Hydrogen plant

Transient flames vertical

Can hydrogen and the latest burners reduce carbon emissions?

Representatives from Air Products presented at the Greener Aluminium Online Summit in June an announced its plans to be the first company in the world to begin building a large-scale green hydrogen production facility. This article looks into the importance of hydrogen for a sustainable future.

The risks of climate change need little introduction. The most recent Intergovernmental Panel on Climate Change (IPCC) report delivered the news that we now have less than a 9-year window to act on climate change and limit global warming to 1.5°C. It also stated that limiting warming to 2°C will not be enough to prevent the most serious impacts.

To limit global warming to as close as possible to 1.5°C, the most important challenge today is the decarbonisation of the global economy and the key to meeting this challenge is to electrify as many economic activities as possible and use hydrogen - primarily made from renewable sources - in other harder-to-abate areas.

Aluminium – a unique material

Due to the unique combination of characteristics of being lightweight, yet durable, and its ease of recyclability, aluminium has revolutionised industries from construction and transportation to consumer packaging. Its ability to be repeatedly reused - around 75% of all the aluminium ever produced is still in use today – gives it a significant environmental advantage. It is a record unmatched by other materials, and a compelling argument to as to why aluminium will be a hero of the circular economy. Its light weight will also play an important role in enabling other sectors to reduce carbon emissions – particularly in transportation.

However, aluminium production is estimated to generate around 2% of global greenhouse gas emissions. While this may seem small in relation to other sectors - 3% from aviation or 6% from food waste – it is a sector that still needs to take its part in accounting for, and addressing, its contribution to the climate emergency.

In 2018, global demand for aluminium was 95 million megatonnes - two thirds of which was met by primary aluminium and one third from recycled aluminium. The International Aluminium Institute (IAI) suggests that due to rapid population and economic growth, between now and mid-century, global demand for aluminium will increase by up to 80% by 2050, including both recycled and primary metal. And despite an increased projected supply of metal coming from recycled sources, the IAI estimates that up to 90 million megatonnes of primary aluminium will still be required per annum by 2050.

At the same time, the International Energy Agency's (IEA) suggests that the industry will need to dramatically reduce its emissions by 80% by 2050.

Carbon pricing as a tool for change

For many aluminium production companies, one of the primary considerations for deciding where to locate their smelters is not the carbon footprint of candidate countries' electricity, but pricing. As a result, China produces over 60% of the world's aluminium, mostly from coal power. And while one tonne of aluminium produced in Europe creates around five tonnes of carbon dioxide (CO_2) emissions, that number rises to 15 tonnes in China. So, there is considerable opportunity for lower carbon fuel solutions.

According to analytics and consultancy firm, Wood Mackenzie, to meet the requirements of the Paris Agreement, direct emissions from metals production must halve over the next 20 years.

Their view is that the global price of CO_2 per tonne should rise dramatically by 2030 in order to keep global warming below 2°C. This would radically change the production economics of emissive industries, like metals production, and significantly encourage use of renewables as energy feedstock.

As aluminium is second only to steel in emissions and competes with nickel for highest levels of intensity, it stands to be considerably affected by carbon pricing so there is now greater impetus for the sector to turn to lower carbon energy sources.

According to the IEA's aluminium tracking report from October of 2020, on the current trajectory, "by 2050, primary aluminium production will be emitting 2.83 billion tonnes per annum, which is the equivalent of over 90% of the CO_2 emissions from all of the passenger vehicles in the world today. That doesn't sit comfortably with the CO_2 gains from using aluminium to lightweight vehicles that is being promoted by the industry today".

Reducing carbon and the role of hydrogen

It is generally agreed by environmental and energy bodies that a realistic pathway to zero carbon emissions for the aluminium industry needs to be a three-fold approach: continuing to reduce energy intensity, adoption of inert anodes, and the shift to using 100% renewably generated power.

Low or zero-carbon hydrogen, being produced from renewables, nuclear or fossil fuels with carbon capture, utilisation and storage (CCUS), can help to decarbonise a range of sectors, including long-haul transport, chemicals, iron and steel, where it is proven difficult to reduce emissions. Fuel switching to green hydrogen (defined below) and CCUS offer the most credible pathways.

From the position of Air Products, one of the world's leading industrial gases companies that now regularly supplies hydrogen to environmentally committed aluminium producers, hydrogen can represent just such a carbon emission-free energy source and pathway.

Although hydrogen gas has neither color, nor odor, it is now typically identified with a color that associates the gas with the way it is produced, along with the raw feedstock and the emissions emitted in its production. Several colors are used for hydrogen and generally range from grey to blue and all the way to green.

Grey hydrogen is mainly produced by the reforming of fossil fuels such as natural gas, LPG, or naphtha via steam methane reforming (SMR) and accounts for about 95% of the hydrogen gas that is produced worldwide today. Grey hydrogen is the lowest cost to produce, requires less equipment and a smaller footprint. Nevertheless, its acceptance is coming under pressure for environmental

reasons as the SMR process generates CO_2 that is vented into the atmosphere.

Similarly, blue hydrogen is produced from fossil fuels but with a lower carbon intensity due to sequestration or repurposing of the CO_2 emitted. Carbon emissions are reduced through the capture and storage of a portion – up to 90% - of the CO_2 produced in the process. The cost of blue hydrogen production depends on feedstock, utilities, the incremental cost involved in handling of the of CO_2 (including recovery, compression, storage, transport via pipelines, sequestration), and the availability of carbon credits.

Green hydrogen is produced by electrolysis of water using electricity from renewable sources and meets the lowest carbon threshold as clean energy sources are used to separate hydrogen from other compounds such as water molecules. These can include wind, solar, hydro and even geothermal energy. In terms of cost, various factors are involved, with the greatest one being the cost of the actual electrolysis process, but the cost of generating renewable energy has fallen significantly in the past decade.

Air Products accelerating the hydrogen economy

Air Products has been a supplier of hydrogen since 1975 and was the first liquefier to the US National Aeronautics and Space Administration (NASA). With its long history of expertise in all areas of hydrogen production including SMR, gasification and electrolysis, it now holds a worldwide leadership position in hydrogen production and recovery. Air Products owns and operates over 110 hydrogen plants around the globe and has an established reputation for safe, reliable and cost-effective supply of the gas. In under three decades, it has completed over 250 hydrogen projects in over 20 countries and currently with nearly 9,000 tons per day of capacity.

Air Products is a member of the Hydrogen Council, a global CEO-led alliance with a united and long-term vision to accelerate the hydrogen economy. The company has plans to produce 100% green hydrogen from a world-class plant in the high-technology industrial cluster at NEOM in Saudi Arabia.

In addition to Air Products' ability to supply hydrogen gas as a fuel for more sustainable aluminium melting, its advanced gas technologies including its innovative transient heating technology and smart process control systems can be used in conjunction with hydrogen or hydrogen fuel blending to boost reverb furnace performance and further minimise carbon emissions.

Transient heating oxy-fuel burners with Process Intelligence

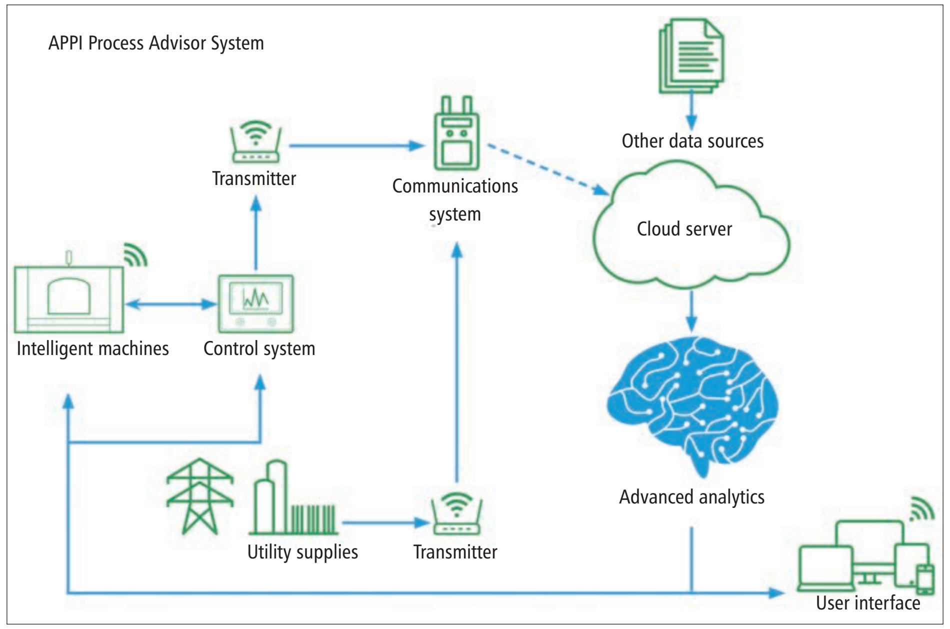
In both reverberatory (reverb) and rotary furnaces, heat transfer from the flame to the melt charge takes place either directly from the flame to the charge or indirectly from the flame via the refractory walls of the furnace, and then from the refractory walls to the charge.

In a rotary furnace, the rotation enables the hot refractory to pass under the metal charge, thereby transferring heat more effectively from refractory to the metal. Therefore, rotary furnaces have very high efficiencies - up to around 90%. Such high efficiency is especially suitable for oxy-fuel combustion as the higher available energy can be more efficiently transferred to the melt.

Reverb furnaces are inherently less efficient than rotary furnaces in transferring available energy to the metal. Due to reverb furnaces being stationary and typically larger - with burners normally mounted horizontally - the heat transfer from the flame to the melt is more limited, with efficiencies of around 65%. Conventional oxy-fuel burners with higher energy levels and heat flux therefore become more difficult if the heat cannot be transferred to the melt effectively.

Conventional oxy-fuel burners can present additional challenges in reverb furnaces such as:

- Localised overheating due to higher radiation from oxy-fuel burners, especially to the roof;
- Non-uniform heat distribution in the furnace due to lack of convection with reduced flue gas volumes and poor furnace pressure control;
- Quicker cut back in firing rate of oxy-fuel burners due to control thermocouple temperatures reaching set point too quickly from higher radiation;
- Yield losses due to non-uniform heat and oxygen distribution close to the metal; and
- Higher NO_x due to interaction of the oxy-fuel flame with leakage air from the atmosphere or with the air fuel flame in oxy-fuel boost cases, where the flame interaction is not controlled.



For more effective heat transfer in reverb furnaces, the answer lies in the Transient Heating burner. Usually mounted on the furnace roof, the burner typically has four nozzles directed toward four quadrants of the furnace below. Using proprietary control techniques, coupled with temperature feedback, it can direct heat to any combination of the quadrants, so delivering the efficiency benefits of direct flame impingement, while avoiding overheating by limiting the firing in any one direction.

The amount of energy and time spent directing the heat flux towards a particular area of the furnace can be pre-set to a given frequency or automated by strategically located sensors in the furnace to direct more heat to colder areas and less heat to hotter ones. This results in energy being delivered where and when it is most effective. The heat release profile can also be customized for a specific furnace's needs, using the burner's ability to adjust velocity and flame length.

Air Products' patented Transient Heating oxy-fuel burner is the only smart burner technology in the world to incorporate diagnostic sensors and wireless communications to help direct heat down toward the melt, sequentially to all areas of a reverb furnace. Known as Air Products Process Intelligence (APPI), this smart technology improves monitoring and control of the combustion system, tracks key process parameters, sends alerts and provides remote access to important data. The APPI Process Advisor system can also calculate when the aluminium has reached tapping temperature, helping to predict when the melting process is complete.

The combination of the Transient Heating Burner and APPI, has demonstrated up to 40% increase in productivity and fuel efficiency, which is directly converted to CO_2 emissions reduction and up to 20% reduction in metal losses in reverb furnaces.

Conclusion

Aluminium has many environmental benefits, from its ability to be repeatedly reused to enabling other sectors to reduce carbon emissions. At the same time aluminium production generates ~2% of global CO_2 emissions, and emissions may increase as demand for aluminium increases. Decarbonizing aluminium production can be accelerated by shifting to renewable energy and reducing energy intensity. Green hydrogen produced via electrolysis of water using renewable electricity can provide a reliable source of energy for aluminium production while significantly reducing carbon emissions. Likewise, the use of oxy-fuel combustion technologies can improve the energy efficiency of aluminium furnaces.

Traditionally, there has been a reluctance to incorporate oxyfuel combustion in reverb furnaces as the technology rarely met the needs of the melting operation. But oxy-fuel combustion technology has made significant progress over the last two decades, with its performance and reliability greatly improved. With the advent of technologies like Air Products' Transient Heating oxy-fuel burner, real productivity, yield and fuel efficiency have repeatedly shown themselves to be significant benefits to reverb furnace operations.

However, it is expected that one of the biggest and most important benefits of using an alternative low-carbon fuel like green hydrogen and optimising furnace performance with the latest burner technology is the aluminium industry's opportunity to significantly reduce its carbon footprint. ■