REFINE LANCES FOR SCRAP MELTING AGGREGATES

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Abstract

The smelting units, which are used for melting metal waste, are equipped with lances for blowing gaseous media. In case of refining lances, this is oxygen. These gaseous media enable, in particular, the melting of scrap and the intensive homogenisation of the resulting melt. In this connection, blowing systems have been developed both for blowing the gaseous media onto the melt surface or into the melt itself and also for blowing the gaseous mixture with powdery substances. In the design of the blowing systems and the individual lance heads and nozzles, it is necessary to respect certain recommendations, the derivation of which is based on long experience and knowledge gained in this field. The present paper summarises these recommendations for the design and construction of the refining lance heads. Furthermore, the paper describes lance heads made of cast and forged components including the method of their cooling by circulating water. The paper deals with only a part of the whole rather complex issue, but the design recommendations and description of the design of selected refining lance heads should help designers and engineers to navigate this issue as well as the process of designing systems that meet high quality, efficiency and operational reliability requirements.

Keywords: steel production, metal scrap processing, oxygen lance, nozzle, gas blowing, lance heads

1. INTRODUCTION

If gaseous medium is blowed into metallurgical aggregate for waste metal processing, then we want to achieve certain technological effect at melt processing or gaseous products. Within this context the character of mutually interaction between blown gas and melt or generally told by environment inside of reactor, which is substantially affected by lance design, is very much important. Wide spectrum of various lance designs are used in thermal reactors at different industrial branches, which are intended to different purposes [1,3,5]. In the following text we will focuse most of all to refine lances used in metallurgical aggregates for scrap iron processing.

2. FACTORS AFFECTING REFINE LANCES DESING

Metallurgical aggregates for iron waste processing (melting) are equipped with various types of lances for gaseous media blowing. Design of the lances is given by the purpose for which the lances are designed. The main technological process is provided by the so-called refining lances by which refining oxygen is blown to the surface or below the melt level. It depends on the construction of the aggregate [6,3].

Lance design has a significant influence on the parameters of the output stream of refining oxygen, which significantly influences not only the metallurgical parameters but also the economic indicators of the aggregate [7].

It is therefore necessary that the lance design respects also requirements for lance service life and reliability of the production unit in addition to the above-mentioned indicators. Multinozzle lances (lance tips) with convergent-divergent and cylindrical nozzles (see **Figure 1**) are designed for refining oxygen blowing, the number of which depends on the intensity of the O_2 blowing and in case of oxygen converter there are from three to six nozzles. The mutual position of the nozzles depends on the design of the lance tip. When designing and assessing nozzle function, we proceed with the following parameters:

- maximum O_2 mass flow rate through lance and the corresponding O_2 resting pressure in the lance,
- optimum number of nozzles and cross-sections ratio,
- static pressure value in front of the nozzle,
- corresponding value of the flow pulse and the action coefficient of the outlet stream on the melt bath,
- dimensions of the reactor working profile (spraying, angle between nozzles),
- the area on the bath surface which is affected by the outlet stream and the penetration of the O_2 outlet stream into the melt.

Lances for blowing of gaseous media on the melt surface in the working space of high-temperature reactors for metal making are exposed to severe working conditions. In the case of oxygen blowing into the steel bath, there is intensive heat generation, metal and slag spraying on the lance tip, and at the same time waste gases are released. It is reported that the surface temperature of the bath (reaction zone) reaches values from 2000 to 2500 °C [2] and the temperature difference between the remaining volume of the bath is in the range of 400 to 700 °C [4]. Operating experiences shows that the following factors have a decisive impact on the service life and perfect function of the lance:

- radiation effect of the bath and reactor lining,
- thermal effect of exhausted gaseous products,
- effect of melt spraying on the lance tip,
- aerodynamic characteristics of the lance,
- position of the nozzle in the workspace - distance of the nozzle from the bath surface,
- quality of the materials used for lance manufacturing,
- manufacturing method,
- blowing intensity,
- number, shape and dimensions of individual nozzles in the lance,
- design of the cooling system (central, peripheral).

All these factors are related to the heat load of the lance and especially its tip. The outer surface of the lance is therefore exposed to a high heat load. To prevent breakage of the lance material, we must keep the material temperature within the appropriate limits and hence there is the need to cool the lance. Lance inner surface is intensively cooled.

Water is used as the cooling medium. However, the lance material is exposed to high thermal stresses, which may cause cracks especially at the weld points between the copper lance tip and other steel parts. The design of the lances should meet the following requirements:

- simplicity with regard to production and assembly,
- use of suitable materials,
- minimum heat consumption from the reactor working space,
- optimal media supply with respect to pressure losses,
- optimal shape of the cooling system, avoiding incrustation and excluding film boiling,
- low noise intensity,
- as small splash and melt ejection as possible together with maximum oxygen utilization,
- as long service life as possible, service life should not be lower than the duration of the high temperature reactor campaign.

3. FORGED AND CAST REFINING LANCES TIPS

It is said that in the case of the basic oxygen furnaces, the lance service life is about several hundreds heats. It may be from 100 to 500 heats and it depends on many individual parameters of steel melting shop [2].

The material used to manufacture lance tips is electrolytic copper [8,9]. It is a material wchich has a high thermal conductivity and therefore the thermal stresses do not appear at such intensity as it would be in the case of other materials. Conversely, it was shown that the deoxidation elements such as e.g. phosphorus, which are contained in a limited amount in the copper acts against diffusion of oxygen into the surface of the lance tip and thus prevent cracking. Although these small amounts of chemical elements reduce, to a certain extent, the thermal conductivity, they can, on the other hand, prolong the service life of the lance.

The tips of the upper refining lances of the steelmaking aggregates (LD converters, heard furnaces. EAF) are, at the present time, manufactured in the form of forgings and (or) castings [4]. Forgings have to be machined to the final form, and the individual parts are then soldered and welded together.

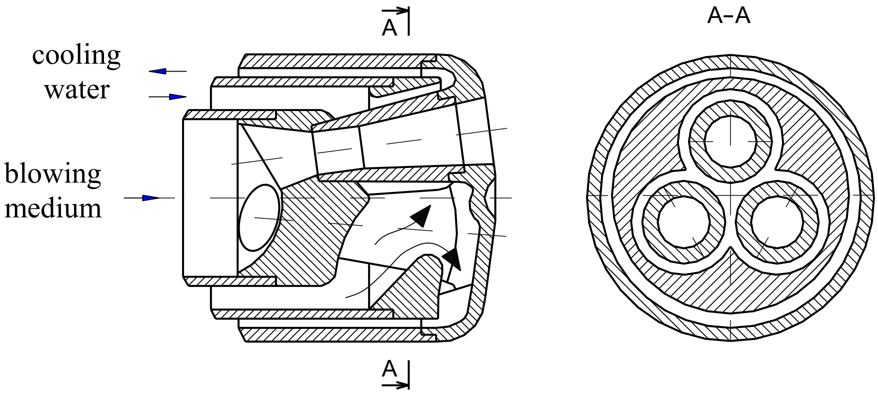

Figure 1 Three-stream lance tip consisting of six parts

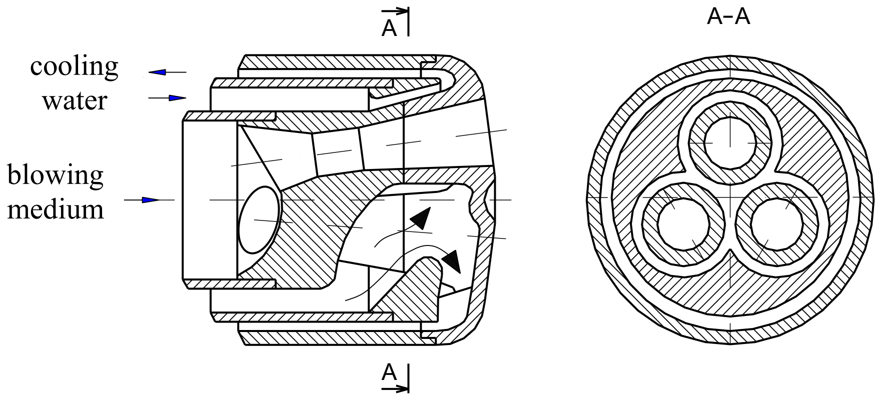

Figure 2 Three-stream lance tip consisting of three parts

Examples of the lance tips designed for so called upper blowing to the oxygen converter and which consist of several forgings are shown in the **Figure 1** and **Figure 2**.

While the lance tip in **Figure 1** consists of six forged parts and has six connecting points (nine places for total lance head assembly), in **Figure 2** there is a lance tip consisting of three forged parts (**Figure 3**) and it has only three connecting points (six places for total lance tip assembly).

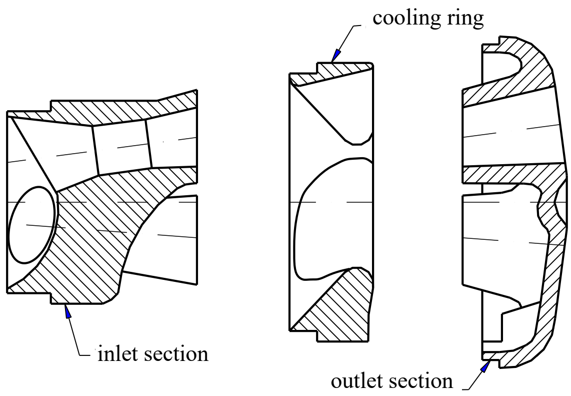

Figure 3 Main parts of three-stream lance tip from Figure 2

Another advantage of the lance tip in **Figure 2** is the fact that the connecting plane between the inlet and the outlet part is moved further from the front face of the lance tip, thereby making it better protected from the thermal load from the front face of the lance tip.

Cast components, on the other hand, save material, reduce production costs and simplify production and assembly. An example of a cast lance tip is shown in **Figure 4** and **Figure 5**.

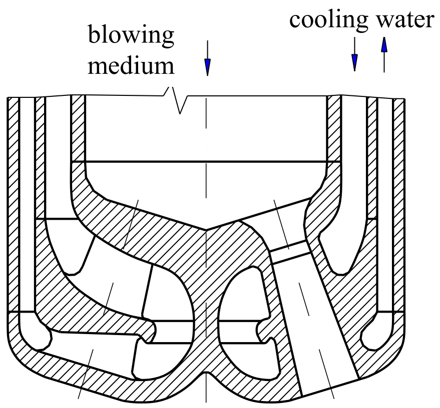

Figure 4 Longitudinal cross-section of the cast lance tip

4. COOLING OF REFINING LANCES

The cooling system design is of great importance for increasing the lance service life [10]. Lances are cooled by technical water at a pressure of 0.5 to 1.0 MPa. Cooling water velocity inside the lance tip is in the range of 1.8 to 6 $m \cdot s^{-1}$. Stagnation areas of the cooling water flow should not be in this system, as the bubble boil then change to the film boil and thus the coefficient of heat transfer from the nozzle wall to the cooling water decreases sharply and the lance tip may be burnt through.

Under operating conditions there are thermodynamic changes in both the working space of the high temperature aggregate and the parameters of the cooling water. These are in particular the heat transfer coefficient from the working space to the lance tip material, the cooling water flow velocity and the purity of the inner walls changes.

Good cooling of the lance and inner nozzles also depends on the thickness of the walls. The thickness of the lance tip wall depends on its dimensions, design, construction, production technology and type of use, and ranges from 6 to 12 mm [4].

Because of lance high heat load the thermal stresses arise during operational period, which may ultimately lead to the deformation of the particular outer tube. Bellows or stuffing compensators are used to compensate these adverse effects of thermal expansion.

If we go back to the layout (design) of the lance tips in the **Figure 2** and **Figure 3**, then cooling water is directed through the cooling rings, which can be divided or in whole.

Structural design of cooling channels must ensure continuous velocity changes of cooling water flow in the whole area of cooling ring. Cooling water velocity gradually increases and reaches a maximum when entering into the output annulus formed by the lance outer pipe and the pipe which divides water inlet and outlet.

Central convergent-divergent nozzle with a single or two-layer nozzle arrangement (**Figure 5**) or profiled nozzles with a central cooling system (**Figure 6**) are lance tips designed to increase the cooling effect.

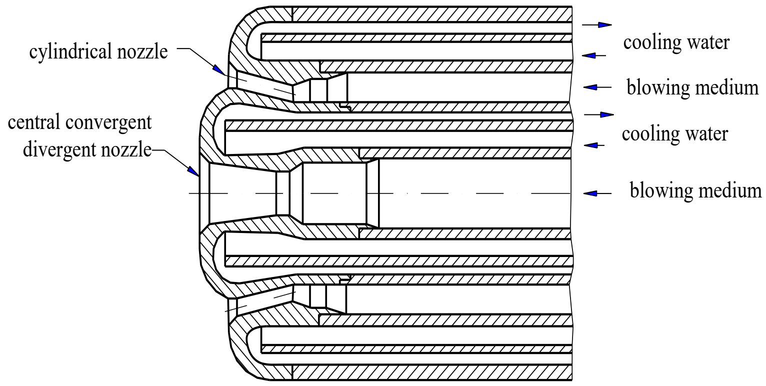

Figure 5 Multinozzle lance tip with central convergent-divergent nozzle

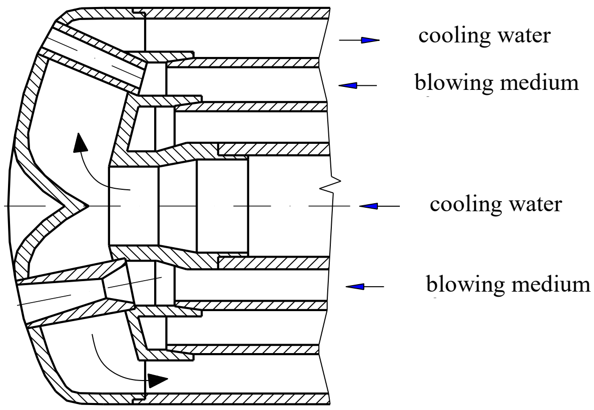

Figure 6 Multinozzle lance tip with central front part cooling

5. CONCLUSION

Refining nozzles are an important part of scrap metal processing units. A properly designed lance and its head significantly influences the technological process of melting metal waste and thus also affects its productivity and economic indicators. Certain recommendations must be respected when designing blowing systems, individual lance heads including their nozzles. The aim of this article was to summarize these recommendations for the design of refining lance heads and also to describe the types of lance heads manufactured from cast and forged components, including the method of their cooling by circulating water and selected information on the materials used. The information provided should help designers and engineers to navigate this issue and assist them in designing blowing systems that meet high quality, efficiency and operational reliability requirements.

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