# Hybrid Torch for Tundish Plasma Heater

## 1 Introduction

In continuous casting machines, the molten steel from the ladle is transferred to the mold via a tundish. Because the molten steel in the ladle and tundish loses heat to the refractory material and by surface radiation, it is impossible to prevent its temperature from falling prior to ladle transfer. Nippon Steel Engineering has previously developed tundish plasma heaters (TPHs) to address this problem and these have demonstrated their worth at numerous production facilities. The company has now developed a new hybrid torch that combines graphite and metal torches.

## 2 Benefits of Tundish Plasma Heating

A TPH heats the molten steel in the tundish by generating a plasma arc between the plasma torch and steel. This provides a means to control the temperature of the metal in the tundish and thereby to significantly reduce the variability of the steel temperature at the time of ladle transfer. This offers the following benefits for productivity and quality:

(1) Casting at the optimum and consistent temperature of steel can reduce quality defects.

(2) Casting speeds that are free from the constraints of steel temperature can increase productivity

(3) Refractory and energy costs of the converter or arc furnace can be reduced by allowing a lower tapping temperature

## 3 Conventional Plasma Torches

The features of a TPH are described elsewhere, in Vol. 6 of the Nippon Steel & Sumikin Engineering Technical Review. This current paper focuses solely on the TPH torch.

### 3.1 Metal torch configuration

Figure 2 shows a diagram of the metal torch conventionally used for a TPH.

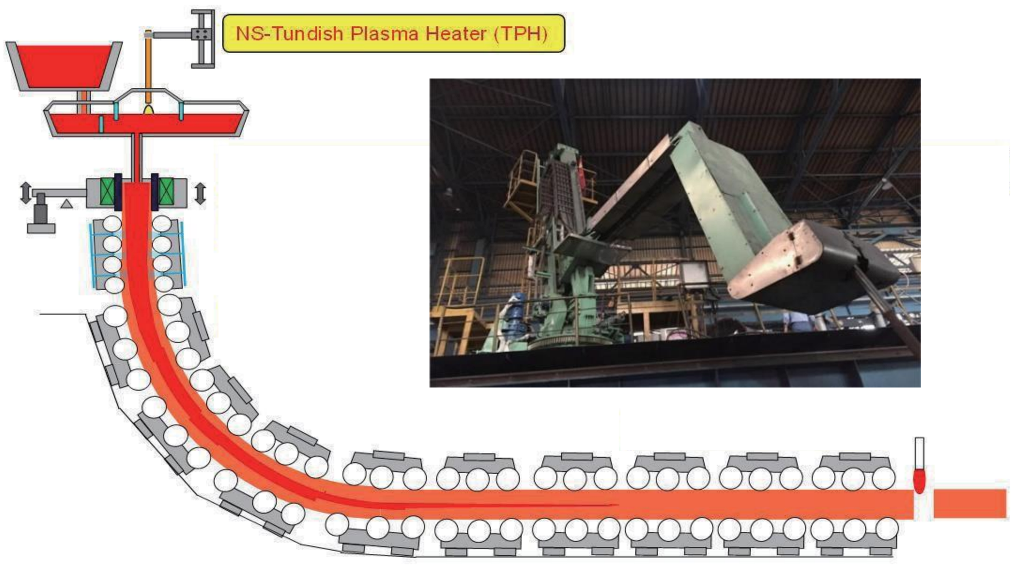


Figure 1 Role of TPH in continuous casting machine

The torch is made up of a metal electrode through which an electric current is passed and a surrounding metal nozzle. Inert gas is supplied between these two structures to maintain stable plasma formation. The interior of the torch is water-cooled to protect it from the heat radiating from the plasma and to minimize electrode wear.

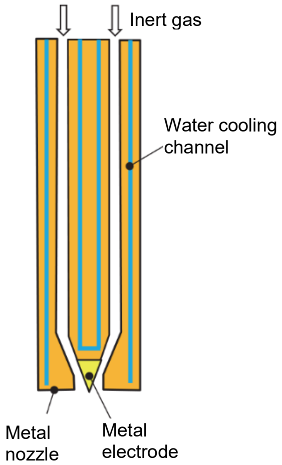


Figure 2 Configuration of metal torch

### 3.2 Issues with metal torches

1) Electrode replacement cost when operating at high output

The plasma arc forms from the cathode to the anode resulting in repeated collisions between the stripped-off electrons that make up the atmospheric molecules of the plasma medium. The energy given off by these collisions imposes a high thermal load resulting in electrode wear. Since increase of the plasma output significantly enhances the erosion of the metal electrode, operators may have to reduce the output to minimize the electrode replacement cost.

2) Thermal efficiency

The thermal efficiency with respect to the electric power input to a TPH is typically around 60% due to the various heat losses in the system, including to the refractory material, inert gas (argon or similar), and torch cooling system.

### 3.3 Work undertaken to enable use of graphite torches

To overcome the issues highlighted in the previous section, Nippon Steel Engineering has since 2013 been developing a torch that uses a graphite rather than a metal electrode (see Figure 3). Use of the same consumable graphite electrodes as arc furnaces improves thermal efficiency by eliminating the need for torch cooling. Switching from metal to general-purpose graphite also cuts the cost of electrode replacement and eliminates concerns about operating at high output.

On the other hand, graphite torches suffer from their own problems in the form of unwanted electrical discharges due to electricity flow between the graphite torch and the metal-shell TD cover through which it is inserted, and electrode wear due to oxidation outside the TD cover. These pose an impediment to reliable operation and prevent practical application.

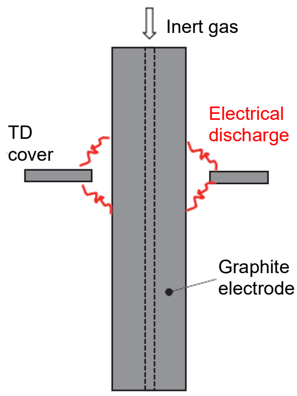


Figure 3 Configuration of graphite torch

## 4 Hybrid Torch

To overcome the above issues with graphite torches, Nippon Steel Engineering has developed a hybrid torch that is made of metal in the vicinity of the TD cover and only uses graphite for the electrode itself (see Figure 4). Table 1 lists the characteristics of the different torch configurations.

The hybrid configuration provides reliable operation by eliminating the problems of unwanted discharges and torch wear due to oxidation while still maintaining the high output and low replacement cost of a graphite electrode. This allows the full output capacity of the machine to be utilized and raises the thermal efficiency to about 70%. Replacement is also simplified and the replacement time shortened by using bolts to attach the metal and graphite sections of the torch to each other.

Plant trials of a plasma heating system with a hybrid torch have been completed and the system is in routine use at a Nippon Steel plant. The plan is to install three of the systems at Japanese steel plants during 2020.

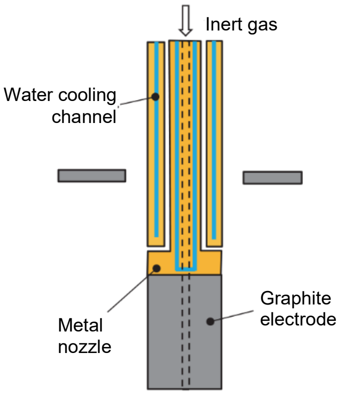


Figure 4 Configuration of hybrid torch

Table 1 Comparison of torch characteristics

| | Metal torch | Graphite torch | Hybrid torch |
|---|---|---|---|
| Output | 0.7 MW (constrained by electrode wear) | 1.2 MW (increased discharge at high output) | 1.2 MW |
| | △ | △ | ○ |
| Replacement cost | Metal nozzle + metal electrode | Graphite electrode (lifetime shortened by unwanted discharges) | Graphite electrode (+ metal parts) |
| | △ | ○ | ○ |
| Thermal efficiency | 60% (approx.) | 70% (approx.) | 70% (approx.) |
| | △ | ○ | ○ |
| Unwanted discharges | None | Unwanted discharges between TD cover and graphite electrode | None |
| | ○ | △ | ○ |
| Side-arcing between torches | None | at high output | None |
| | ○ | △ | ○ |

## 5 Future Plans

Nippon Steel Engineering intends to continue striving to improve customer satisfaction by supplying products through a highly reliable product development process based on customer needs together with after-sales service that continues beyond commissioning.

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