Enabling Improved Waste Heat Recovery in Digestion for Energy and Carbon Footprint Reduction

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Abstract

As large industrial process heat users, the CO_2 emissions of alumina refineries are considered "hard to abate". The digestion area, as the largest single energy consumer in the form of process steam, is critical to both minimising overall refinery energy consumption and delivering net zero carbon in the most economical way. In future, the traditional goal of maximising heat recovery from digestion will be supplemented with a similarly important goal of recovering waste heat from other refinery sources to digestion via mechanical vapour recompression (MVR) as a direct substitute for fossil-fuel based steam. Reviewing the digestion energy balance, single and dual stream heating technologies and incorporating refinery waste heat recovery, this paper explores digestion configurations that lower refinery energy consumption and carbon footprint. It is shown that incorporating waste heat recovery can reduce digestion energy input by more than half with single stream significantly outperforming dual stream. Increasing the number of live steam heating stages further improves this energy benefit.

Keywords: Digestion, Energy, Waste heat, Mechanical vapour recompression (MVR), CO_2 emissions.

1. Introduction

Recent years have seen a global acceleration in the energy transition and the pursuit of efforts to limit climate change temperature increase to 1.5 °C as called for in the 2015 Paris Agreement. There has been widespread adoption amongst nations and corporations of "net zero" CO_2 emissions targets by 2050. The International Aluminium Institute has published its own pathway for the industry in-line with 1.5 degrees of global warming [1]. Like the International Energy Agency's Net Zero by 2050 roadmap [2], this pathway calls for a pronounced drop in emissions in the decade post 2030. Multiple different decarbonisation initiatives are already underway across the aluminium value chain [3] with 2022 marking the first year total greenhouse gas emissions from the aluminium sector did not grow despite aluminium production growth [4].

Reported uptake of renewable electricity projects as well as future energy use scenarios [5] indicate that there will be an unprecedented change in energy sources globally. Future projections suggest that clean electricity will become the new linchpin of the global energy system. Such a shift is also likely to result in electricity becoming the dominant energy source for alumina refining.

With a vast amount of new energy infrastructure required, the scale of the net zero challenge is huge. Rolling this out at the scale and speed required to meet climate change targets will require a paradigm change to traditional methods of infrastructure delivery [6]. Typically, today's prices for electricity are substantially higher than those for energy in the form of fossil fuel derived heat. Alumina refineries are very large users of process heat. Thus, despite year-on-year falls in costs as the number of solar photovoltaic (PV) and wind projects accelerates, the alumina industry can anticipate rising energy bills as its energy mix is decarbonised.

To offset energy related alumina production cost increases and limit new energy infrastructure requirements, future step changes in alumina refinery energy efficiency seem likely. As the largest refinery energy consumer, the digestion area will need to be adapted to realise these energy and emission consumption benefits.

2. The Role of Digestion in Bayer Process Energy Consumption

Bayer process alumina refining energy consumption consists of energy for steam generation, energy for alumina calcination and electricity for rotating drives and machinery, with an approximate split of 55 %, 35 %, 10 % respectively (see Figure 1), depending on individual refinery efficiency and equipment technology. The digestion area is the dominant user, typically 75 % or more of the steam energy consumption, with spent liquor evaporation the next largest user. Heating in digestion is needed to meet the desired temperature for dissolution of alumina from the bauxite ore into caustic liquor (145 to 150 °C for “low temperature” gibbsite digestion or 250 to 280 °C for “high temperature” boehmite or diaspore digestion).

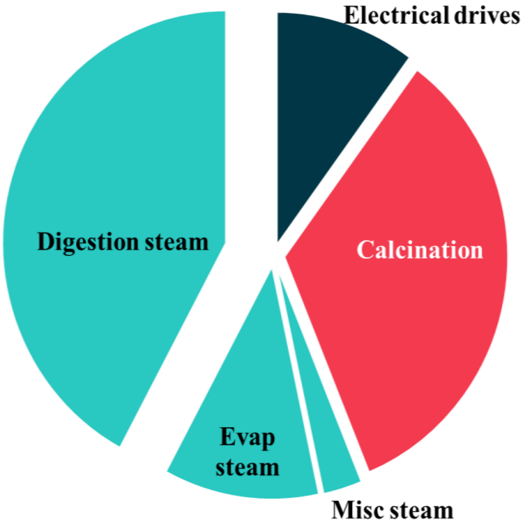

Figure 1. Energy split in the Bayer process by consumer.

Figure 2 provides another view of the contributors to overall refinery energy consumption. Digestion energy input must ultimately compensate for sensible heating in digestion to overcome the digester approach temperature, irrecoverable low-grade heat as well as discharge stream sensible heat losses [7].

Digestion steam consumption is influenced by a multitude of factors such as liquor yield, bauxite quality etc. but within the digestion area this is practically governed by the digestion heat recovery, i.e., the temperature approach between the last regenerative heating stage and the target digestion temperature. It is important therefore to adequately recover the available heat in digester product discharge to the digester feed with installation of sufficient heat exchange equipment and area [8]. In multi-flash systems this energy recovery is greatly influenced by liquor boiling point elevation and the approach temperature between the condensing vapour and slurry or liquor discharge temperature from each heating stage, with ever increasing amounts of area being required to reduce the temperature approach [9].

7. References

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