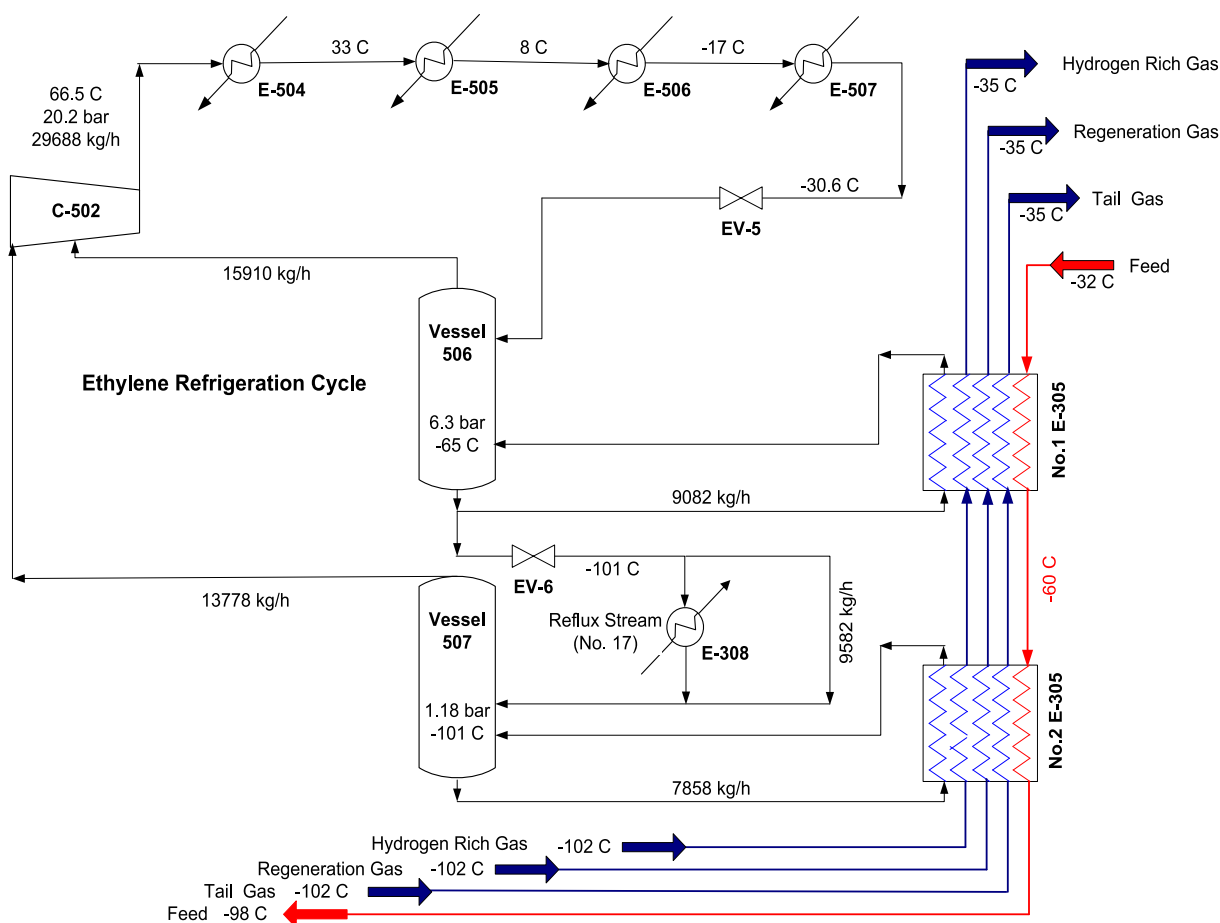


Fig. 1. Schematic diagram of olefin plant (ethylene cycle).

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