CARBON PRODUCTS: A MAJOR CONCERN TO ALUMINUM SMELTERS

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Abstract

For decades the world wide primary aluminum production grew at a rate of five percent per year. If this growth rate continues the world aluminum production will increase from today's production of thirty eight million tons to over sixty eight million tons in 2020. With the aluminum growth the requirement for carbon raw materials and, products – petroleum coke, coal tar pitch, anodes and cathodes - will grow simultaneously.
For each carbon product an outlook is given regarding availability, quality, price and production facilities. China's role as important supplier and consumer for coke, pitch, anodes and cathodes will be reviewed.

The World aluminum production and its carbon requirements

For decades the World aluminum consumption and production grew at a rate of five percent per year. If this growth rate continues, the World aluminum production will increase from today 38 million tons today to 68 million tons in 2020. At the beginning of this century China was a very small aluminum producer and contributed to less than 10% of the World aluminum production. This has changed dramatically. In 2015 China will produce as much of aluminum as all other countries in the World. By 2020 China will be the dominant aluminum producer. Consequently China will have a big impact on demand for carbon products.

Table 1: World aluminum production and carbon requirements

	2008 MM tons	**2020** MM tons
Aluminum	38	68
Anodes	21	28
Cathodes	0.26	0.41
Green/calcined coke	20/14	35/27
Coal tar pitch	4	7

In the following sections an assessment will be made regarding carbon products availability and quality.

Petroleum coke, not a quantity but a cost and quality problem

Petroleum coke is a by product in the refining of crude oil and is considered by the refineries a waste product. For the aluminum industry, however, petroleum coke is an essential raw material for the production of anodes. The physical and chemical properties are essential, whether green coke can be used for calcination and applied for anode manufacturing.

In 2008 the world wide green coke production will be approximately 100 million tons, of which the major part is considered as fuel coke which typically has high sulfur (> 5 %) and high metal (V, Ni, Fe etc.) contents. Such coke is not used by the aluminum industry due to the environmental impact of SO_2 emission and the influence on metal purity.

One quarter of the green coke is transformed by the world wide calcining industry into calcined coke of which 75 % is used by the aluminum industry.

China as an important producer and consumer of petroleum coke applies widely a calcination technology, which was developed some seventy years ago in Europe but got totally forgotten. The "*shaft calcination*" compared to a rotary kiln uses a slow calcination process where green coke is filled on top of so called shafts and flows by gravity through these shafts in 24 to 36 hours, resulting in a heat up rate of 1°C per minute (compared to 50°C in a rotary kiln). Thanks to this very slow heat-up rate, green coke with high (12 %– 16%) volatile combustible matters (VCM) can be calcined. Furthermore such green coke typically is extremely fine which does not allow calcination in a rotary kiln as the yield will drop to very low levels (65% or less). As volatile matters are re-condensing in the upper part of the shafts, the fine particles glue together into bigger lumps. The resulting calcined coke properties are excellent, with high densities, low resistivity and very coarse grain size..

For the time being, China is the only country where more than five million tons of green coke are calcined in shaft kilns. In the future, however, this technology may be applied in other areas in the World, where high VCM and fine green coke is available but is used as fuel coke. In addition to China, Brazil, Argentina and Indonesia have a considerable potential for shaft calcining technology.

The world wide calciners are more or less fulfilling the demand of the calcined coke demand. But with the fast growth in demand a considerable shortage in calcining capacity has to be expected, if no new calciners will be built. Several projects in the Middle East and in South America are planned but need to be realized fast.

In the last 24 months prices for green and calcined coke exploded in the West but even worse in China. In less than six months Western calcined coke prices increased by 50%. In the third quarter of 2008 prices are reaching values of over US$ 500/ton. In China CPC prices are as high as 600 – 700 US$/ton.

During the next 10 – 15 years more green coke will be produced. However, the quality of the crude oil treated in general will have higher sulfur and metal contents. Most of the Chinese new refineries will treat imported higher sulfur crude oil. The big hope for low sulfur coke is in Brazil where by 2015 more than 7 million tons of green coke of acceptable quality will be produced. Part of it will be calcined in shaft kilns.

Coal tar pitch, capacity no problem but quality an issue

The worldwide tar production grows continually with the growing steel industry. Coal tar is a byproduct in the cokefication of coal in coke ovens.

Tar production gradually shifted from the West to China where in 2008 more than 50 % of the World wide tar will be produced. By 2012 it will be over 60%. Pitch prices have increased considerably due to the strong demand on one side and the higher oil price.

Pitch quality and consistency is mainly a problem for Chinese pitches, where so called modified pitch is produced which is heat treated and contains higher QI from mesophase. Western pitch producers are now cooperating with Chinese tar and pitch manufacturers and are teaching them, to produce high quality Western type pitch.

For environmental and workers hygiene reasons, pitch is transported in liquid form in dedicated ships.

Coal tar pitch coke an interesting carbon product.

Coal tar pitch coke is an interesting carbon material. Actually 700’000 metric tons are produced annually in Russia, South Africa and Japan. Except for Russia where direct coking of coal tar is applied, a delayed coking process is used. For one million ton pitch coke 3 million tons of raw tar is required. The world wide potential for pitch coke is estimated to be over two million tons. Coal tar pitch is successfully applied in Söderberg smelters but can also be used as blending material for prebaked anodes. However, an adaptation of the production process and equipment is required, since the pitch coke is extremely hard.

After graphitization, pitch coke which is very pure can be used for the production of electrodes and cathodes.

Anodes, a quantity, cost and quality problem

In 2008 the world wide aluminum industry requires 21 million tons of anodes of which more than 90 % are produced in smelter owned anode plants.

The third party merchant anode market grows constantly due to the following facts:

- Smelters often increase their existing capacity due to an increase of the cell amperage. Often the anode plant can not be expanded or the purchase of third party anodes is more economic than expanding the plant.
- Bake furnaces need to be repaired in regular intervals. During the production interruption third party anodes are used.
- Older smelters which have been shut down are restarted without the anode plant.
- If Söderberg plants are converted to prebake operation the anode plant can not be adapted easily and it is cheaper to buy anodes from the market.
- Last but not least in some countries with severe government restrictions the production of anodes is not permitted as is the case for Iceland, where already today more than one million tons of metal require nearly 600’000 tons of third party anodes.

Of the 1.8 million tons of third party anodes nearly 50 % are produced in China which exports its anodes to Russia, Europe, North America, the Middle East and Australia. ALUCHEMIE Rotterdam with one half million of tons of anodes is by far the world largest anode producer. Its anodes are mainly sold to European smelters. Some quantities are produced in the US with a dedicated market in Canada. In Venezuela anodes are used by the local industry. Some quantities are sold from Egypt which has some excess anode capacity available as long as the Söderberg smelter has not been converted totally.

Since 2008 Chinese anode export has severe problems. The demand of the fast growing Chinese aluminum industry is strong. The price for Chinese petroleum coke, which typically has rather low sulfur and metal contents was exploding and will reach by the end of the year over 700 US dollars resulting in anode export prices of 800 dollars and more. In August the so called “rebate” (value added tax) of 13 % is no longer returned to the manufacturers which had to increase the anode price further. Except for some anode plants which are supervised by Western specialists, the Chinese anode quality is not consistent, making it difficult to use such anodes in high amperage cells, where highest anode quality is required. We therefore believe that the long term competitiveness of Chinese anodes is rather uncertain.

Cathodes, a quantity, cost and quality problem

The Western cathode manufacturers produce about 160’000 metric tons. 60’000 tons are produced in Eastern countries, while China produces more than 200’000 tons. The Chinese and the Eastern cathodes are mainly of amorphous composition, where anthracite is mixed with graphite. For high amperage cells only graphitized cathodes can be used to reach the stringent requirements regarding resistivity and low current consumption.

In the fast growing world wide aluminum industry, where large smelters with high amperage cells are the rule, the cathode supply becomes a critical issue. In 2008 210’000 tons of cathodes are used of which 50% are still of amorphous grade. However, the demand for graphitized cathodes is growing fast and will reach nearly 400’000 tons by 2020, while amorphous cathodes will disappear.

New cathode production facilities as well as process development is urgently needed to satisfy the growing demand.

For new smelters the cathode supply becomes a very critical issue:

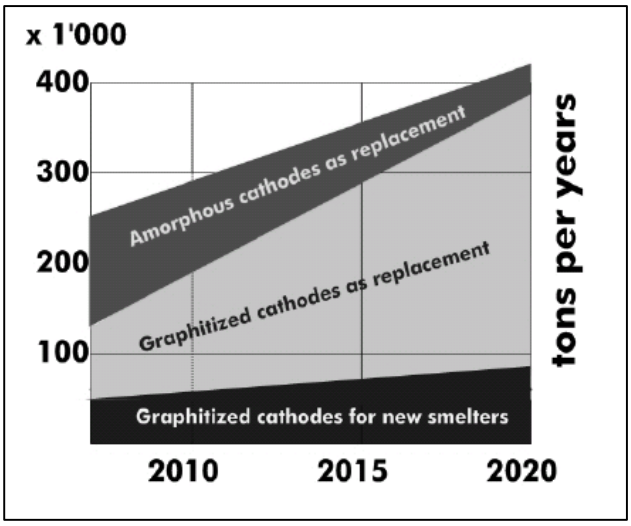

Figure 1: The development of the cathode market 2008 – 2020.

An approach to solve the carbon problem

With the dramatically increasing prices of all carbon products, new creative and innovative ideas are necessary in order to guarantee a constant supply of anodes and cathodes to the aluminum industry.

Petroleum coke

The coke quality will continue to gradually decline. Higher sulfur coke will be used for anodes, resulting in SO_2 emission levels above environmental regulations. It has to be anticipated, that waste gas scrubbing systems will have to be installed requiring considerable investments. As with higher sulfur levels also the metal contents (V, Ni, Fe etc.) will also increase. Blending methods are necessary to cope with this problem.

Lower sulfur cokes are expected to come on the market mainly in Brazil, which has plans to increase its green coke capacity from today 2 million tons today to over 7 million tons in 2015. A considerable amount of this new low sulfur green coke is a very fine material with high VCM contents (volatile combustible matters) of up to 14%. Such coke can hardly be calcined in rotary kilns, since the losses are very high such that economic production is not possible. Therefore, we believe that shaft kiln calcining technology, which is widely and successfully applied in China will be introduced in Brazil. In shaft calciners the fine, high VCM material can be used to produce a coarse high density calcined coke, with excellent physical properties. The technology has great merits, since its investment cost is half of rotary kilns, its operating cost is lower due to the smaller losses during calcination and also the CO_2 emission levels are 50% lower than rotary kilns. No external energy is required and carbon losses are smaller.

Pitch coke can also be blending material for higher sulfur calcined cokes. However, the anode production process needs to be adapted for this extremely hard material. We estimate a potential of over 2 million tons may be used in the future.

As a remote possibility the aluminum industry needs to cooperate and invest in oil refineries that treat high sulfur crude. Desulfurization and demetallization allows the drastic reduction of sulfur and metal levels in the green coke. The draw back, however, is the very high investment cost which only can be borne by the aluminum industry. For the oil industry, petroleum coke is considered as waste material, and, therefore, will not bear additional investments.

Anodes

To ascertain the long term supply of quality anodes, new high performance technology is required to lower production cost, to increase productivity and guarantee a high quality standard. Future anode plants will have annual capacities of one half million tons, which can be expanded to one million tons.

Anode quality is an important factor to reduce anode consumption and thus reduce cost and emissions of green house gases.

For the third party merchant market, new cost efficient anode facilities are needed to cope with the growing market and the decline of the Chinese anode supply.

Cathodes

New production facilities, producing graphitized cathode blocks are urgently needed, to supply the many new smelters coming on stream, as well as existing smelters for cathode replacement.

An intensification of process and product development is required to meet the always increasing specification.

More low sulfur pitch coke as raw material should be used. For this, however, product development is required.

An integrated solution: a carbon production center

We have studied extensively the possibility to build a new carbon production center which will have:

- An anode plant with 500’000 tons capacity which can be expanded to one million tons.
- A cathode plant with an initial capacity of 30’000 tons to be expanded to 60’000 tons.
- A shaft calcination plant with an initial capacity of 150’000 tons to be expanded to 300’000 tons.

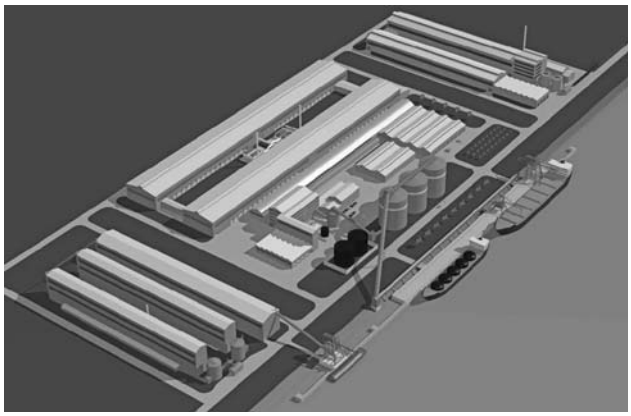

Figure 2: Carbon production center

Possible locations for such a project are either close to the market e.g. in Europe or the Middle East, or close to the raw materials, e.g. in Brazil.

Several projects are presently under investigation and the realization of one to two projects is expected before the year 2015.