BOTTOM TUYERES OF HIGH-TEMPERATURE UNITS - DIVISION, REQUIREMENTS AND SELECTED OPERATING PARAMETERS

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Abstract

Special designs of nozzles or tuyeres are used in high-temperature units treating metal scrap for blowing gaseous technological media into the melt below the bath level. The higher technology utilisation of media is achieved by the blowing of media into the melt below the bath level. Due to the momentum of the discharge stream, which flows directly into the melt, the melt is set into intensive motion, which is very advantageous especially from the point of view of both temperature homogenization and homogenization concerning the chemical composition of the bath. The structural design of the majority of these tuyeres considers one or more channels composed of steel tubes or formed directly in the basic refractory material of the tuyere. From the point of view of structural design of these tuyeres, it is very important to know the dependence of exit parameters of blown media on the design parameters of the tuyere, in short on boundary conditions. The contribution contains division of and requirements for tuyeres and also description of chosen results of mathematical modelling of gaseous media flow through a channel with given dimensional parameters.

Keywords*:* Mathematical simulation, homogenisation, tuyeres, gas blowing

1. INTRODUCTION

Perfect bath homogenization is a technologically very important factor that has, especially in the aggregates for the metals production, affect on the quality of the produced material. For the purpose of the melt homogenization so called tuyere blocks are used which are built-in into the refractory lining layer and are located primarily in the bottom of the hearth steel furnaces and ladles. Except tuyere blocks for example the homogenizing nozzles are used for the purpose of the steel homogenizing. This nozzles are inserted into the liquid bath from above [1]. They are mainly used in cases when it isn't for example from technological reasons possible to blow through bottom of the aggregate, in case where high work security is required and as backup device in case of failure of the buttom blowing device.

Information about quality of the homogenization can be obtained in addition to experiment on a physical model of the aggregate also by numerical modeling [2], [3]. Experimental research of bath homogenization has task to determine the optimal operation method for homogenization, the number of tuyere blocks, number of jets , the number of nozzles and their placement in the hearth of the furnaces or in the bottom (walls) of the ladles or in other kind of metallurgical vessels.

Special designs of tuyeres are used in high-temperature units for blowing gaseous technological media into the melt below the melt level [4]. This special tuyeres may be formed by one or more channels made of steel tubes or directly in the basic refractory material.

2. DIVISION OF AND REQUIREMENTS FOR TUYERES

All the types of tuyeres presented below, with the exception of nozzles introduced into the melt from above, are built in the refractory lining of thermal units. They can be divided as follows:

a. tuyere blocks with directional and non-directional porosity
b. ring tuyeres
c. bifurcated tuyeres
d. tube tuyeres

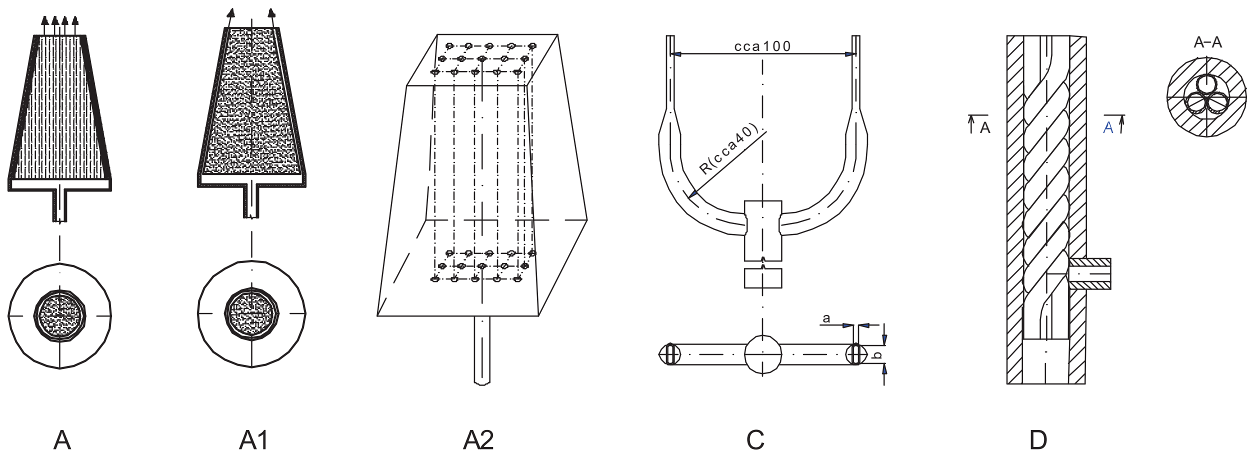

Fig. 1 A- non-directional porosity, A1-directional porosity, A2-MTP tuyere, C-bifurcated tuyere, D-tube tuyere

Tuyeres of the groups ***A*** to ***C*** work with a relatively low gas flow rate less than about 0.3 $m^3.min^{-1}.t^{-1}$. In metallurgical units, they are widely used. Their disadvantage is the fact that the only gaseous medium can be blown by them at the given instant of time. These tuyeres are not used for blowing oxygen into the bath.

Tuyeres of the group ***D*** work with a higher gas flow rate and in addition, they are able to use simultaneously two different gaseous media, including oxygen. This group of nozzles can be also designated as bottom or underflow nozzles. They are used for the intensive blowing of oxygen together with a protective gas and make it possible to blow even lime dust in a mixture with a gaseous medium. These types of tuyeres have undergone expansion not only in the metallurgical but also in the energy and chemical industries, including e.g. high-temperature units for waste treatment.

General requirements for tuyeres can be characterised as follows:

1) a gas blown must flow into the melt, if possible, in a form of a large quantity of bubbles of a small diameter (it must be dispersed as much as possible),
2) in a certain time period, a tuyere must enable the flow of the required quantity of gas (pressure losses caused by the tuyere should be as small as possible; it is necessary to form a certain reserve here to avoid potential infiltration in the case of a drop in the pressure of the gas blown. In connection with the infiltration of steel it is necessary to say that, for example, in the course of ladle filling, it is recommended at tapping to maintain a small back pressure of the blown gas so that the ferrostatic pressure of the melt may be eliminated. During the transport of the ladle, this back pressure can be maintained by means of a gas vessel, which is equipped with a back valve and is mounted below the ladle or on a transfer car),
3) a long life - or the wear of the tuyere should not differ much from the wear of other linings of the unit, where the tuyere is used (mechanical resistance at increased temperatures),
4) maximum safety in the course of use,
5) maximum economy (minimum purchase and operational costs).

A tuyere is characterised above all by its permeability (this cannot be confused with so-called porosity in the case of tuyere blocks - because the closed pores are, from the point of view of gas conducting, of no importance). Permeability is the amount of gas passing through the cross sectional flow area of the tuyere per unit time observed.

In the unit, tuyeres are located either in the bottom or in the side wall. The optimum location in the hearth of the given unit should be practically a result of model and in service tests.

The optimum location of a tuyere must ensure:

- the achievement of maximum effects of bubbling of the gas through the liquid bath
- the minimization of wear of unit lining
- good access, maximum safety and minimum labouriousness in the course of tuyere replacement

3. CHOSEN CALCULATION RESULTS

For the calculation (mathematical modelling), it is necessary to acquire as accurate as possible data concerning both the entry of the gaseous medium and the geometric dimensions of the channel. Here, so-called boundary conditions of calculation are referred to. The more accurate the determination of boundary conditions is, the more accurate results may be expected.

It is very important to express the dependence of physical properties of blown medium [5] depending on its temperature and in the desired temperature range. In the **Table 1** are given as examples of physical properties depending on temperature for argon.

Table 1 Physical properties of argon depending upon temperature

	Designation	Units	Range	Value, dependence
Molecular weight	M_{Ar}	$kg.kmol^{-1}$		39.95
Density in normal state	ρ_N	$kg.m^{-3}$		1.784
Specific heat capacity	c_p	$J.kg^{-1}K^{-1}$	T=<273-2000>[K]	c_p = 2.74E-7T^3 –3.67E-6T^2 +7.07E-06T+ 520.3
Thermal conductivity	λ	$W.m^{-1}K^{-1}$	T=<273-2000>[K]	λ = 5.53E-12T^3 –2.18E-8T^2+5.54E-5T+0.0027
Dynamic viscosity	η	Pa.s	T=<273-2000>[K]	η = -1.28E-11T^2 + 6.34E-08T + 4.39E-6

In practice, the calculations are performed in two steps. First, minimum mass flow rate of blown medium (Q_{m-min}) must be determined. Minimum mass flow rate of blown medium (Q_{m-min}) is such mass flow rate that ensures the static pressure of it in the exit cross-section of the channel is equal to the ferrostatic pressure in the same point on given computational conditions.

This mass quantity (Q_{m-min}) theoretically ensures (at the given boundary conditions), that the liquid metal won´t penetrate into the tuyere channel.

In the second step, the calculation for conditions (Q_{mp}) corresponding to the defined operating state is performed.

To designers it is important to know how design of tuyeres affects output parameters of blown media flow [6]. For the experiment, we have chosen one of many channels forming a so-called MTP (multiple tuyere plug - **Fig. 1-A2**) tuyere.

Channel of the length of 750mm and the diameter of 3mm was tested. The temperature of argon at the entry into the channel T was 293K. We supposed that the channel was produced directly in the refractory lining. Argon we have chosen as the blown medium. Nominal mass flow rate was set Q_{mp}=3.1298.10^{-4} kg.s^{-1}. The goal of numerical solving of argon flow through a channel of the diameter d and the length l was to determine the distribution of basic state quantities v, p, ρ and T (velocity, pressure, density and temperature) along the length and in the exit (transversal) cross-section of the channel. Mass quantity Q_{m-min} was calculated, its value was determined to 0.78.10^{-4} kg.s^{-1} .

The course of changes in the mean values of observed state quantities of argon along the length of the channel is documented by selected graphs given below.

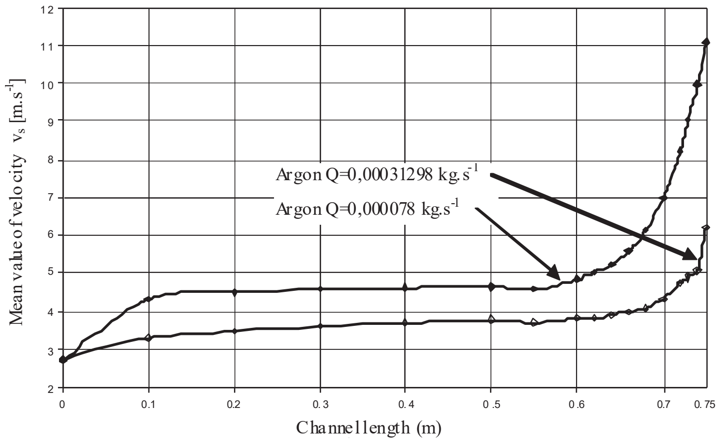

Fig. 2 A course of the mean value of velocity along the length of the channel

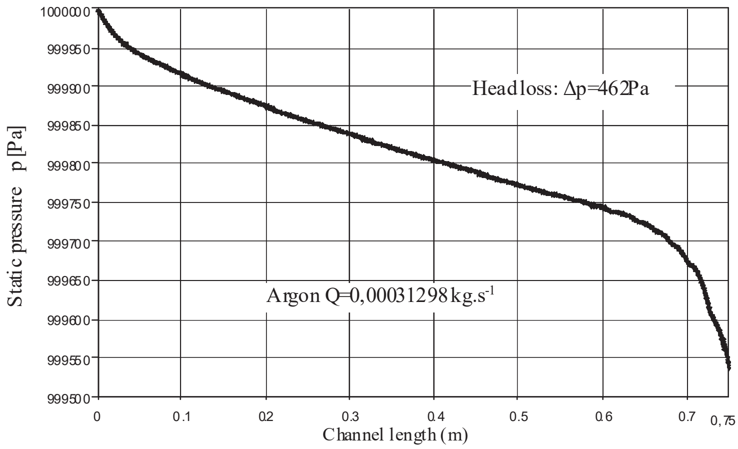

Fig. 3 A course of static pressure along the length of the channel (operating state)

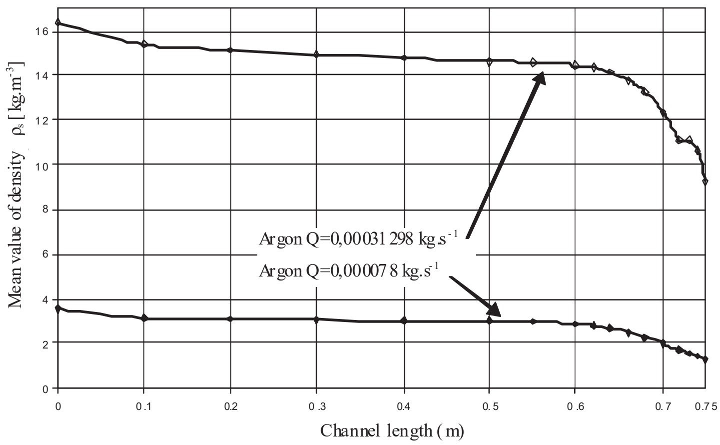

Fig. 4 A course of the mean value of density along the length of the channel

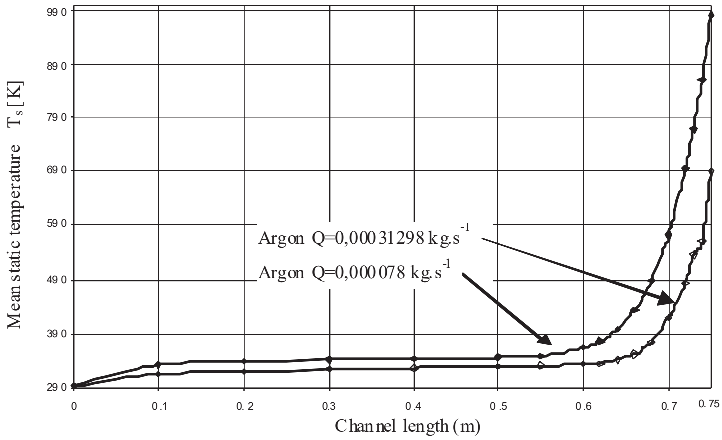

Fig. 5 A course of mean static temperature along the length of the channel

4. CONCLUSION

By the determination of Q_{m-min}, a limit was determined below which the mass flow rate of gaseous media through one channel should not theoretically drop for the given length of the channel, the entry temperature of gaseous media and the static pressure in the exit cross-section.

If we evaluate changes in the state quantities on given computational conditions in the operating state, which interests us most, the following can be stated:

- temperature and velocity of flowing gas increased towards the exit cross-section (**Fig. 2**, **Fig. 5**),
- static pressure and density of flowing gas decreased towards the exit cross-section (**Fig. 3**, **Fig. 4**),
- the highest velocity is in central axis of the channel and the lowest velocity is near the walls of channel, density is changed in the same way and with temperature it is reversely,
- with an increase in the entry temperature of gas at the constant length of the channel, a decrease in pressure loss, a change in density, an increment in temperature and velocity in the exit cross-section occur,
- with an increase in the length of the channel at the constant entry temperature of gas, changes in all observed state quantities grow.

REFERENCES

[1] MIKOLAJEK, J., ROZUM, K. et al.: Technical solution of devices for argon blowing in tandem furnace. Final Report, VSB - TU Ostrava, HS č. 390770, 45 p.

[2] KOVÁŘ, L.,: Mathematical Simulation of Gaseous Media Flow Through Blowing Elements in Metallurgical Aggregates. In METAL 2012. 21st. International Conference on Metallurgy and Materials: 23. - 25. 5. 2012 Brno, Hotel Voroněž, Czech republic [CD-ROM]. Ostrava: TANGER: May, 2012, pp. 243-248, ISBN 978-80-87294-29-1.

[3] KOVÁŘ, L., BOJKO, M.: The determination of exit parameters of media flowing through narrow channels of bottom tuyeres of high temperature units. Transactions of the VSB - Technical University of Ostrava - mechanical series 1/2008, ročník LIV. FS VSB-TU Ostrava 2008, pp.137-144, p. 258, ISBN 978-80-248-1891-7, ISSN 1210-0471.

[4] MIKOLAJEK, J.: Steelworks equipment I. Textbook VSB Ostrava, 1985, 206 p.

[5] HAŠEK, P.: Tables for heat engineering. Textbook, 2nd Edition. VSB-Ostrava 1980, 247 p.

[6] KOVÁŘ, L., MIKOLAJEK, J. et al.: Studies of melt movement in tandem furnace hearth for selected gas blowing variant. Research report VSB-TU Ostrava. 2005, 54 p.