THERMAL PLASMA IN EXTRACTIVE METALLURGY

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I. Thermal plasma applied to metallurgical processes produces the materials with new properties; simplifies the production cycle and equipment; falls in line with prospective energy consuming system (electrical energy and hydrogen).

2. The mostly prospective field of thermal plasma industrial application is the production of metal and ceramic materials with new properties - chemical, physical, mechanical - determined by specificity of plasma processes - quick heating, high temperature and high rate of reaction in plasma of a given content and sharp quenching (spherical, ultra-disperse, surface active and pure powders, metastable nitrogen containing alloys, pure monocrystals).

3. Obvious and scientifically proved advantages of thermal plasma jet and furnace processes are: significant reactions speed-up in gases and in gas carried disperse materials; pronounced intensification, continuity and high output of processes; the possibility of carrying out few-stage and even one-stage processes, simplifying the production cycle; compactness of the central plasmatron-reactor unit; lower capital investment and reduced product cost; improvement of labour and environment conditions; possibility of automatic regulation and control of process; service staff reduction. These advantages determine the technical and economical efficiency of substituting the conventional technological routes by plasma routes based on electrical energy.

4. Modern metallurgy and chemical technology tends to utilize raw materials completely and to develop processes without wastes, eliminating environment pollution. Combined with hydro- and chlorine metallurgical processes thermal plasma makes it possible to decompose and separate complex raw materials on early stages of their treatment, facilitating essentially further treatment.

The following processes are developed on semi-industrial scale: zirconium decomposition in a jet plasma reactor (Tafa-Ionarc, USA) with formation of zirconium oxide and silicon dioxide mixture (300 kW, 400 ton per year); fuming of tin oxides from lean tin slags in a rotating plasma furnace (NPL, Great Britain). Plasma jets and furnaces are promising for processing: phosphate ores, alumosilicates and titanium ores, ilmenites and magnetites, wastes of refractory and rare metals, metallurgical dusts and slags (e.g. vanadium containing converter slags, tungsten concentrates).

5. For thermal plasma recovery of metals from oxides and halides solid carbon, raw and converted natural gas and hydrogen are used as reducers. Reduced metals may be obtained both in compact form and as powders of various dispersity. Reducing process may be organized directly in plasma jet, in falling film or in a molten pool.

Plasma-jet technology is effective for reduction of compounds with rather low sublimation temperatures, e.g. oxides and ammonia salts of W, Mo, Re, some haloid compounds, when short residence time in high temperature jet zone is sufficient for substance transfer into gaseous phase. Reduction of tungsten oxide in hydrogen arc plasma linear plasmatron (300 kW) and a direct flow reactor has been developed on semi-industrial scale. By rapid cooling (quenching) metallic tungsten powder with globular particulates and a specific surface of I0-I2 m^2/g was produced (IMET, VNIITS, VNIIETO, USSR).

Noranda (Canada) has been developing plasma process of direct dissociation of molybdenite (MoS_2) to molybdenum and sulphur.

Nickel and cobalt oxides have been carbon reduced in the plasma furnace with a crystallizer (USSR).

Betlehem Steel (USA) has developed plasma reduction processes for producing iron and ferrovanadium in a I MW falling film plasmatron-reactor unit. The blast furnace-converter steel production route and direct iron reduction - electric furnace melting route may be substituted by single-stage process of producing pure iron ingot (0,0I% C). Magnetite and gematite concentrates and hot rolling wastes have been melted and prereduced with hydrogen-methane plasma mixture in a falling film reactor and fully reduced under the slag heated by plasma jet in the ceramic crucible with 200 kg/hour (750 ton/year) productivity. Ferrovanadium has been produced on 500 kW power level by carbothermal reduction of V_2O_5 with iron scrap added to the melt.

6. Rising scarcity of fossil fuels and transportation difficulties tend to work out wider use of electrical energy and hydrogen for metallurgical processes. High economy of deficient fuels - coke, natural gas and oil - is becoming conceivable and even their full exclusion from energy balance may turn prospective. As expected in 25-50 years' time the gradual substitution of thermal energy from hydrocarbon fuels with electrical energy generated in coal or nuclear power stations - as well as by hydrogen energy - favours the use of thermal plasma for pyrometallurgical processes.

Plasma heating of industrial gases (nitrogen, oxygen, hydrogen et al.) and activation of flames in arc or HF plasmatrons can provide considerable technical and economical advantages for intensifying big-scale chemical and metallurgical processes. Most promising for thermal plasma are: heating-up and activation of reducing gases (including preheated by nuclear reactors off-heat); conversion of methane by carbon oxides and furnace off-gases; heating of sulphur containing off-gases of sulphide ore processing.

7. Thermal plasma jets for technological applications are generated in direct and alternating current arc discharge as well as in electrodeless high-frequency induction and capacity discharges. Main requirements for industrial plasma generators are: power, efficiency and continuous service life with active plasma forming gases. By I979 arc plasmatrons have been built for power up to 3-5 MW (Westinghouse, USA, Institute of Thermal Physics, USSR) with efficiency 60-90% and service life up to 200 hr. High frequency (0,5-I5 MHz) plasmatrons for power up to I MW (Tafa, USA, Institute of High Frequency Currents, USSR) have efficiency 50-75% and HF generator service life up to 2000 h.

Plasma jet reactors for processing gases and disperse materials and plasma melting furnaces are being developed and built for use in extractive metallurgy.