An efficient approach to aluminium

The primary aluminium production industry is the world's largest industrial consumer of electrical energy. ENEXAL is advancing the industrial practice of the primary aluminium industry towards a sustainable pathway. Here, **Dimitrios Boufounos** (ALSA – ENEXAL coordinator) and **Professor Ioannis Pasapliaris** (NTUA – ENEXAL scientific coordinator) discuss the ongoing successes of their project

What initially attracted you to researching primary aluminium production?

IP: It is well-known that the primary aluminium production is an energy- and resource-intensive industry that offers a metal considered vital to numerous aspects of modern life. It was a big scientific challenge for me, as a metallurgical engineer and an academic professor, to work in this research field and develop new technologies to render the aluminium industry more environmentally-friendly. The key driving force behind this research was the long-term cooperation I had with the Aluminium of Greece production plant and the scientific team of the Laboratory of Metallurgy of the National Technical University of Athens. They supported me from the development of the research idea to the implementation of the project.

How are you working to ensure the industry can remain competitive while also becoming increasingly environmentally-friendly?

DB: Here at the Aluminium of Greece, environmental protection and health and safety measures have always been prime issues. Numerous RTD projects have been undertaken over the years to investigate possible uses for the bauxite residue – such as an additive or an alternative raw material for cement production, brick production and road construction. Our plant was the first aluminium refinery of western Europe to install filter presses for de-watering the bauxite residue slurry and allow its dry storage. Recently a 334 MW co-generation plant was installed, producing both electricity and heat for plant operations, greatly improving the overall energy utilisation. With such actions the plant not only remains competitive in the global market but aspires to set the standards for environmentally friendly primary aluminium production.

Could you briefly summarise the major objectives of the ENEXAL consortium and discuss the benefits it offers to primary aluminium production?

IP: The ENEXAL project seeks to solve two major problems extant within the industry: the disposal of the bauxite residue (red mud) of the Bayer process and the reduction of the energy and carbon intensity of the Hall-Heroult process. If both ambitious objectives are achieved, then one could definitely speak of a sustainable primary aluminium production schema with practically close to zero solid wastes. There would also be a reduction in energy consumption and GHG emissions.

Are you looking to develop any new business approaches that will enable industrial effectiveness and efficiency in the primary aluminium market?

DB: Definitely! So far, numerous projects have been able to treat or transform the bauxite residue into useful products. However, none of these have as yet been applied industrially, as they are economically unattractive. The bauxite residue treatment process developed through ENEXAL seems to be able to surpass this problem and may even prove to be profitable, opening new markets for the aluminium industry. The concept of merging different production lines in one plant, where the waste of one line feeds the next, is the business approach of the future. Through the ENEXAL bauxite residue treatment process we hope to establish the creation of two products, pig iron and mineral wool, from bauxite residue.

How would you sum up your current development status?

IP: We are proceeding according to our initial plans and are satisfied with the results so far. The technical feasibility of the production of pig iron and mineral wool from bauxite residues has been proved and we are currently preparing for a long-term pilot scale demonstration of the process. The initial tests on the carbothermic reduction of alumina are satisfactory and we expect to have their final results before 2014.

Where would you like to focus your research efforts in the near future? Are there currently any plans in the pipeline you would like to discuss?

DB: It is rather soon to discuss future plans, but if all goes well with the bauxite residue treatment process, we wish to further develop the process in order to extract small amounts of rare earth oxides from the bauxite residue. A research project in cooperation with NTUA is already being formulated as the next step from ENEXAL.

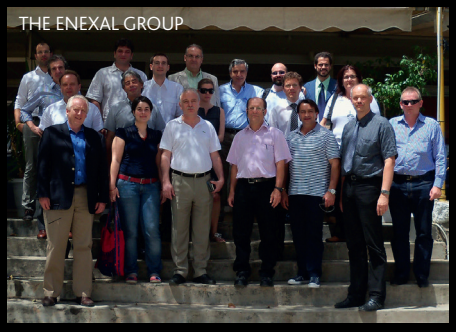
Energy efficiency in an energy-intensive industry

Concentrating on the development of three novel technologies fundamental to the improvement of primary aluminium production, **ENEXAL** is at the forefront of innovation in the industry. It is expected that their novel technologies will play a key role in the sustainability, competitiveness and viability of the sector

CONSUMING AROUND 1 PER CENT of all globally produced electric energy, the primary aluminium production industry is the world's largest industrial consumer of electrical energy. It is also ranked among the most CO_2 intensive industries. Nearly all the electricity consumed in primary aluminium production is used in the Hall-Héroult process for the electrolytic production of aluminium from aluminium oxide. This process is also currently responsible for 2.5 per cent of the world's anthropogenetic CO_2-equivalent emissions. In financial terms, the energy cost in primary aluminium production accounts for approximately 30 per cent of the total production cost.

In addition to the worrying electrical consumption and CO_2 emissions, the process of primary aluminium production also generates huge quantities of waste in the form of slurry known as 'red mud'. This is essentially a conglomeration of bauxite residues, the primary by-product of the 'Bayer process', which produces aluminium oxide from bauxite ore. Approximately 2 kg of bauxite residue on a dry basis is generated per kg of produced aluminium; this equates to 120 million tonnes on a dry basis globally each year. Although bauxite residue is a non-toxic waste, concerns have been raised regarding its complex handling and disposal requirements, which arise from its fine particle size and high alkalinity. With this in mind, these huge quantities of waste have previously resulted in substantial land use for disposal.

Such environmental concerns contribute to significantly higher alumina production costs: in the first instance, large amounts of energy are used to separate the bauxite ore into aluminium oxide, while the resultant red mud waste is produced in almost equal quantities. Thus, in terms of resource efficiency, the Bayer process has a worryingly low exergy efficiency.


THE ENEXAL GROUP

In light of all the problems inherent in the industry, many changes have to be made in order for the primary aluminium industry to remain viable, competitive and sustainable. The industry as a whole has to operate in a more intelligent way in order to become more energy-efficient and meet the environmental requirements of our times. Only with newer, more advanced technologies and novel business strategies can these problems be tackled. Once new measures are in place, the industry can begin to maintain a viable and competitive place in the world's markets, and start to explore more exciting business opportunities. It is with all this in mind that the 'Novel Technologies for enhanced energy and exergy efficiencies in primary aluminium production industry' (ENEXAL) project emerges as a vitally important source for change, through its development of three novel technologies for the improvement of the primary aluminium production industry.

WHAT IS ENEXAL?

ENEXAL is a research project co-financed by the European Commission, which seeks to promote energy efficiency in this energy-intensive industry. The project strives to provide the primary aluminium industry with more innovative and 'greener' technological and economical solutions. ENEXAL's research is being developed around a three-pronged approach, in which the team is endeavouring to:

- Improve the energy and exergy efficiency of the production process
- Ensure significant reductions in the industry's GHG emissions
- Ultimately eliminate all solid wastes currently produced in the production process

In terms of the project's impact on future industry and technology, Dimitrios Boufounos

In order to achieve such significant improvement in the primary aluminium production industry, the ENEXAL project seeks to demonstrate three novel technologies. These are:

1. A high-temperature carbothermic reduction of aluminium oxide (alumina) in an electric arc furnace (EAF). This will result in 10 per cent energy savings and a 65 per cent reduction in current GHG emissions
2. A moderate temperature carbothermic reduction of alumina in a novel solar furnace. This can reduce current energy use by 68 per cent
3. A bauxite residue treatment in an EAF. This will achieve total conversion of the bauxite residues of the Bayer Process. Better still, these can be converted into valuable products like pig iron and mineral wool. As a direct result , the exergy efficiency of the Bayer Process will be increased and solid wastes will be eradicated

(ENEXAL's Coordinator) is in no doubt: "The ENEXAL project is of key importance for future plant operations".

THE HIGH TEMPERATURE CARBOTHERMIC REDUCTION OF ALUMINA

Primary aluminium production currently involves molten salt electrolysis of the aluminium oxide (alumina) in the Hall-Heroult process. ENEXAL aims to replace this process with a completely different technology based on the carbothermic reduction of alumina, which will reduce the aluminium metal production's energy consumption. As part of this aim, two alternative processes are being investigated in Rheinisch-Westfalische Technische Hochschule Aachen (RWTH), which will utilise specially designed electric arc furnaces. These have different aims, including a proposed carbothermic co-reduction of aluminium and silicon oxide in the production of aluminium-silicon alloy. Silicon is traditionally used in cast aluminium alloys, which comprises-approximately 30 per cent of all worldwide aluminium utilisation. Additionally, the project is investigating the gaseous production of metallic aluminium through the high temperature (2500 °C) carbothermic reduction of alumina.

In both cases, the experiments performed so far have had positive results. The EXENAL group is continuing the work and is optimistic for a successful outcome in the achievement of the overall research target in this field.

THE MODERATE TEMPERATURE CARBOTHERMIC REDUCTION OF ALUMINA

Another technology being investigated in the ENEXAL project, involves the carbothermic reduction of alumina, which will use a new solar furnace. Currently, the Eidgenössische Technische Hochschule Zürich (ETHZ) and the Weizmann Institute of Science (WIS) are developing a process for producing gaseous aluminium under vacuum, which harnesses concentrated solar radiation as the only heat source. The tests which have already been performed in a laboratory solar furnace at ETHZ have proved the feasibility of the proposed process – utilising temperatures around 1600 °C, and pressure less than 1 mbar. Subsequently, real scale experiments are due to be performed in 2013 at WIS's 50 kW solar tower in Israel.

THE BAUXITE RESIDUE TREATMENT PROCESS

In the Bayer process aluminium oxide is typically separated from the bauxite ore under intense chemical conditions, leaving behind an equivalent weight of bauxite residue. The process is carried out in an appropriately designed electric arc furnace capable of treating such fine materials. An important feature of the ENEXAL project is a novel process which has been developed in the National Technical University of Athens (NTUA) for transforming the bauxite residues into marketable by-products. These are pig iron, which is suitable for secondary steel production, and alumina-silicate fibres which are used in the production of mineral wool insulation products. Better still, these products may not only cover the cost of the proposed process but, due to the high market price of mineral wool fibres, they may even present a remarkable source of additional potential profit for the aluminium industry.

Overall, this method eliminates the need for bauxite residue pre-treatments and significantly reduces energy and labour costs. It also improves the overall environmental issues associated with the aluminium industry, as it diminishes the quantity of solid residues disposed to the environment.

LOOKING FORWARD

All three technologies, after laboratory optimisations, are due to be demonstrated in pilot scale and their products will be evaluated by appropriate industrial end users. Following this, site optimisation studies will lead to the formation of a new primary aluminium production schema to integrate these into current industrial practice. This will further reduce energy and CO_2 emissions, ultimately improving the efficiency of the whole process.

INTELLIGENCE

ENEXAL

NOVEL TECHNOLOGIES FOR ENHANCED ENERGY AND EXERGY EFFICIENCIES IN PRIMARY ALUMINIUM PRODUCTION INDUSTRY

OBJECTIVES

To increase the energy and exergy efficiency of operations in the primary aluminium industry.

PARTNERS

Aluminium of Greece, Greece

National Technical University of Athens, Greece

Rheinisch-Westfalische Technische Hochschule Aachen, Germany

Eidgenössische Technische Hochschule Zürich, Switzerland

Weizmann Institute of Science, Israel

Faculty of Technology and Metallurgy, University of Belgrade, Serbia

Sirmium Steel, Serbia

D'Appolonia s.p.a, Italy

Pegaso Systems s.r.l., Italy

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