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Reduction of greenhouse gas pollution in non-ferrous metal industry : Indian perspective

MALTI GOEL
Department of Science and Technology (DST), New Delhi

ABSTRACT

This paper highlights the need for improving energy and materials efficiencies in the non-ferrous metal industry. The process changes taking place in the production of copper, zinc, aluminium and lead are discussed. The conventional techniques of metal extraction from ores, are being replaced by environmentally friendly bio-hydrometallurgy/bio-reactor technology. Considerable work in this direction on laboratory scale is being done in the national laboratories and academic institutions in India. In order to achieve its full potential further research and development as well as commercialisation of bioreactor processes developed are needed.

Keywords : Green house gases, Materials efficiency, Bio-hydrometallurgy, Non-ferrous metals.

INTRODUCTION

Greenhouse gas emissions and their accumulation from the anthropogenic and industrial activities have given rise to the need for taking technology based initiatives for environment pollution control. In the metal forming industry this dilemma can be addressed in two ways: (i) by reducing the energy consumption and/or improving the energy and material efficiency of the metal forming process, and (ii) by extraction/processing of the metal in an environment friendly manner i.e., reduction in pollutant emissions in the concerned process. As a result, metal industry is undergoing dramatic changes and the new technologies are in the offing to replace the one's that have been practiced for over 50 years.

The report of Secretary-General of United Nations (UN) has highlighted the need for energy and materials efficiency improvement in the context of global environment [1]. In a study commissioned by United Nations, three scenarios for metal industry with respect to technological actions upto 2020 are analysed (Fig.1). In the *business as usual case,* the continual use of current technology is presumed. The second situation is *state-of-the-art* replacement of existing stock with most efficient technologies currently available. The third scenario is *ecology* driven and assumes adoption of advanced technologies which are now under development or demonstration. This scenario with energy and materials efficiency improvement by the use of advanced technology show substantial reduction in annual energy consumption by 2020. It is estimated that increased materials efficiency in addition to the energy efficiency, will further decrease the growth rate of energy consumption by 0.2% per year. The report recommends "there is need for detailed information regarding technical options for energy and materials efficiency improvements for use in national policy making, as well as for the development of international initiatives ...... The quality and availability of information on energy and materials efficiency provided through, government, energy agencies, vendors, trade and consumer associations or other appropriate bodies need to be improved".

On Research and Development (R&D) the recommendations are more explicit. "Energy efficiency improvement has a large potential in the medium and long term and is generally seen as a major driver to reduce environmental impacts and reconstruction of energy systems ...... Reallocation of Research, Development and Demonstration (RD&D) budgets is needed to reflect the importance of efficiency improvement ......".

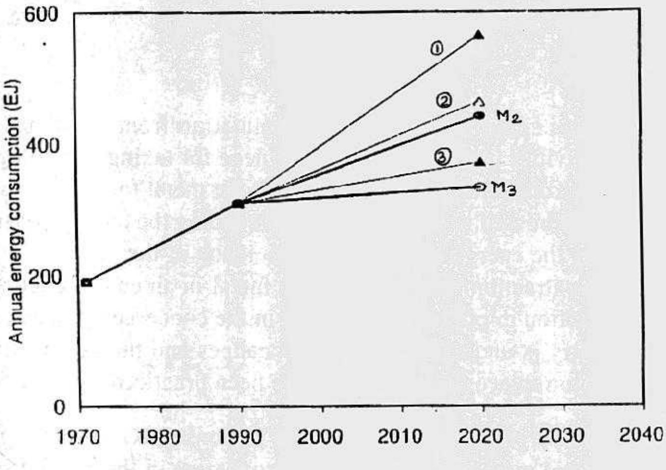

Fig. 1 : Three scenarios for aggregate world energy consumption upto 2020. The thin lines are for only energy efficiency case. The thick lines represent scenarios with both energy and materials efficiency improvement [1].

The improvement of materials efficiency is enabled from two perspectives in metal industry i.e., *materials forming and materials use*. Materials forming, being major consumer of commercial energy produced at a place, any endeavor to achieve saving in consumption of energy would lead to a gain in terms of materials as well as benefit to the environment. It is desirable to develop new processes for metal forming as well as metal use through improvements in designs [2]. It can be seen that the industrial processes leading to metal forming have remained unchanged for last 50 years or so or ever since the beginning of industrial revolution with little improvements. It is the environmental concerns which are now demanding much higher efficiencies in production to control the pollution [3,4]. The contributions of metal forming processes to environmental pollution for Aluminium, Copper, Lead and Zinc are discussed in the following sections. The changes taking place with new technologies that are in the offing are also described. The current perspective of Indian non-ferrous industry is also dealt in. It is required to pursue vigorously research and development strategies to address to environmental problems. A few examples of R&D efforts initiated by the Government to improve the energy and materials efficiencies and support to new processes developments for selective metals are cited.

CONTRIBUTION OF METAL FORMING TO GREENHOUSE GAS EMISSIONS AND OTHER AIR POLLUTANTS

The metal forming industry is direct and indirect source of environment pollution. The major sources in the entire life cycle of a metal are : *mining, raw material handling, mineral processing, metal extraction, product design, manufacturing process, utility, recycling and operation.* Each of these would have some potential for improvement in efficiency through technology improvement and upgradation. Presently though not possible to quantify materials efficiency separately, improvement in energy efficiency can be targeted to achieve materials efficiency and its can form the basis of monitoring pollution. The major gaseous pollutants from the Al, Cu, Zn and Pb industries are shown in Table 1.

Table 1 : Major gaseous pollutants from non-ferrous metal industries

Metal	Major Gaseous Pollutants	
	Direct	Indirect (in terms of energy demand)
Aluminium	CF_4, C_2F_4, SPM	8.7 kg of CO_2/kg of Al
Zinc	SO_2, SPM	Data on CO_2 emission/kg of metal not available
Lead	SO_2, SPM, toxic gases	
Copper	SO_2, SPM	

Aluminium

Aluminum plays a vital role in industrial development and has emerged as a substitute for wood, copper and steel etc. Extraction of aluminium from its ore has large energy requirements. In a smelting process 8.7 kg of carbon dioxide production is estimated as a result of energy consumption, thermal energy used and for reduction of alumina to aluminum. It is estimated that CO_2 burden of aluminum industry is about 1% of total anthropogenic emissions.

In the Hall-Heraults Smelting process for aluminum production[5] fluorine reacts with carbon electrodes to form CF_4 and C_2F_6. Both these gases though emitted in small quantities have lifetimes of over 10,000 years. CF_4 has a strong infrared absorption band at 7.8 μm and its global warming potential is estimated at 4100, 6300 and 9800 over period of 20, 100 and 500 years. Thus because of their extremely long lifetimes CF_4 and C_2F_6 become most potential greenhouse gases from their only anthropogenic source i.e., aluminum industry. CF_4 is found responsible for 1.7% of the total warming potential of all global anthropogenic greenhouse gas emissions. When combined with CO_2, aluminium production is the most potent source of greenhouse gas emissions. With the anticipated world growth rate of 3.5% for aluminum demand, this can become significant, if response strategies for minimizing CO_2 and CF_4 emissions are not developed.

Copper

Copper has been extracted by pyrometallurgical route for several hundred of years. Technology has changed considerably from the use of vertical furnace to a horizontal furnace. The process remains the same as copper is produced from molten copper sulphide, directly converted to metal by blowing air. As a result for each ton of copper, two tons of sulphur dioxide is produced. With increasing environmental regulations and control, this SO_2 is transformed into sulphuric acid and production of 3 tons of acid per ton of copper is a good estimate.

Further innovations from energy considerations are taking place and the modern smelting routes are being introduced for copper production. The new technology such as flash smelting are being considered potentially sound. It offers the option of reducing SO_2 to elemental sulphur by injecting a reducing agent in the gas stream. Another option is injecting NH_3 gas to form ammonium sulphate as a co-product. The sulphuric acid is mixed with phosphate and heated to produce fertilizers. However, the by-product is phospho-gypsum and it introduces new waste disposal problems, hence it is not very acceptable.

Development of hydrometallurgical route resolves the problem of sulphur dioxide pollution as it produces elemental sulphur directly from sulphide ore concentrate. The copper is produced from the copper containing solution by leaching. The steps involved include stripping of copper from solvent, washing of solvent for reuse and electrowinning of copper. Pressure leaching of chalcopyrite for copper extraction offers several environmental benefits [6] over the smelting route and with the development of more efficient electrowinning of Cu, this technology will become more and more acceptable in future. It is estimated [7] that about 7,50,000 tons of copper throughout the world is being produced from this route.

Zinc

Most zinc production is being done using retort process which is also highly polluting and energy intensive. However, the development of roasting - leaching - electrowinning route is being considered more favourable from environmental considerations. It directly produces elemental sulphur in place of SO_2 as a by-product. Its application was considered more beneficial for low Zn concentrates which are not economical by the retort process. This, however, led to formation grade of ferrites which need to be treated for solving waste disposal problem. Pressure leaching for zinc has been developed to overcome the ferrite problem. Use of bio-hydrometallurgy process for Zn extraction from tailings and concentrates has also been developed.

Lead

Lead is produced mainly by oxidation of Galena concetrates followed by reduction of lead oxide using carbon. Not only the lead vapours are toxic but sulphur dioxide produced need to be converted to H_2SO_4. Application of hydrometallurgical route has been suggested to overcome these problems but has not been used commercially as yet.

INDIAN PERSPECTIVE OF NONFERROUS METAL INDUSTRY

Indian non-metal industry though growing since the independence, has faced stagnation in 1980s. In 1990s there has been some upward surge with the opening of the economy. Currently, the policies for private sector participation in different sectors are being evolved. From the production and demand profiles of selected nonferrous metals (Table 2), it can be seen that there are significant shortfalls in terms of production and demand. For example, production of copper is about 60,000 tons per annum whereas domestic demand is approaching 2,00,000 tons. The share in private sector in the industrial production is estimated at 12.73% on an average with aluminum having the largest share of 45%.

Despite low production and also very low per capita consumption of metals in our country as compared to USA or Germany, metal industry is very much conscious of environment impact management and has taken steps for pollution control by achieving energy saving particularly in aluminum industry as well as by installations of devices like; electrostatic precipitators, gas cleaning plants, sulphuric acid plant and/or alkali scrubbing plants in different metal plants for end-of-pipe treatment. Current developments for such technologies in non-ferrous metal industry are reviewed by Viswanathan et al [8].

Table 2 : Indian industry perspective for selected non-ferrous metals

Metal	Ore Reserves (MT)	Average Production per annum (1995-96 data) (MT)	Expected demand growth rate upto 2000 (%)	Consumption per capita at present level (gm)
Aluminium	2900	0.5	10	500
Zinc	390	0.15	5 to 6	138
Lead	—	0.08	6.5	83
Copper	732	0.2	10	210

RESEARCH AND DEVELOPMENT

As regards to process changes, Regional Research Laboratory at Bhubneshwar has established research activity in the area of hydrometallurgy for extraction of non ferrous metals. The copper and zinc industries have adopted to hydrometallurgy routes based on leaching and bioleaching followed by electrometallurgy which involves electrowinning. Hindustan Copper Ltd., Malanjkhand; Atomic Minerals Division, Hyderabad; Hindustan Zinc Ltd., Udaipur; Agharkar Research Institute, Pune; Indian Institute of Science, Bangalore; National Metallurgical Laboratory, Jamshedpur and Bose Insitute, Calcutta and few other are having experience in this direction.

A pilot activity for copper extraction by hydrometallurgical route has been initiated at RRL, Bhubaneshwar and is being pursued by Hindustan Copper Ltd. A plant of 2.5 ton/day chemical bioleaching has been set up at Hindustan Copper Ltd. Hindustan Zinc Ltd. is proposing to set up a semi continuous pilot plant of 1MT/day for zinc extraction.

For India biohydrometallurgy assumes a great national significance [7] not only for copper but for other non-ferrous metals as well. Haldar et al [9] strongly feel that development of biohydrometallurgical process for removal of silica from magnesite and bauxite ores results in lowering the sintering temperature for magnesite and upgradation of bauxite for aluminum production and offers several benefits. The motivation for applying hydrometallurgy process is resource conservation besides environmental considerations. The process also leads to energy saving except for the electro-winning part. Bioleaching extraction of other non-ferrous metals viz., nickel, gold, cobalt and manganese are the other potential areas suggested.

Aluminum industry has taken several effective measures for energy conservation. It has been noted that use of scrap metal leads to significant reduction in energy consumption. The recycling of aluminium scrap not only helps in reduction of energy requirements to 5% of the primary process with a corresponding decrease in CO_2 emitted in generation of energy but also in the reduction of CF_6. Use of hydroelectric power in place coal burning and modernization of Hall - Heroult Cell have been suggested as other means for reducing pollution from the aluminum industry.

In affecting process change research and development must become a continuous activity not only to sustain and upgrade the current operations in the industry but to be able to introduce new processes. In this era of rapid technology change its can be achieved more effectively through collaborative projects. The Government though initiation of joint technology projects; those in partnership under S&T programme of Ministry of Mines and Department of Science and Technology as well as Industry with a R&D laboratory/academic institution is supporting R&D for development and introduction of new processes in such industries. Some examples on non-ferrous metals include column flotation development for zinc extraction at Rajpur Dariba Mines, development of energy efficient materials using advance aluminium composites for mining industry, bioreactor technology for recovery of zinc from tailings/concentrates and pilot scale demonstration for production of gallium metal among others [10].

A few remarks are made here about technology support projects needing special attention. Unlike a R&D project in basic or applied research which is individual based, a technology project requires a participation from number of groups or number of organisations. Formulation of a technology problem with complete consensus among participating agencies is desirable for its success. These projects can be managed through formation of R&D consortia. The other related issue is the accepted code of conduct in transfer of technology. There is no international code in technology transfers. Most of the time it is done on case to case basis. A great deal of advance preparation and consensus on different issues is required for making it happen. It would be desirable that all major projects for technology transfer/adaptation have a year-marked component for Research and Training for their successful implementation. For this in-house R&D cells in industries are also needed to be strengthened and upgraded.

CONCLUSIONS

The need for controlling emissions through increasing energy and materials efficiency has been discussed. The changes being brought out through technology change in non-ferrous metal industry can lead to better environmental conditions. India having reserves of high order, the production of metals leaves much to be desired. As the productivity would increase, the remedial environment measures would become more and more important. The examples of R&D projects supported by the Government to upgrade current operations and to introduce new processes have been presented. Much more efforts to evolve the strategies for R&D and increasing investment in R&D are required by the industry.

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