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Plasma furnace processing of ilmenite with emphasis on India

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Abstract:

Global demand for Titania slag expected to trend with economic growth which is strongly influence consumption of Tio2 for the production of paint, paper, and plastics. The important mineral resource is ilmenite for the production of Titania slag, by using plasma furnace technology which covers a broad range of activities such as refining of minerals, extraction process, value added materials. Major attraction of using plasma in metallurgical operation, especially in the last two decades have emerged from its ability to deliver high grade heat to any environmental independently of oxygen potential. This paper describes the plasma furnace processing of ilmenite in order to attain high grade Titania rich slag

***Keywords* — Titania slag, ilmenite, plasma furnace**

I.INTRODUCTION

India is endowed with enormous resources of heavy minerals which take place laterally coastal stretches of the country and also in inland placers. Heavy mineral sands contain a group of seven minerals, via, ilmenite, leucoxene (brown ilmenite), rutile, zircon, sillimanite, garnet and monazite. Ilmenite (FeO.TiO2) and rutile (TiO2) are the two chief minerals of titanium.Thermal plasma technology uses to separate rich slag containing around 80% titanium dioxide and high value pig iron (fe) from ilmenite (fetio3) using an innovative process and suitable machinery to reduce power consumption. This process is eco-friendly and produces least amount of pollutants. Thermal plasma technology is one of the environmental friendly process for the production of Titania slag. Actively increasing demand in pigment industries giving it's much more important to produce pig iron products, Titania rich slag. Hence, plasma furnace appears to be an ideal reactor for the ilmenite processing.

II. Plasma technology

a plasma is essentially an ionized form ofgas which may comprise molecules, atoms, ions (in ground or excited state), electrons and protons, and is sufficiently ionized to becomeelectrically conductive.[1]When an electric arc is established in between two electrode in the presence of gas, the gas becomes partially ionises and electrical conductive. Overall a plasma maintains electrical neutrality,a plasma can be of two types, the equilibrium or thermal or hot plasma and the non-equilibriumor cold plasma. In the former, the temperature of the electrons is close to that of heavy particlesand chemical equilibrium prevails. [2] In the later, the electron temperature is far above the sensible temperature of heavy particles, which is closer to room temperature.[3]The temperature in the cage of thermal plasma ranges from 2000 to 20000 K, most processes of practical interest operate between 4000 to 7000 K.[4] a transferred arc plasma ascends from a direct current arc being transferred to from the cathode to anode. In the non-transferred arc plasma, arc struck between two counter electrodes. Plasma furnace allows the direct use of fine feed materials.

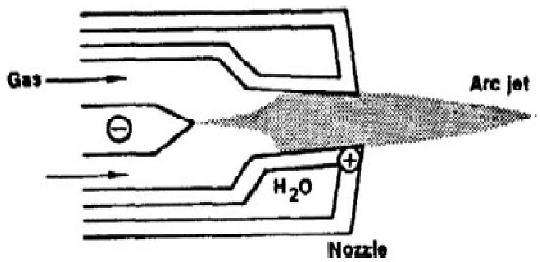

Fig 1- diagram of non-transferred arc plasma torch

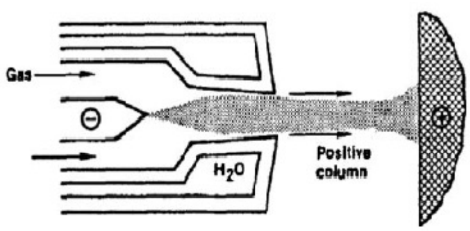

Fig 2- diagram of transferred arc plasma torch

III. Thermal plasma treating of ilmenite

Richards Bay Minerals (RBM), currently the only South African producer of Titania slag, employs four rectangular six-in-Iine graphite-electrode furnaces for the smelting of ilmenite.Each furnace is 19 m long, 8 m wide, and has a power supply rated at 105 MVA (each pair ofelectrodes being supplied by a 35 MVA transformer). Each of these three-phase open-arcfurnaces is rated at 69 MW. [5] The process technology, originally developed by Quebec Iron &
Titanium (QIT Fer et Titane) of Sorel, Canada, was supplied to RBM in the mid-1970s, andwas adapted to smelt fine ilmenite obtained from a beach-sand deposit on the north-easterncoast of South Africa.RBM's ilmenite is of too low a grade to be used directly for the production of pigment or synthetic rutile. The company, therefore, followed the slag-beneficiation route, and currently produces about half of world Titania slag output. [6]For manufacture of titanium dioxide pigment, ilmenite is first treated chemically to obtain upgradedilmenite, commonly called as synthetic rutile. There are two major pigment production processes namely chloride process and sulphate process depending ondifferent operating characteristics and feedstock requirements. Plants employing chloride process consume high TiO2 content feedstock's like synthetic rutile and chloride slag. Ilmenite obtained from Mineral Separation Plant (MSP) is chemically treated to remove impurities such as iron to obtain synthetic rutile (90% TiO2) in Synthetic Rutile Plant (SRP). India is well known for its largest ilmenite reserve in the world.
Alternatively, ilmenite can be imperilled to high temperature smelting to discrete iron in its elemental form from the Tio2 rich slag. The melting point of ilmenite is 1392°c. After undergoes various extents when ilmenite react with carbon at a temperature of around 1200c, reduction of oxides of iron takes place to following reaction. [7]

$Fe2O3C \rightarrow 2FeO + CO$

$FeO + C \rightarrow Fe + CO$

$2TiO2 + C \rightarrow Ti2O3 + CO$

During high temperature, charged composed of ilmenite and carbon first melts with reduction of iron.

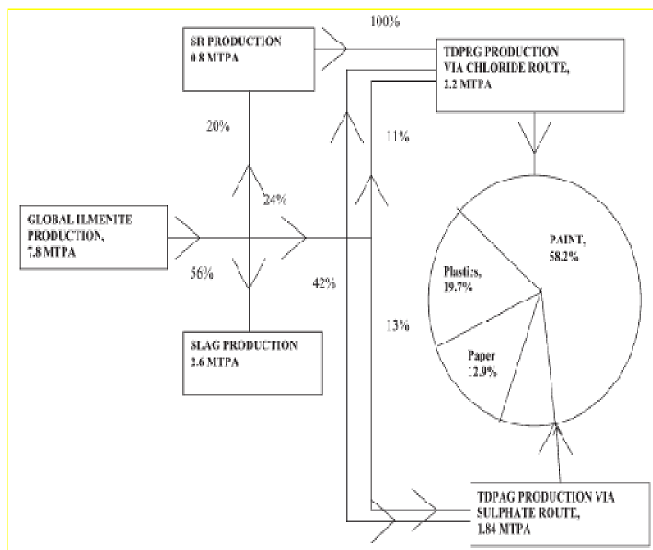

Fig 3- global ilmenite distribution to pigment industries

Advantages. Ilmenite is used mainly for the manufacture of ferrotitanium and synthetic rutile i.e., titanium dioxide, a white pigment. Because of a unique combination of itssuperior properties of high refractive index, low specific gravity, high hiding

power and opacity and non-toxicity, titanium dioxide finds application in the manufacture of all types of white and pastel shades of paints, white walled tyres, glazed papers, plastics, printed fabrics, flooring materials like linoleum, pharmaceuticals, soaps, face powders and other cosmetic products, etc. Because of its non-toxic nature, it is used in cosmetics, pharmaceuticals, and even added to foodstuffs as well as in toothpastes to improve their brightness. Titanium dioxide is used in the manufacture of many sunscreen lotions and creams because of its non-toxicity and ultra violet absorption properties. Synthetic rutile is used for coating welding electrodes as flux component and for manufacture of titanium tetrachloride which in turn is used in making titanium sponge. Global TiO2 pigment production capacity wasestimated to be 5.7 million tonnes per year. TiO2 pigmentproduced by either process is categorised by crystal form as either anatase or rutile. Rutile pigment is less reactive with the binders in paint when exposed tosun light than the anatase pigment and is preferred substance in outdoor paints. Anatase pigment has abluer tone than rutile, is somewhat softer, and is used mainly in indoor paints and in paper manufacturing.Depending on the manner in which it is produced and
Sub sequently finished, TiO2 pigment can exhibit a widerange of functional properties, including dispersion,durability, opacity, and tinting.

IV. Plasma furnaces

Plasma furnace used for smelting of ilmenite are two types-three-phase ac arc furnace and dc arc furnace. Ac arc type furnace consist of a foundation, shell, bottom, tapping port for slag, electrode devices, and controlling electric supply by transformers, ventilation system. the dc furnace based on two electrode system.The electrical and physical
Characteristics of the DC transferred plasma-arc furnace were found to be well suited to thesmelting of ilmenite. Such furnaces has capacity to accept powder charge to offer much more efficient energy transfer to the charge compared to ac arc furnaces.Small-scale batch tests have been carried out in a 50 kW DC transferred plasma-arc furnaceat Mintek, and in a 40 kW water-cooled plasma furnace at the Mineral Resources Centre ofthe University of Minnesota, to investigate the reduction of ilmenite to yield a high-gradetitania slag and a pig iron by-product. The work was aimed at producing a slag suitable foruse as a feedstock for the fluidized-bed production of titanium tetrachloride. [8]

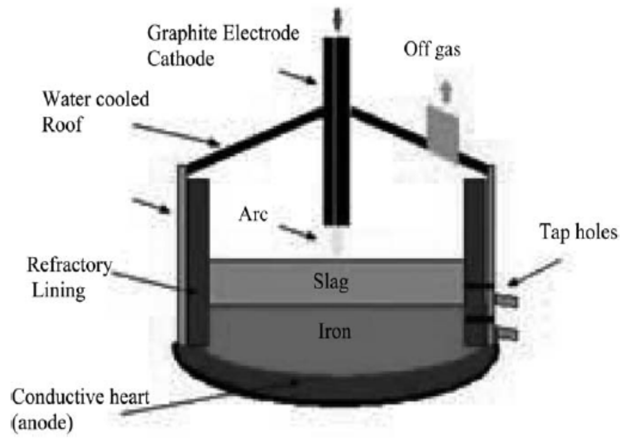

Fig 4- diagram of dc furnace

V. World review

World resources of anatase, ilmenite and rutile are more than 2 billion tonnes. World reserves of ilmeniteare estimated at 700 million tonnes in terms of TiO2 content. Major reserves are in China (29%), Australia(23%), India (13%), South Africa (9%), Brazil and Madagascar (6% each), Norway (5%) and Mozambique(2%). The world reserves of rutile are 48 million tonnes in terms of TiO2 content. Major rutile reserves are located in Australia (50%), followed by South Africa (17%), India (15%), Sierra Leone (8%) and Ukraine (5%).World production of ilmenite and rutile concentrates was 11.40 million and 0.84 million tonnes, respectively, in 2012.Canada contributed 23% of ilmenite production, followed by South Africa and Australia (12% each). Australia produced 52% of world rutile output, followed by South Africa with 15% and

Ukraine 12%. Fig 5 shows the production of ilmenite in the world.

Country	2010	2011	2012
World: Total (wt. of concs)	**10400**	**10900**	**11400**
All form of TiO_2 (e)	**5700**	**6100**	**6300**
Australia Ilmenite	1339	1277	1344
Leucoxene	160	225	228
Canada(e)@	2400	2500	2700
China(e)	1000	1100	1100
India*	663	700e	700e
Mozambique	678	637	574
Madagascar	273e	490	530
Norway	864	870	831
South Africae	1200	1369	1400e
USAe	200	300	300
Vietname	881	870	1164
Ukraine(e)	600	600	600
Other countries	142	201	176

Fig 5- production of ilmenite in world (in tonnes)

VI. Indian scenario

India is endowed with large resources of heavy minerals which occur mainly along coastal stretches of the country and also in inland placers.Ilmenite and rutile along with other heavy mineralsare important constituents of beach sand deposits found right from Moti Daman-Umbrat coast (Gujarat)in the west to Odisha coast in the east.The ilmenite resources estimation for the areas exploredup to 2012 has been completed and the resources are up from 520.38 million tonnes to 593.50 million tonnes (including leucoxene), inclusive of indicated, inferred and speculative categories.[9]

Themost significant deposits which are readily available and attract attention of industry for large-scaleoperations are as follow; Mining and processing of beach sand is carried out by the IREL,At IREL, Chavara, Beach Sand was collected over a strech of 22 kms between Neendakara and Kayamkulam in Kerala and was transported to plant site. The unit has adopted wet mining operations involving use of two Dredge and Wet Concentrator (DWC) of 100 tph capacity each to exploit the inland deposits away from the beaches. Chavara ilmenite is

The richest in TiO2 content (75.8% TiO2) and has great demand in India and abroad for manufacture of

Pigments.IREL carried out trial runs of expansion of capacity of ilmenite to 200,000 tonnes at Chavara

Plant in Kerala and has commissioned it successfully. The company has plan to expand MSP capacity atOSCOM to produce 4.7 lakh tonnes of ilmenite and associated minerals by the end of 2014.FIG 6 shows production of ilmenite in India. [10]

State	2010-11	2011-12(R)	2012-13(P)
ILMENITE			
India : Total	**663217**	**751163**	**738524**
Kerala	113240	86454	68555
Odisha	206139	188000	184570
Tamil Nadu	343838	476709	485399
RUTILE			
India : Total	**26593**	**16598**	**16527**
Kerala	5969	5664	3075
Odisha	8043	7874	7170
Tamil Nadu	12581	3060	6282

Fig 6- production of ilmenite and rutile in India (in tonnes)

VII. Thermal plasma melting operation

Laboratories of Bhubaneswar and Trivandrum have also newly involved in making the slag process more cost effective via dc arc furnace of special design, in which a moving bed of metallised OSCOM ilmenite is subjected to the arc heat through a centrally placed graphite cathode for very short duration. Such low input power is adequate in melting and settling of the iron particles leaving the semi fused slag on top of it. The slag lump gets easily disintegrated and, after dilute acidLeaching, contains 96%TiO2 value. The processseems to have good potential. [11] In recent investigation fromthe same laboratory on the in-flight processing route in a static bed reactor, Titania rich slag could be made from metallised ilmenite. The slag obtained is of high quality, and energy consumption gets reduced comparatively in the above other chemical processes. Ilmenite from IREL, Chatrapur, Orissa and its thermally activated products such as metallised ilmenite and Titania rich slag were characterised to find out their suitability for the production of synthetic rutile (SR). [12]

RRL Bhubaneswar has been working on thermal plasma processing of ilmenite. In such static bed dc plasma reactor, the energy consumption was found to be about 3–4 kW h kg21 of ilmenite for conversion to slag.Fig 7 shows the reserve in India.

State/Deposit	Ilmenite reserve (In million tonnes
Andhra Pradesh	
1. Bhavanapadu Hukumpet	10.18
2. Kakinada (Phase I-VIII)	13.84
3. Kalingapatnam	5.80
4. Narasapur	2.92
5. Nizampatnam	19.26
6. Srikurman (South)	8.60
7. Visakhapatnam (Bhimunipatnam)	2.88
8. Amalapuram (Phase I-III)	3.10
9. Pandurangapuram-Voderevu (Bapatla-Chirala coast)	10.39
10. Vetapalem Coast (Chirala coast)	5.31
	82.28
Kerala	
1. Chavara Barrier beach	13.17
2. Chavara Eastern Extension (Phase-I)	17.02
3. Chavara Eastern Extension (Phase-II)	49.26
4. Trikkunnapuzha-Thotapally Beach & Eastern Extension	9.50
5. Alapuzha-Kochi	5.88
	94.83
Maharashtra	
Ratnagiri	3.68
Gujarat	
Moti Daman-Umbrat coast	2.77
Odisha	
1. Brahmagiri (Phase IV)	37.98
2. Chatrapur	26.72
3. Gopalpur (Phase I-IV)	6.39
	71.09
Tamil Nadu	
1. Kudiraimozhi	22.86
2. Ovari-Periyatalai-Manapadu (Teri)	24.01
3. Sattankulam Teris	41.26
4. Cuddalore-Pudupattuchavadi	4.67
5. Vayakallur (Block I-IV)	3.54
6. Manavalakurichi	2.04
7. Midalam	1.64
	100.02

Fig 7- resources of ilmenite and rutile in India

VIII. Conclusion

Plasma furnaces have been successfully applied to the production of a variety of materials.The major chunk of consumption of ilmenite is for the manufacture of synthetic rutile.Global demand growth for Tio2 expected to trend with economic growth and the production of paint, paper and plastics.Ilmenite and rutile along with other heavy minerals are important constituents of beach sand deposits found right from Moti Daman-Umbrat coast (Gujarat) in the west to Odisha coast in the east. A transferred arc plasma furnace of the molten anode configuration is well suited to smelting of ilmenite for the production of high grade Titania slag and pig iron product. The electrical and physical properties of plasma reactor configuration are compatible with both the process chemistry and physical properties of Titania slag. Hence, India has excellent reservoir of ilmenite and it can produce more amount of Titania slag by using plasma furnace technology. It looks well suited and viable technology for the production of Titania slag.

IX. References

1- *D. A. Donaldson, R. R. Apa, T. L. Eddy and J. E. Flinn: 'Heat transfer in thermal plasma processing', HTD, Vol. 161, 41–51;1991, New York, NY, ASME.*

2- T. B. Reed: 'Induction-coupled plasma torch', J. Appl. Phys., 1961, 32, 821–824.

3-. V. Dembovsky: 'Plasma metallurgy – the principles'; 1985, New York, NY, Elsevier.

4- MacPherson, R.D., Mineral processing at Richards Bay Minerals. In Proceedings of the 12th CMMI Congress, Glen, H.W. ed. (Johannesburg: The South African Institute of Mining and Metallurgy, 1982), VoJ. 2, pp. 835-840.

5-Robinson I. SA's developing timnium industry. Eng. News - Mining, 25 September 1992.

6-Brent A.D. The smelting of ilmenite in a D.C. transferred-arc plasma furnace with a molten anodeconfiguration. Report No. M304, Randburg, Mintek, 15 July 1987.

7- P. C. Pistorius and C. Coetzee: 'Physicochemical aspects of titania slag production and solidification', Metall. Mater. Trans. B, 2003, 34B, 581–588

8- U. Hu¨ tter: 'Refractories and conductive bottom design for DC-arc furnaces, system ABB', Radex-Rundschau, 1992, 2/3, 83–95

9-Department of Atomic Energy, Mumbai. Fig (5, 6, 7).

10- N. A. Barcza, T. R. Curr and U. K. Maske: 'The application of thermal plasma technology to large-scale pyro metallurgical processes', Proc. Extraction Metallurgy '85 Symp., London, UK, June1985, Institute of Mining and Metallurgy, 709.

11-P. S. Mukherjee: 'Plasma smelting studies of solid waste effluent From dichromate plant', Proc. Int. Symp. On 'Recycling waste Management and clean technology', San Siberian, Spain, 1999, 175–181. ER

12. P. S. Mukherjee, S. K. Chaudhary, V. N. Mishra and P. N. Mohandas: 'Melt separation of titania rich slag and pig iron from Pre-reduced ilmenite using thermal plasma', Trans. Indian Inst. Met., 2002, 55, (6), 543–550.