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Character of diphase stream force in powder injection technique

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ABSTRACT

Purpose: The method of pneumatic injection of powdered reagents into liquid alloys in some moment of melting process is known since many years. Mostly it is carrying out with use of submerged lance but in some cases that technique is difficult or impossible at all to use. This is the reason for making investigations in the field of powders injection with non-submerged lance.
Design/methodology/approach: The main experimental method was measurement and recording of time-changing diphase stream force value with use of dedicated laboratory stand. The recorded data made possible to show character of force in form of graphs and calculation of stream parameters. The last step was formulating of statistical equations joining all important parameters of the process.
Findings: In the course of the work was found a diphase stream force character (especially interesting are start and end point of injection). The influence of main pneumatic parameters on the force value was analyzed too.
Research limitations/implications: The future experiments will be conducted with use of Fluent 6.2 program for checking the results in computer simulations. The limitation is number of values being analyzed in experimental plan.
Practical implications: The invented 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 problem of stream force in powder injection process is in Poland only analyzed by Department of Foundry and nobody (in author's opinion) was analyzed it with connection in powder injection. Originality of the researches is a computer recording and analyzing of the diphase stream force. The results should interest every who wants to learn more about pneumatic powder injection.
Keywords: Casting; Powder injection; Injection lance

1. Introduction

The knowledge about powder injection processes is nowadays quite wide. There are many industrial applications in different industry areas e.g. metallurgy or foundry. Deoxidation, desulphurization and dephosphorization, recarburization, other refining processes – are the main use of powder injection processes [1-6]. 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 [7-10]. 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 of powdered materials used in foundries (carburizers) is added in large quantities and method with submerged lance must be preferred but the second group of materials (alloy additions) is added very often in small quantities and then a non-submerged lance could be used [11,12]. Although, because of some 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 [13-15]. The reason is that conventional methods of alloy additions introducing gives a proper results too [13-16]. 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 interesting. Very important is a short time of injection process, that last few minutes or less with small temperature decreasing what is the next advantage of the method. But the problem not yet 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 [17-18]. These problems do not exist with use of new lance with flange, invented in Foundry Department and described in the previous papers [19,20].

Fig. 1. Research stand – real view

2. Work methodology

In Foundry Department the experiments were carried out to find the character of diphase stream forces on liquid metal surface in powder injection process. The short description of work methodology and apparatus are announced below.

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

2.1. Apparatus and experimental method

The research stand is presented on fig. 1 and its exact description was presented in previous papers [17-20]. It is the same apparatus that was used in early made experiments, but instead of furnace, ladle or others the last part of it is an measuring device connected to PC computer.

The experiments were conducted as next part of the experimental plan for various lances geometries, pneumatic parameters and injected powdered materials. The previous results were presented on earlier AMME and CAMS conferences. Use of PC computer with dedicated program allowed to measure stream force value with frequency 10 measurements per second. So we can say that we have almost continuous stream force measurement. The powdered material used in the experiment was polystyrene with granulation 0,4mm with the air as a carrier gas. The distance between lance outlet and a measuring device's surface was establish at three levels: 10, 40, 80mm because one of the problem we wanted to solve was how that distance influence on stream force's value.

3. Description of achieved results of own researches

3.1. Results of the experiments

The results of the measurements and calculations were put into tables and next the computer analysis was made. It made possible to obtain the graphs show time-changing character of stream force. Some of the graphs (in that level of experiments were made 27 graphs for various geometrical and pneumatic process parameters) was presented below on the Fig. 2, 3 and 4. When you look at them you can see a characteristic peak at the end of the blowing. It is connected to moment when the last portion of diphase mixture is blowing through the injection lance. From technological aspect's point of view the most important is the period of force stabilization in the middle of the cycle because in the real industrial conditions it is the same.

It is clearly seen that stream force's value increases when the pressure in powder container increases too. The reason is that mass concentration of diphase stream depends mostly on that parameter (in not changed geometrical conditions). It is obvious that the duration of the process is longer when the concentration is less but in some cases (e.g. modification on liquid metal stream of cast iron) it is better than short injection time and high level of mass concentration. With increasing of diphase stream force value the powder stream range in liquid should be enough for proper powder distribution in liquid alloy, what is important for enable appropriate technological indexes of pneumatic injection process.

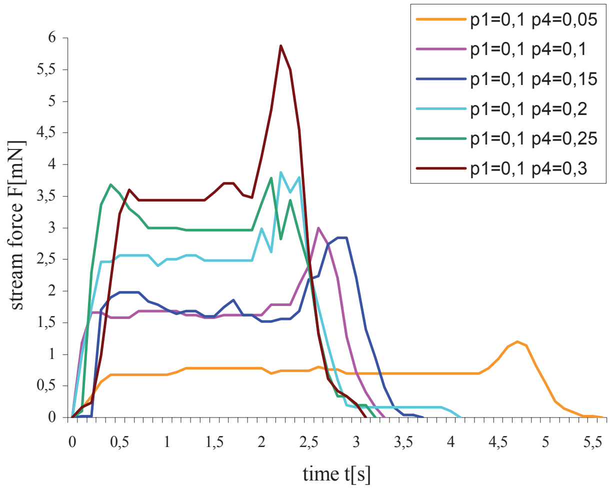

Fig. 2. Stream force character for parameters as follows: lance diameter d_w = 6,1mm, distance between lance outlet and measuring device's surface H = 10mm, carrier gas pressure p_1 = 0,1MPa, powdered material – polyethylene with granulation 0,4mm

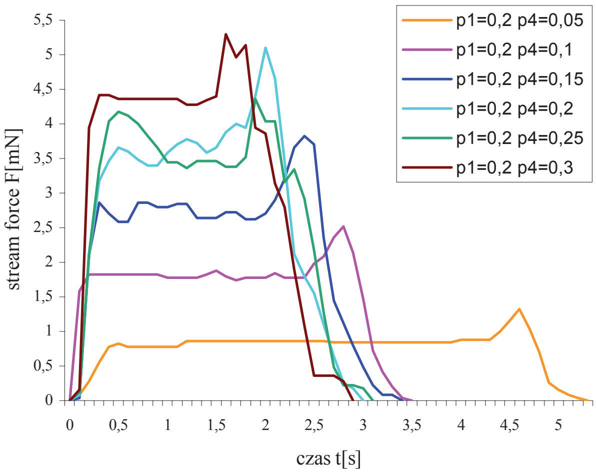

Fig. 3. Stream force character for parameters as follows: lance diameter d_w = 6,1mm, distance between lance outlet and measuring device's surface H = 10mm, carrier gas pressure p_1 = 0,2MPa, powdered material – polyethylene with granulation 0,4mm

4. Conclusions

The described experiments were carried out to find an answer, what is the character of stream force's time-changing and which parameters mostly influence on it.

The experiments have drawn to the following conclusions:

1. Velocity of the carrier gas in the lance outlet depends mostly (in the same geometrical conditions) on inside injection lance diameter.
2. Diphase stream force value increases with pressures increasing and decreases with increasing of distance between lance outlet and measuring surface (liquid metal bath).
3. The proper period of injection cycle for industrial conditions is in the middle of the process, when the stream force has good stability.
4. Decisive influence on the analyzed force has mass concentration of the diphase mixture and velocity of carrier gas in the lance outlet.

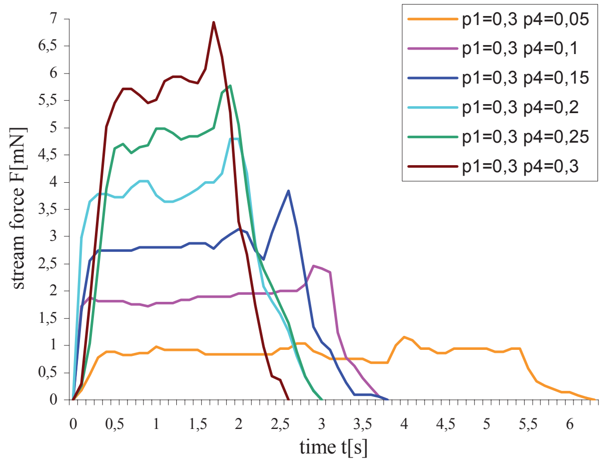

Fig. 4. Stream force character for parameters as follows: lance diameter d_w = 6,1mm, distance between lance outlet and measuring device's surface H = 10mm, carrier gas pressure p_1 = 0,3MPa, powdered material – polyethylene with granulation 0,4mm

Simultaneously there are continuing the simulation experiments with use of CFD program Fluent version 6.2. Although it is the start level of this work we can say that the results shown in the short paper are positively verified by this technique. We hope that the results of the computer simulations we will expose on the next conferences.

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References

[1] J. Jezierski, Pneumatic injection of ferroalloys into liquid cast iron, Doctoral Thesis, Silesian University of Technology, Gliwice, 2002 (in Polish).

[2] K. Janerka, Z. Piątkiewicz, H. Szlumczyk, Review of injection carburizing plants for liquid metal treatment in arc furnaces, Proceedings of the II-nd International Scientific Conference AMME, Gliwice 1993, 126-132.

[3] H. Szlumczyk, Z. Piątkiewicz, K. Janerka, Diphase stream resistance of flow on pneumatic conveyor pipeline contraction, Proceedings of the II-nd International Scientific Conference AMME, Gliwice 1993, 215-221.
[4] Z. Piątkiewicz, H. Szlumczyk. K. Janerka, Pneumatic conveying in industrial applications, Proceedings of the I-st International Scientific Conference AMME, Gliwice 1992, 167-175.
[5] K. Janerka, S. Jura, Z. Piątkiewicz, H. Szlumczyk, Diphase stream parameters influence on carburization rate, Proceedings of the III-rd International Scientific Conference AMME, Gliwice 1994, (in Polish), 155-161.
[6] J. Gawroński, M. Cholewa, J. Szajnar, K. Janerka, Method of pneumatic inserting of reinforcing elements to matrix of composite casts, Proceedings of the 8-th International Scientific Conference AMME, Gliwice-Rydzyna-Pawłowice-Rokosowo 1999, 217-233.
[7] J. Jezierski, J. Szajnar, Dependence between diphase stream force and parameters of powder injection process, Archives of Foundry, Year 2006, Volume 6, No. 22, in Polish.
[8] J. Jezierski, Pneumatic powder injection into liquid alloys as a tool of quality improving, 13-th Metallurgical & Material Conf., Hradec nad Moravici, Czechy, 2004, on CD-ROM.
[9] J. Jezierski, J. Szajnar, Diphase stream parameters influence on powder injection indexes, IX Int. Conf. TP'2005, Sielpia – Kielce, 2005, (in Polish), 136-144.
[10] J. Jezierski, Possibilities of using the fine ferroalloys fractions in its pneumatic introduction into liquid cast iron, Proceedings of the 12-th International Scientific Conference AMME, Gliwice- Zakopane 2003, (in Polish), 415-423.
[11] J. Jezierski, Pneumatic injection of ferroalloys into liquid cast iron, 12-th Metallurgical & Material Conf., Hradec nad Moravici, Czechy, 2003, on CD-ROM.
[12] K. Janerka, Mechanism of mass exchange in pneumatic recarburization of liquid ferrous metals, Proceedings of the 12-th International Scientific Conference AMME, Gliwice-Zakopane 2003, (in Polish), 415-423.
[13] D. Bartocha, K. Janerka, J. Suchoń, Charge materials and technology of melt and structure of gray cast iron, Journal of Materials Processing Tech., vol. 162-163, 2005, 465-470.
[14] K. Janerka, J. Jezierski, Z. Piątkiewicz, H. Szlumczyk, Rate of the process in pneumatic liquid metal carburizing, Proceedings of the MME, Gliwice 2000, 533-537.
[15] K. Janerka, S. Jura, H. Szlumczyk, J. Jezierski, D. Homa, Devices for liquid bath recarburization in EAF's, Solidification of Metals and Alloys, PAN Katowice, v. 1, nr 39, 1999, (in Polish), 113-120.
[16] K. Janerka, Parameters in pneumatic recarburization process, Proc. of the Third Scient. Conf. M^3E'2005, Gliwice – Wisła, 2005, (in Polish), 531-536.
[17] J. Jezierski, Description of powder injection process by diphase stream forces, Proc. of the Third Scient. Conf. M^3E'2005, Gliwice – Wisła, 2005, (in Polish), 537-540
[18] J. Jezierski, Analysis of diphase stream forces in pneumatic powder injection, 14-th Metallurgical & Material Conference, 20-22.05.2005r., Hradec nad Moravici, Czechy, 2005, on CD-ROM.
[19] J. Jezierski, J. Szajnar, New injection lance construction for powder injection into liquid alloys, 15-th Metallurgical & Material Conference, 23-25.05.2006r., Hradec nad Moravici, Czechy, 2006, on CD-ROM.
[20] J. Jezierski, J. Szajnar, Method and new lance for powder injection into liquid alloys, Journal of Achievements in Materials and Manufacturing Engineering, Volume 17, Issue 1-2, July-August 2006.
[21] J. Jezierski, K. Janerka, J. Szajnar, Powder injection into liquid alloys as a tool for its quality improving, Archives of Foundry, Year 2006, Volume No 18 (1/2), PAN Katowice, 535-540.