J. JEZIERSKI, K. JANERKA

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PARAMETERS OF A GAS-SOLIDS JET IN PNEUMATIC POWDER INJECTION INTO LIQUID ALLOYS WITH A NON-SUBMERGED LANCE

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The paper presents powder injection into liquid alloys with a non-submerged lance. The parameters of the diphase gas-solids jet were found as the most important factor to achieve good efficiency of the process. If the parameters are improper, the jet will not penetrate the liquid and the solid particles will not be uniformly distributed. The jet cone profile is often crucial for diphase jet penetration, so this parameter was analyzed along with particle velocity on the lance outlet and the experiments proven this assumption. The use of a high-speed camera allowed to capture and analyze jet motion, which verified the data of previous authors and that in the literature. Experiments of both the model and real injection into molten cast iron proved both the mathematical model and numerical simulation.

Key words: pneumatic injection, cast iron, ferroalloy, injection lance, gas-solid jet

INTRODUCTION

The problem of efficiently introducing various additions into liquid metals and alloys still exists in steel primary and secondary metallurgy and in foundry engineering [1-2]. The method and results of this process can significantly affect the final quality of the produced material as well as production costs [3-4]. Also, the method of pneumatic injection can be successfully employed to utilize many metallurgical or foundry wastes, such as dusts, spent molding sand, fine fractions of ferroalloys or ground graphite electrode scrap, etc. [5-7]. That is why developing different methods is still important, and experiments in this field of research were carried out to prove the efficiency of pneumatic injection of ferroalloys without injection lance immersion into the molten alloy. The authors have been developing the method for several years now and subsequent stages of the experiments were reported in previous papers [8-9]. In this paper the experimental results obtained during experiments with a high-speed camera are presented together with some theoretical considerations.

EXPERIMENTAL WORK

The character of the diphase gas-solid which penetrates the liquid is most important for pneumatic injection efficiency. Many different methods have been used over the years to describe the jet, and various parameters were selected as best describing it. In the described research the jet radius was chosen as the most important factor influencing the overall jet character and as highly important for the jet's character inside the liquid metal. Based on some theoretical assumptions as well as on previous own experiences [9], Formula (1) was developed. The Formula expresses the critical jet radius r_s as a relationship between the distance from lance outlet z, injection lance diameter d_l, velocity of the carrier gas on lance outlet w_{gl} and velocity of the gas in the jet axis w_{go}.

$$r_s = 0{,}45 \sqrt{z\, d_1 \frac{w_{gl}}{w_{go}}} \qquad 1)$$

The graph explaining the idea of critical jet radius r_s is shown in Figure 1, where all significant parameters were pointed out.

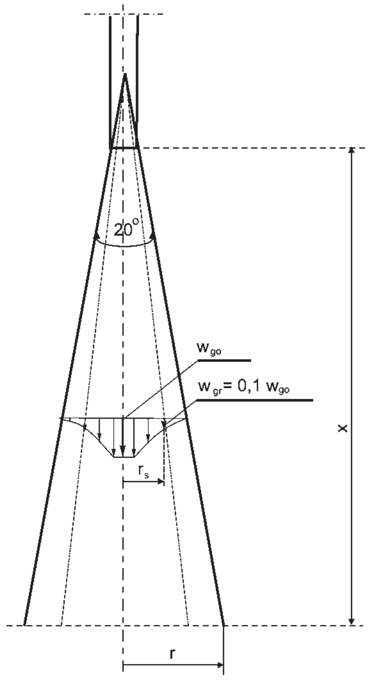

Figure 1 Critical jet radius r_s [9]

J. Jezierski, K. Janerka, Silesian University of Technology, Department of Foundry Engineering, Gliwice, Poland

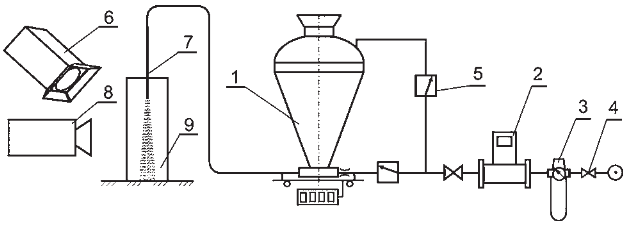

Figure 2 Laboratory stand for high-speed camera observation: 1- pneumatic feeder, 2- gas flow meter, 3- pressure reducer, 4- gas valve, 5- manometer, 6- halogen lamp, 7- injection lance, 8- high-speed camera Phantom v210, 9- powder receiver [9]

Independently from the theoretical considerations, laboratory experiments were carried out using a high-speed camera of high quality and resolution. The camera made it possible to observe and then accurately measure the motion parameters of each selected powdered particle inside the jet. The laboratory stand is presented in Figure 2 and was thoroughly described in [9].

RESULTS AND DISCUSSION

The critical jet radius is the value which ensures that a jet of such geometry and dimensions possesses enough energy and dynamics to successfully penetrate a liquid environment. To check the correctness of the Formula (1), experiments with an anemometer recording and some numerical modeling (reported in [8-9]) were carried out. The results proved that the Formula describes, in good approximation, gas velocity and jet developing phenomenon, which is visible in Figure 3 and Figure 4, where the experimental data and those calculated using Formula (1) were compared. Figure 3 presents the results of the anemometer tests, whereas Figure 4 presents both the calculated results (solid line) and the anemometer results (line marked with asterisks). It shows that the measured and calculated jet profiles are almost the same, which proves the correctness of Formula 1.

To finally check the obtained results, a powder injection of ferroalloy FeSi75 into molten gray cast iron was carried out using the same equipment as during the laboratory work (see Figure 2). The installation's working

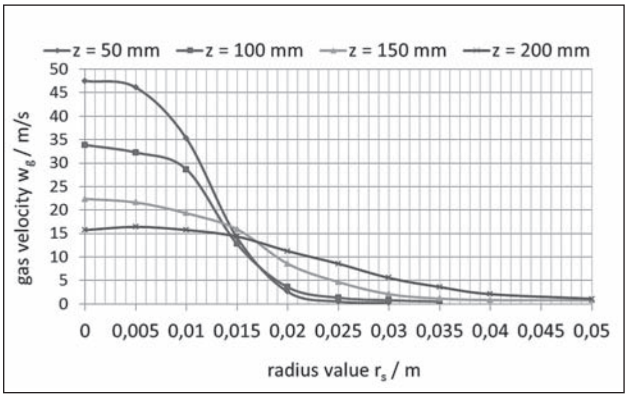

Figure 3 Profile of gas evacuating the lance for various distances *z* from its outlet and various jet radius values r_s, gas flow 0,2 m^3/min

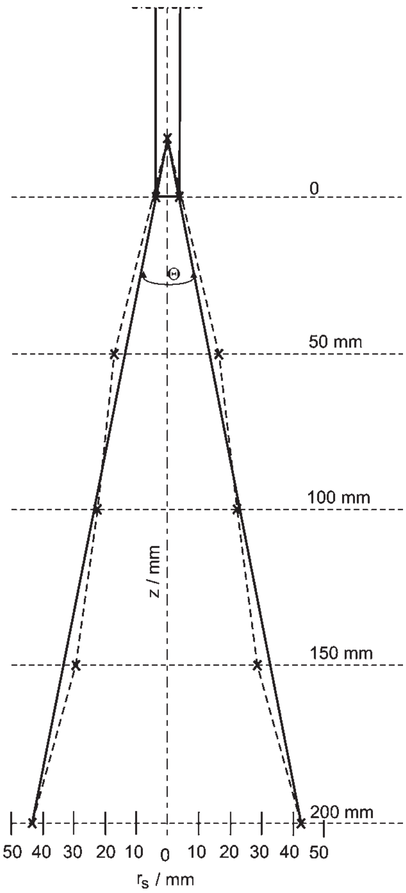

Figure 4 Jet profile for the calculated data (solid line) and experimental data (broken line with asterisks), gas flow 0,2 m^3/min

parameters were adjusted in quite a wide range to cover the effects that would be possible to obtain. The results of an improper set of parameters are presented in Figure 5.

The carrier gas pressure and diphase jet concentration were improper, thus the jet profile and its dynamics were not good.

The jet did not penetrate the liquid cast iron and all of the ferroalloy grains gathered on the surface, thus resulting in low process efficiency, less than 20 % of the Si yield. The opposite situation is presented in Figure 6, where the results of a proper selection of parameters were shown.

There, all of the ferroalloy was successfully blown into the molten cast iron and the final effectiveness was over 80 %. This situation was achieved for a high value of pressure inside the pneumatic feeder, which resulted in

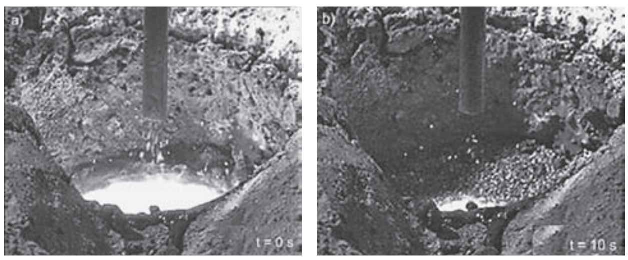

Figure 5 FeSi75 pneumatic injection for the improper parameters for the beginning (a) and end (b) of the injection

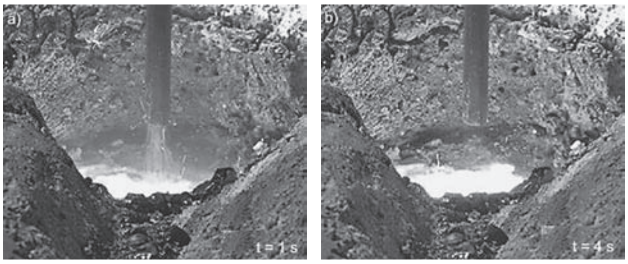

Figure 6 FeSi75 pneumatic injection for the proper parameters for the beginning (a) and end (b) of the injection

quite a dense diphase jet of proper shape and cone angle, exactly the same as was estimated by formula (1).

CONCLUSIONS

The paper presents the evaluation of a model of pneumatic powder injection using a non-submerged lance. The experiments allow to draw the following conclusions:

The so-called critical jet radius and the formula describing its value are a good way to describe the pneumatic powder injection process without injection lance submersion.

Well-adjusted injection parameters result in stable and uniform jet penetration into the liquid bath, without splashes and a huge gas volume being introduced along with the powdered material. Such a situation is better because there is a lesser temperature drop.

It is possible to use the injection method without lance submersion under a molten metal bath for ferroalloy additions into cast iron.

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