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Method and new lance for powder injection into liquid alloys

J. Jezierski*, J. Szajnar
Division of Foundry, Institute of Engineering Materials and Biomaterials,
Silesian University of Technology, ul. Konarskiego 18a, 44-100 Gliwice, Poland
* Corresponding author: E-mail address: jan.jezierski@polsl.pl

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ABSTRACT

Purpose: The pneumatic powder injection into liquid alloys is known since many years. It is use in many metallurgical processes (recarburization, alloy additions introduction, desulphurization etc.). The problem in some cases is to prevent the carrier gas introduction into liquid bath.

Design/methodology/approach: The objectives were achieved by researches with laboratory injection stand. The main research method was measurement of stream parameters and computation of pneumatic injection indexes.

Findings: The new injection lance was invented and analyzed and this is one of the main subjects of this paper. The lance has a construction, that makes possible even complete elimination of carrier gas introduction into liquid metal with proper particles stream range. The paper shows the results of the tests of lances with various geometrical parameters and model experiments with diphase stream force measurement.

Research limitations/implications: The future research should be made with various type of powdered materials to find the question what are the limits of changing the most important parameters (grain size, stream concentration etc.). The limitation is number of values being analyzed (in powder injection processes there are many) in experimental plan.

Practical implications: The lance can be used for powders pneumatic injection but only for small its quantities (e.g. microalloying) because non-immersed lance should be used with low stream concentration. The usage of that lance can decrease liquid alloy heat losses (not introducing carrier gas into liquid) and lance consumption (non-immersed in liquid bath).

Originality/value: The original value of the paper is taking into account the parameter called by authors "diphase stream force" on liquid metal surface being "attacked" by particles (or carrier gas stream). Nobody (in author's opinion) was analyzed that problem with connection in powder injection processes. The paper can be helpful for everybody who is studying pneumatic injection processes.

Keywords: Casting; Powder injection; Diphase stream; Stream forces

1. Introduction

The method of pneumatic injection of powdered materials is now very well known and used in many metallurgical processes for increasing their effectiveness and yield ratio of injected elements e.g. alloying [1,2,3]. Deoxidation, desulphurization and dephosphorization, recarburization, other refining processes – are the main use of powder injection processes [4,5,6,7]. That method is not often use for inductive furnaces because of its construction and melting conditions. In such situation better is method with non-submerged lance what prevents carrier gas introduction into liquid metal bath [1,8]. It is very important from liquid metal temperature point of view and low gas content after injection processes. The most important powdered materials which are introduced into furnaces in foundries are carburizers and alloy additions. The first group is added in large quantities and method with submerged lance must be preferred but the second group of materials is added in small quantities and then the non-submerged lance could be used [9-13]. Although, because of some not yet solved problems, the injection of powdered ferroalloys for increasing its content in liquid alloy e.g. cast iron is still only a margin of injection technique usage [14-16]. The reason is that conventional methods of alloy additions introducing brings a good results too [17]. But it is important that small grain size of ferroalloys is a waste material in production of lump ferroalloys. For this reason industrial application of pneumatic injection in alloy additions is reflection worth. Very important is a short time of introduction process too, that last for few minutes or less with small temperature decreasing what is the next advantage of the method. But the problem still have to be solved is preparing the lance or injection process modification that will make possible to achieve proper particles stream range in liquid medium without significant bath temperature decrease and gas content after process [1,13,14]. These problems do not exist with use of new lance with flange, invented in Foundry Department and described in the paper.

2. Work methodology

In Foundry Department the experiments were carried out to find the answer what is the influence of forces on liquid metal surface attacked by diphase (gas-solid particles) and monophase (only gas or only solid particles) stream in powder injection process. The short description of experimental method, apparatus and work methodology are announced below.

The results presented in the paper are part of a large scaled experimental plan that should explain some important relations between injection process technological indexes and dynamics of the stream being introduced.

2.1. Apparatus and experimental method

The research stand is presented on fig. 1. It is the same apparatus that was used in early made experiments, but instead of furnace, ladle or other the last part of it is an measuring device 6. The device is measuring and recording a value of stream force and send data to PC 9. The main part of the stand is powder chamber feeder 1 (with mixing chamber located on the bottom). The mixture of carrier gas and powdered particles is going through pipeline 2 to the injection lance 3 (new designed lance with a flange). The stream force measured on device 6 is next send by electronic recording device 4 to the computer. It makes possible to analyze recorded in real time data. Carrier gas (in these experiment – air) is taken from pressurized air network 7. The injection lance is located on a special movable arm 8 – possibility to adjust the various lance positions. The value H it is a distance between lance outlet and measuring surface of the device 6. It is one of the most important variable when we use a non-immersed lance for powder injection processes.

During the experiments the lances with different inside diameters (d_w=5,6; 6,1 and 7,6 mm) were used. The experiments were conducted for two kinds of lances: with and without the flanges and the gaps for every diameter listed above.

The lance with a flange used in experiments is shown below on the fig. 2. Its construction (four longitudinal gaps on outlet) stopping the carrying gas by separation of propelled particles from two-phase flux.

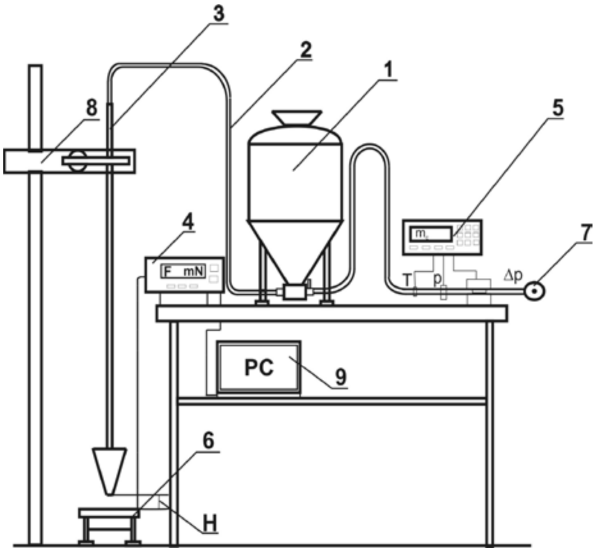

Fig. 1. Research stand

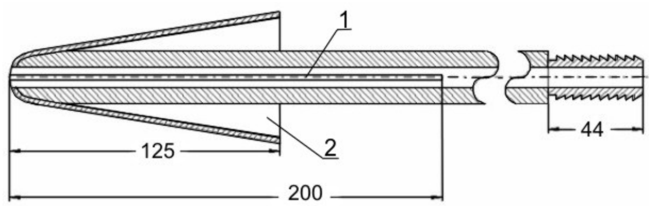

Fig. 2. Injection lance with a flange: 1- conical flange, 2- four longitudinal gaps.

2.2. Description of the experiments

The single experiment has been carried out as follows:

a) putting into pressure container a weighed portion of powder (powdered FeSi, polyethylene and others),
b) closing of a bell valve,
c) setting of a distance between a lance and measurement surface of a device,
d) carrier gas flow opening and pressure parameters setting,
e) measurement of main process parameters as blow-in time, pressure in some points of installation, gas flow and stream force value recording,
f) shut off a gas flow after process.

Because the efficiency of injection processes (and its pneumatic parameters and character in liquid medium) depends on a powder grain size, it was one of the independent variables. The fraction of powders were:

- fraction 1: a mean grain size $d_{śr}$ = 0,1 mm,
- fraction 2: a mean grain size $d_{śr}$ = 0,5 mm.

Apart from a grain size there were three another independent variables during experiments:

a) a carrier gas (air) pressure (three levels of changing: 0,2; 0,3; 0,4 MPa),

b) a gas into dispenser pressure (six levels of changing: 0,05; 0,1; 0,15; 0,20; 0,25; 0,30 MPa),
c) a distance between lance outlet and device's surface (0, 40 and 80mm).

In order to compare a stream force value there were carried out the experiments with monophase stream (carrier gas only) too.

Next step was a statistic analyze of collected data, and finding the connections between parameters of the process and formulating the conclusions and suggestions for next researches.

One of the most important problem in powder injection with non-submerged lance is obtaining the proper one- (only particles) or two-phase jet in liquid medium. The experiment were performed with model liquid (water) and the character of the stream was observed on the photographs made. The next step was analyzing the jet range in various process parameters such a carrier gas pressure p_1, pressure in the powder dispenser p_4 and inside diameter d_w of the lance. On the fig. 3 the idea of the stream range in liquid is shown.

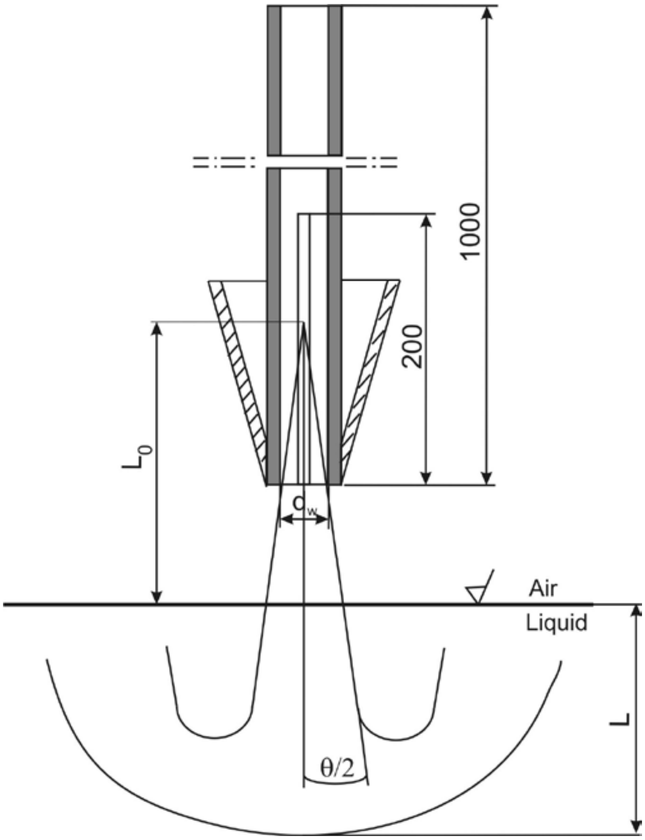

Fig. 3. Jet range in liquid in injection process with non-submerged lance; L_0-distance between liquid surface and virtual start point of conical stream, θ-jet angle, L-jet range in liquid.

3. Description of achieved results of own researches

3.1. General remarks

The results of the measurements and calculations were put together in tables as shown for example in Table 1. The pressure p_1 it is a carrier gas pressure changing from 0,1 to 0,3 MPa, the pressure p_4 it is pressure in powder feeder above the charged material, changing from 0,05 to 0,30 MPa, V_N it is a carrier gas flow in m^3/s, force F it is a measured stream force in mN and w_k it is a gas velocity in the lance outlet. Table 1 is prepared for lance inside diameter d_w=5,6mm without a flange and with distance H=0mm (lance outlet in contact with measuring surface of the device).

Table 1.
Results of the measurements and calculations, normal lance.

No	p_1 MPa	p_4 MPa	V_N m^3/s	F mN	w_k m/s
1	0,1	0,05	0,00187	0,14	126,7
2	0,1	0,10	0,00227	0,20	153,9
3	0,1	0,15	0,00270	0,26	183,3
4	0,1	0,20	0,00307	0,34	208,2
5	0,1	0,25	0,00345	0,40	234,2
6	0,1	0,30	0,00383	0,48	260,2
7	0,2	0,05	0,00233	0,22	158,4
8	0,2	0,10	0,00270	0,28	183,3
9	0,2	0,15	0,00313	0,36	212,7
10	0,2	0,20	0,00350	0,42	237,6
11	0,2	0,25	0,00390	0,50	264,8
12	0,2	0,30	0,00433	0,60	294,2
13	0,3	0,05	0,00275	0,30	186,7
14	0,3	0,10	0,00313	0,36	212,7
15	0,3	0,15	0,00363	0,46	246,7
16	0,3	0,20	0,00407	0,56	276,1
17	0,3	0,25	0,00448	0,62	304,4
18	0,3	0,30	0,00500	0,72	339,5

The same tables were prepared for every lance and distance between lance outlet and measuring surface of the device. The statistic analyze have led to results shown in equation 1 (for instance), where the influence of the carrier gas parameters in the velocity in lance outlet were mentioned.

$$w_k = 29{,}03 + 47{,}68\,p_1^2 + 4{,}974\,p_4 \qquad (1)$$

The equation 1 was obtained in injection of powdered FeSi with air as a carrier gas. The similar equations were formulated for every combination of stand geometry, powder properties etc.

4. Conclusions

The experiments were carried out to find an answer, what is the influence of the main parameters of the pneumatic powder injection process on the stream force values and what is the importance of lance construction (new lance with a flange) on the achieved results. The problem of achieving the proper diphase jet range in liquid medium (stream force-dependent) injected from above of bath surface was mentioned too.

The experiments have drawn to the following conclusions:

1. The method of pneumatic powders shooting with non-submerged lance made possible to achieve proper level of the diphase stream force and jet range in liquid medium.
2. Decisive influence on mentioned above parameters have the carrier gas velocity in the lance outlet and mass jet concentration, that cause proper kinetic energy of powder particles, which is essential to immersion into liquid.
3. The regulations of the stream velocity can be done by carrier gas pressure changing or by changing the geometry of the dispenser's mixing chamber.
4. The highest values of the analyzed parameters are obtained with grain size of particles equal 0,5 mm and a distance between lance outlet and a liquid bath surface equal 40 mm. The use of the smaller grains or bigger distances requires carrier gas pressure increase.

The results of the researches indicates that method of pneumatic injection of powder with non-submerged lance can be used at industrial conditions e.g. for production of low-alloyed cast irons (small quantity of powder to introducing).

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