§7. Development of Microwave Transfer System from Crystron Generator to Furnace

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1. Introduction

When 1 ton of pig iron is produced, about 530kg of coke is consumed and about 2 t of CO_2 gas is emitted. In Japan, 13% of total CO_2 gas in Japan was emitted from ironmaking in 2007. As the theoretical carbon consumption is 380kg per 1 ton of pig iron production, the exergy loss of blast furnace is estimated in about 150kg of carbon. 150kg of 380kg is used as heating and reaction energy.

Microwave is the coherent electromagnetic wave of 0.3 to 300GHz. Because of longer wavelength by 10^5 than radiant heat, microwave can volumetrically penetrate into powdery resources. Ishizaki and Nagata[1] showed that 10g of carbon-composite pellet including 5 g of total iron as magnetite was rapidly reduced to pig iron during about 10 min under about 6 mW/cm^3 of microwave at 2.45GHz. This means that it is possible to produce pig iron from iron ore during 30 min using the microwave furnace with 60 kW for producing 1 ton of pig iron per day. As the theoretical energy of heating and reaction of resources is 48 kW, the exergy loss is 12 kW. The energy efficiency is 80% and higher than the existing blast furnace. Rapid reaction could make the furnace size and the surface area small to decrease the emission exergy loss and also reduce the construction cost. Authors have constructed 120kW microwave furnace. The present study developed the crystron generator and waveguide for this furnace.

2. Experiments

The furnace with graphite lining inside was developed for producing 1 ton of pig iron per day. There were 4 systems of 30kW crystron generators, The microwave transfer system composed of water cooled isolator, 3-stab auto tuner and directional coupler was examined, as shown in the figure.

3. Results and discussions

(1) Design of microwave applicator for ironmaking

The furnace with the productivity of 1 ton of pig iron per day was a cylindrical stainless tube of 120 cm diameter and 60cm height, which inside was insulated by lining of porous alumina bricks and covered with a graphite seat. The hearth was composed of porous alumina bricks with a graphite seat cover and heated by auxiliary heaters in order to prevent pig iron solidifying.

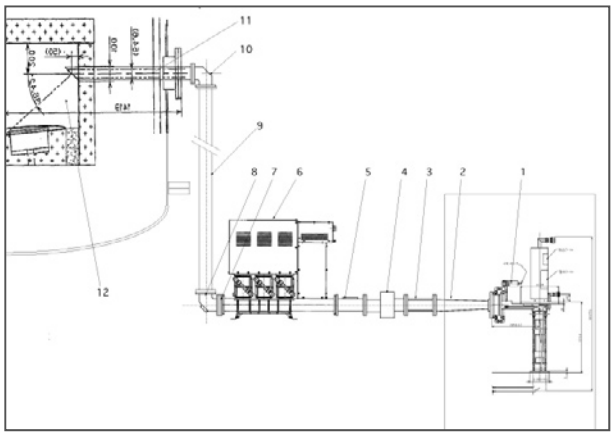
(2) Estimation of net electric power of crystron microwave generator

In the furnace of Tokyo Institute of Technology, 8 microwave beams of total 20kW in maximum have been concentrated into the center of applicator to make high energy zone. The productivity of pig iron of the furnace is 1 kg per hr and the power of microwave is 1.25kW. As 1 ton of pig iron making per day is 42 kg per hr and the electric power of microwave of 52.5kW is required.

4 crystron microwave generators with 33kW at 2.45GHz were employed in parallel and the maximum power was 132kW. The electric power of high voltage for crystron was necessary to be 275kV in 400V of 3 phase alternating current. The inverter power supply of high voltage was set in an insulating oil tank. The high voltage current was led out by a coaxial cable and connected to the high voltage connector of polycarbonate plates in a cubicle on the stand of crystron.

(3) Microwave transfer system from crystron to applicator

One microwave transfer system was composed of the standard parts, as shown in the figure. From



crystron microwave generator① to appli-cator⑫, water-cool-ed isolator④, direct-ional coupler⑤ and 3-stab auto tuner⑥ were connected.

No	Parts
1	Crystron generator
2	Up-taper tubu
3	Colgate wave guide
4	Water-cooled isolator
5	Directional coupler
6	3-stab Autotuner
7	Silica Window
8	Corner bent with arc detector
9	Water-cooled wave guide
10	E Corner bent
11	Water-cooled wave guide
12	microwave furnace

(4) Development of radiation way of microwave

4 microwave guid-es was horizontally set on 4 sides at the upper part of the furnace. The end of guide was cut at an angle of 36.42 degree in order to focus microwave into the hearth.

4. Conclusions

The development of high power microwave generator has some problems on its transfer system because of plasma generation. The new microwave generator and its transfer system should be innovated.

1)K.Ishizaki and K.Nagata: *ISIJ Int.*,46(2006),pp.1403-1409.