PLASMA FURNACE WITH CERAMIC CRUCIBLE

Dr. Gerhard Scharf
VEB Edelstahlwerk, Freital, GDR

Dr. Walter Lugscheider
VOEST ALPINE AG, Linz, Austria

1. Introduction

Several reports have been given in the last years on the use of low temperature gas plasma in metallurgy. Little data refers to plasma furnaces with ceramic crucibles as well as the obtained operating practice in making high alloy steels from scrap. Plasma remelting furnaces with water - cooled Copper crystallizers up to 5 t ingot weight, however, have along with VAR, ESR and EB a reserved place among the special metallurgical procedures. Japan often reports on the results with a combined 500 kg induction plasma furnace.
Research work in the GDR let to building and commissioning plasma furnaces of 15 and 35 t for processing scrap.
Along with the low loss recovery of alloy elements, melting under the Ar atmosphere should bring improved properties in the produced steels from low gas contents, high slag purity, avoiding the danger of carburization in comparsion to arc furnaces.

For the development of the new process principle of plasma primary melting it was reasonable to start from the metallurgical experience with arc furnaces and to choose equipment as the furnace vessel which does not differ from the known arc furnace with respect to its geometric parameters.

Starting from results obtained in laboratory scale and pilot plants of the GDR the following advantages were expected for melting of especially high-alloy steels as compared to the arc furnace:

- maximum recovery of the alloy metals contained in the scrap,
- higher melting efficiency,
- the possibility of the production of materials with low carbon content due to the omission of carburizing by graphite electrodes,
- alloying of nitrogen by the gas phase,

- low oxygen and hydrogen content,
- high-quality steels with a quality level superior to that of the material molten in the arc furnace,
- reduction of total iron losses below values obtainable in the arc furnace process,
- suppression of noise,
- removal of the discontinuous loading of the electric mains.

Within the framework of the research and development work which was carried out subsequent main problems had to be solved:

- development of high-power d.c. plasma torches up to 9000 A which were suitable for melting,
- examination of parallel operation of the torches with different torch arrangement,
- development of a suitable bottom selectrode.

one of the main difficulties during development and testing of the high-current torches was the selection of a suitable cathode material and the dimensioning of the cathodes. Sufficient cooling is of great importance for the service life of the torch cathodes which are operated with several KA.

First of all, the procedure without focus seemed to be most favourable one, because in this case the current density on the emitting surface does not exceed the value of 2000 A/cm^2 and hence not so much colling is required. On the other hand, the Joule heat must not be neglected in the case of high amperages; with insufficient cooling this leads to cathode and torch destruction. Tungsten with emitter additions has proved its worth as cathode material.

The simultaneous burning of plasma arcs of 1200 to 1400 mm length was connected with deflections due to the presence of electromagnetic forces. The gas flow which passes through the arc and covers it acts as the counterforce.

A further problem was the formation of parasitic arcs in the range of the torch jacket / nozzle / cathode / scrap and between the torches themselves which result from insufficient isolation and could result in the destruction of the torch.

After evaluation of numerous tests and series of measurements it was found to be favorable to install one torch of 6 to 9 kA instead of several torches of 4 to 6 kA for furnaces up to 5 t heat weight. In this case the arrangement of the torches can be maintained centrally by the cover. With heat weights above 5 t the arrangement of several torches proved to be expedient.

At present, plasma primary melting furnaces are used in three-shift operation only in the German Democratic Republic and in the Soviet Union. In 1969, a 3-t plasma Furnace, in 1972 a 15-t plasma furnace, and in 1977 a 35-t plasma furnace was put into operation in the German Democratic Republic.

In the Soviet Union, a 5-t plasma furnace which is equipped with a vertical torch has been in operation since 1972.

More than 100,000 t of steel ingots, mainly high alloy high-quality steels have been molten in the 15-t plasma furnace in the GDR which was built by VEB Lokomotiv- und Elektrotechnische Werke "Hans Beimler" in Hennigsdorf since its complete changeover to three-shift operation in 1973.

2. Description of the 15-t plasma furnace (Fig.)

The 15 -t plasma furnace is equipped with a pivot cover hearth and wall vessel are arranged separately. In the case of wear of the refractory lining, repairs can carried out quickly by replacement of the upper and lower furnace sections. Hearth wall and cover are lined with high-grade MgCr-bricks which allow a surface temperature of maximum 1850 °C in continuous operation.

To avoid a higher temperature, heat admission to the upper furnace is controlled by appropriate measuring instruments and thus a service life above 150 charges is guaranteed.

Power is fed through three plasma torches which are attached laterally to the upper furnace with horizontal and vertical adjustment. They are operated with direct current through a 15-kV supply of the works system, with appropriate transformers, banks of capacitors, thyristors and chokes being provided for ripple reduction.

Argon is used as the working gas. The contumption per torch amounts to about 8 Nm^3/h. The maximum adjustable amperage is 6 kA in the voltage range of 200 to 600 V. In practical operation about 7 to 8,5 MW are available. With the torch construction used, tungsten cathodes with lanthanum as emitter addition have proved their worth. A water cooled copper anode is used.

3. Description of the 35-t plasma furnace (Fig.)

Just like the 15-t furnace, the 35-t plasma furnace is also equipped with a pivot cover; hearth and side wall are separated so that repairs after wearing of the refractory lining is carried out by replacement of the upper and lower furnace sections. The hearth is banked with magnesite, walls and the cover consist of magnesite-chromium-bricks.

The four plasma torches are attached laterally to the upper furnace with adjustability in two planes. They are operated with direct current through the 15-kV supply of the works system via appropriate transformers, chokes and thyristors. Argon is used as the working gas. The maximum amperage amounts to 10,000 A at a voltage range from 150 to 660 V.

If necessary, the complete torch can be replaced with in a short time without interruption of the process. The arc is ignited contactless by means of the pilot arc feed and an oscillator.

A warning system has been provided to protect the torch against short-circuit with the raw material. Moreover, the complete electric system is coupled with cooling water consumption and the cooling water temperature, the gas consumption and the function of the main mechanismus. All working pears on the furnace are operated oil-hydraulically. Cover, Charging door, tap-hole and torch ducts are sealed so that a slight overpressure exists in the furnace during the melting process and thus the neutral furnace armosphere is abtained which is favourable for the metallurgical process.

The 35-t plasma furnace was planned and designed by specialists of the German Democratic Republic and the Soviet Union in the basis of the experimence gained with the 15-t furnace, then built in the Soviet Union and assembled in VEB Edelstahlwerk Freital, GDR.

Tungsten is used as the cathode material for the plasma torches. The bottom electrode which is located in the hearth consists of a water-cooled copper block. It is equipped with a temperature control unit.

The complete electrical, mechanical and hydraulic equipment of the plant was assembled by Soviet firms and firms of the German Democratic Republic in less than three months and subjected to a successful test. The furnace itself was erected in a new hall side by side with the 15-t plasma furnace in the direct vicinity of the electric arc furnaces.

The electric and plasma melting shop are supplied by one scrap yard. The steel produced in the new plasma steel mill (15-t plasma furnace and 35-t furnace) is cast in a partly mechanized pouring system without special treatment. Both melting shops have a common ingot yrad as well as common catering and attending facilities.

The onstalled capacity of the two plasma furnaces shall guarantee a production of minimum 100,000 t/a of highquality and high-grade steel per annum during the next years.