UNIVERSITI TEKNOLOGI MARA

COMPARATIVE EVALUATION OF THERMODYNAMIC AND THERMOECONOMIC OF STEAM SUPERHEATERS

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ABSTRACT

Since its operation in 2004, a medium pressure steam superheater has suffered erosion-induced tube failures, resulting in reduced active heating surface due to tube plugging. By 2017, the tube plugging problem prompted a decision to opt for replacement to prevent further deterioration which could impact operation. In 2021, a newly designed superheater was installed. This project identified the need to develop a structured engineering analysis towards identifying the effects of tube plugging as well as evaluating the operation of the new superheater relative to thermoeconomic optimization. The first objective is to investigate the impact of heating surface reduction on the first and second-law efficiencies of the steam superheaters. It includes the technoeconomic analysis of the superheaters operation relative to the boiler operation. The final objective is to investigate the effect of superheater efficiencies on downstream equipment which is the air preheater for combustion air to boiler. Data from the original superheater at 2014 and 2017 were gathered from the system database and the installation of a new superheater in 2021 enables a direct performance comparison between the old and new units. The research approach is through empirical analysis of data using the principles of thermodynamics and thermoeconomics. At the design steam flow rate of 80 tonne per hour, the old superheater in 2014 registered higher efficiencies by 7.7% for energy and 7% for exergy compared to the condition in 2017 due to deactivation of tubes. The new superheater was analysed with 61.5% energy and 47.2% exergy efficiencies, which is surprisingly lower than the 2014 old superheater by 6.4% and 3.7% respectively. Results of exergoeconomic analysis show that the energy cost for steam production of the new superheater is RM485.7/kJ compared to RM196.024/kJ (2014) and RM251.049/kJ (2017). Both results indicate that the new superheater is not operating optimally as it is operated in a similar setting with the old superheater. Temperature of the flue gas exiting the medium pressure superheater was noticeably lower after the superheater was redesigned and installed compared to previous superheater. This affected subsequent air preheater in the waste heat recovery system for combustion air to auxiliary boilers. As a result, the average total exergy of the auxiliary boiler in year 2021 after superheater replacement is lower by 6.77% to 7.24% compared to the previous superheater. In summary, tube deactivation impacts thermodynamic efficiencies. Augmenting heating surface area doesn't directly boost energy and exergy efficiencies. Thermoeconomic analysis indicates the new superheater requires three more years to lower heating costs compared to the old one. Alterations in superheater operation influence the performance of other system components like the air preheater and boiler in the waste heat recovery system.

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INTRODUCTION

1.1 Introduction

Plant 1 of PETRONAS Chemicals Methanol Sdn Bhd (PCMSB) was constructed in 1983 and successfully commissioned in year 1984. It was built and owned by Sabah Gas Industries and was later taken over by PETRONAS Methanol Labuan in year 1992. PETRONAS Methanol Labuan was then incorporated along with other PETRONAS chemical plant to form PETRONAS Chemicals Group Berhad. Its main product is methanol with a nameplate capacity of 2300 MT/day.

Efficient energy utilization is a major contributor to a sustainable industry. One of the main challenges when assessing energy utilization is to evaluate its quality, also known as energy-economy. Other concerns are to reduce the fuel consumption and avoid negative impacts on the environment due to consumption of fossil fuels through energy-ecology approach [1]. Therefore, evaluation of energy use and quality is essential for industries, especially for energy intensive industries such as a petrochemical plant.

Petrochemicals are products derived from fossil fuels obtained from crude oil or natural gas. These hydrocarbons are not burned as fuel, instead used as feed for the process industry. Petrochemicals product can be categorized into three types which are i) olefin derivatives ii) aromatic derivatives iii) synthesis gas. Synthesis gas is made of carbon monoxide and hydrogen. This gas is subsequently used in the production of ammonia and methanol [2].