Investigation of energy efficiency improvements in alumina refinery of Seydişehir ETI Aluminium Plant

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Abstract

Energy is an important issue for all industrial processes. Energy saving not only decreases the production costs but also provides environmental benefits, lowering emissions that contribute to global warming. In alumina production, energy is typically 30 - 50 % of the total production cost, depending on technology, equipment design and capability, process condition, raw material type, production rate, etc. In this study, energy and exergy analyses of the Seydişehir ETİ Aluminium Plant (SEAP) were performed. At SEAP, energy consumption is becoming increasingly challenged by rising operating and production costs, therefore, significant process energy reductions are required. To minimize energy consumptions and exergy destruction points, it is important to understand the energy sinks in its alumina production steps. High energy consumption areas in the SEAP are digestion, evaporation and calcination. Thus, the present study covers the energy and exergy analyses of several units in the SEAP such as boiler house, digestion, evaporation and calcination. The Bayer process in which the cyclic chemical process has been used to produce alumina at the SEAP spends significant amounts of unembodied exergy. Therefore, implementation of the performed analysis will result in distinguishable reduction in energy losses and exergy destruction.

Keywords: Alumina calcination; Bayer process; bauxite digestion; energy saving and efficiency improvement; exergy analysis.

1. Introduction

The importance of the energy efficiency in alumina industry is increasing from both an economic standpoint, with the drive to continually decrease operating costs and also from an environmental perspective, with the greater focus on climate change due to greenhouse gas emissions [1]. On the other hand, energy consumption is the greatest contributor to the operating cost in Seydişehir ETİ Aluminium Plant (SEAP), and the marginal contribution of this component is becoming more pronounced. Thus, one of the main targets is to deliver significant reductions in energy resource usages. Although, it is important to understand the energy sinks in the alumina production to determine how to minimize the energy consumptions. They are mainly digestion, evaporation and calcination units, which are also highly energy consuming steps in several alumina production plants, e.g. SEAP.

In general, the analyses of heat flow diagrams of complex chemical processes only consider the first law of thermodynamics. The amount of the energy input from an external source is considered as an absolute measure of the thermodynamic perfection while all the heat losses are implicitly allocated into a system without any participation in heat transfer and assumed not to produce any useful work. Therefore, heat efficiency is used as the main criterion of the thermodynamic perfection [5]. The first law of thermodynamics is conventionally used for the analyses of plant performances and energy consumptions. However, it is not capable to assess the quality of energy. For this purpose, exergy analysis is used, which is a consequence of the second law of thermodynamics. It can measure the quality of energy in a process and has been applied for various industries [6]. According to the second law of thermodynamics, any heat process can be characterized by the increase in the entropy of the system. In this case, the augmented entropy can serve as the main criterion of the thermodynamic perfection in the system. Total of the entropy increases shows an energy supply from an external source, e.g., a thermal power station [5]. Exergy analysis of a process contains several steps such as calculation of exergy losses at the productions steps, distribution of the exergy destructions and exergy efficiency. In other words, this enables the analysis of the size and quality of secondary power resources and expediencies of their utilization [5].

This study aims to decrease energy consumptions in SEAP Bayer Process using energy and exergy analyses and is mainly focused on the production units; boiler house, digestion, evaporation and calcination; with the following potential improvements:

- Using “Indirect Digestion Heating” process in SEAP Bayer digesters (autoclaves) instead of “Direct Steam Injection”, which adds unnecessary dilution that has to be removed by additional evaporation, resulting in increased capital and operating costs and production losses. The new method will enable sending live steam condensate back to the boiler house as the feed water, and the reduction in evaporation discharge liquor caustic concentration due to the elimination of additional dilution in digestion. The new strategy also has the potential to increase the process efficiency and productivity with the provision of a significant amount of energy savings.
- Installation of stationary calciner with high thermal efficiency instead of a conventional rotary kiln, for an energy gain of ~ 1.5 GJ/t Al_2O_3.

2. Methodology

2.1. Exergy analysis of a chemical process

Balomenos et al. (2011) stated that exergy of a non-isolated system is the maximum work that can be obtained from the system during a process that brings the system into equilibrium with its surroundings [3]. Brodyansky and co-workers (1994) added that by the selection of a surrounding medium for all systems the environment of our planet; exergy, which is measured in energy units, can become a universal size of the quality of matter and energy [4]. Exergy is also defined as the resource consumed by dissipative structures to produce a(n) structure/information and remain in states far from thermodynamic equilibrium with their environment or the resource consumed by decaying structures as they proceed to thermodynamic equilibrium with their environment [7].

The standard chemical exergy (e^0_x) can be calculated from its theoretical reaction of formation at the environmental standard state (T_0, P_0) for several substances except fuel using equations 1 and 2.

$$aA + xX + yY \rightarrow AaXxYy \tag{1}$$

according to relationship

$$e^0_x, AaXxYy = \Delta G^0_f, AaXxYy\,(T_0) + \sum_i \nu_i\, e^0_i \tag{2}$$

where $\Delta G^0_f, AaXxYy\,(T_0)$ is chemical free energy of formation of the substance, ν_i is the stoichiometric coefficient, and e^0_i is the standard chemical energy of that element. The standard chemical exergy of elements is related to reference substances found more commonly in the

5 Conclusions

This study aimed to show energy intensive areas in the SEAP Bayer process and the increment of energy efficiencies with possible improvements for each process step. The contribution of the proposed improvements on energy efficiency for both digestion and calcination processes were evaluated and the total benefits in terms of exergetic efficiencies were determined.

Currently total energy consumption of SEAP is around 14.6 GJ/t Al_2O_3, which is slightly higher compared to other boehmitic bauxite processing alumina refineries. The roadmap for SEAP is to perform major changes in the calcination and digestion units. For this reason, SEAP has initiated the replacement of existing rotary kilns with stationary calciner to bring down energy consumption of its calcination process from 3.8 to 2.8 GJ/t Al_2O_3, which also means nearly a 26 % reduction in specific energy consumption.

In the near future, SEAP will change its direct heating technique with live steam injection in the digestion process to indirect heating system to decrease evaporation energy consumption by about 1.4 GJ/t Al_2O_3, and increase the productivity of boiler house by using less live steam for heating of boiler feed water.

The total gain for SEAP in terms of energy savings will be about 2.5 GJ/t Al_2O_3 and exergy efficiency of the process will be improved nearly 17 %. With its own capability, SEAP produces 1 GJ energy for about 8 US$, therefore the total savings will be around 20 US$/t Al_2O_3. Considering the 2.5 GJ/t Al_2O_3 decrease in total energy consumption, SEAP will improve its energy efficiency ranking among the alumina plants in the world at 12 GJ/t Al_2O_3.

6 Acknowledgement

This study is supported by Selçuk University Scientific Research Project Coordinatorship (BAP) with contract number, 15201023. Authors also thank to the Board of Seydişehir ETI Aluminium Plant for the permission and support.

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