WASTE UTILIZATION IN FOUNDRIES AND METALLURGICAL PLANTS -
- SELECTED ASPECTS

Jan JEZIERSKI¹, Krzysztof JANERKA

DEPARTMENT OF FOUNDRY, SILESIAN UNIVERSITY OF TECHNOLOGY, 7 Towarowa,
44-100 Gliwice, Poland, E-mail: jan.jezierski@poll.pl

Abstract

The paper covers a very significant problem present in steel and foundry plants that is a large quantity of
dust generated during production processes. The most important and very often hazardous one is dust
created when the alloy of any grade is produced. It is subsequently sucked out by the dust removal system
from melting furnaces and the question appears what to do with this huge quantity of wastes. At the
Department of Foundry, Silesian University of Technology, Gliwice, Poland, the experiments with use of
pneumatic injection were carried out to utilise various powdered materials (or fine dusts) and some really
good and prospective results were successfully introduced into industry. The results of dusts injection into
metallurgical electric arc furnaces (for slag foaming), fine ferroalloys particles (concerned usually as difficult
to utilise or even as a waste), crushed coal/graphite electrodes (pneumatic injection of carburizers) were
presented in this paper. The ideas of the industrial setups, the main and decisive process parameters and
the results obtained were briefly described. The short information about future plans in the field of the
diphase stream (gas-powder particles) analysis were shortly mentioned. The paper proves that pneumatic
injection technique could be and should be continuously considered as an effective method for dust wastes
utilization.

Keywords: pneumatic powder injection; wastes utilization; metallurgical furnace, furnace dust, powder
injection lance

1. INTRODUCTION

Every metallurgical process as is widely known is a huge source of wastes of any sort: solid, gaseous and
liquid. Many authors claimed that dust caught by dust removal installations of melting furnaces constitutes a
very important part in the whole wastes volume [1,2 and 3]. The next group are the finest fractions of
charging materials (e.g. ferroalloys, carburizers, inoculants) which are generally difficult to use in classical
methods of alloys production (the efficiency of the processes is very poor). The environmental protection is
one of the most important problems nowadays so the pollution limits are very low. As a consequence the
problem of solid metallurgical wastes seems to become a strategic one. In present days the metallurgical or
foundry plant is obliged to utilize its own wastes, especially the most dangerous ones or at least to render
their harmless and transfer to another industry branch for utilization, according to [4].

One of the best from the metallurgical point of view utilization methods of furnace dust from any melting
furnace or the finest fractions of charging materials is pneumatic powder injection directly into molten metal
bath. At the Department of Foundry, Silesian University of Technology the experiments with use of
pneumatic conveying in this field have been carried out for dozens years. Nowadays, as [1,3 and 5] state, in
Poland operate more than ten industrial stands for powdered carburizers injection, installation of furnace
dust injection back to the melting furnace or pneumatic inoculation of alloys (mostly cast iron). The
pneumatic injection of furnace dust back into furnace, fine ferroalloys grains introduction and pneumatic
recarburization processes in melting furnaces are shortly described in the next sections of the paper. All the
results are the original author’s work done in the last few years consequently.
2. PNEUMATIC INJECTION OF DUST INTO ELECTRIC ARC FURNACE

During a steel-making process huge volume of waste in form of dust is generated. In North America, according to [1 and 2], about 700 000 t/year are generated, in Europe about 900 000 t/year, in Japan about 450 000 t/year and in Poland about 60 000 t/year. Owing to this in the 1990s experiments were started to introduce dust back to a melting unit. The Department of Foundry has performed recently the research and industrial implementation of the installation for dust pneumatic injection back into 65 tons EAF for slag foaming. The EAF’s slag foaming method is well known and successfully used as necessary approach for economic electrodes use, energy management and stability from the melting process point of view (electric arc stabilization). The furnace dust was mixed with coal dust in the 3 to 1 ratio to obtain a better pneumatic conveying characteristic (no suspended material in the container after the injection cycle).

The prototype installation for dust recycling and slag foaming in 65 tons metallurgical EAF was characterized by following parameters:
- the dust grain size: 0.005-0.5mm,
- bulk density of dust: 489kg/m³,
- the powdered coal grain size: 0-3mm,
- coal bulk density: 667kg/m³,
- the maximum mass of the dust/coal mixture injected during one heat: 1330kg,
- mass composition of the mixture: 75% of dust + 25% of coal,
- injection duration time: 10-15min,
- mass mixture flow rate: 0.5-2.2kg/s,
- unitary oxygen consumption: 2-4m³/t,
- unitary dust consumption: 5-11kg/t,
- unitary coal consumption: 1-3kg/t.

After the series of experiments in laboratory conditions of the Department of Foundry and afterwards in industrial conditions of the client, the complete installation has a design as has been shown in Fig. 1.

Fig. 1. The setup for dust-coal mixture pneumatic injection into 65 tons EAF: 1- furnace dust container, 2- intermediate dust container, 3- dust pneumatic feeder, 4- powdered coal container, 5- dust feeding screw, 6- coal feeding screw, 7- oxygen lance, 8- mixture injection lance, 9- mixture pneumatic feeder.
During the industrial experiments, a total of 276 controlled melts were conducted. On the basis of the laboratory experiments and industrial tests, it was stated that the pneumatic injection method is very good for utilization of own furnace dust in the plant being analyzed. After several recycling runs, the finally obtained dust was enriched to above 30% of zinc content and about 5% of lead and could have been considered as valuable raw material in a zinc metallurgical plant. The technical parameters of the melt and properties of the steel were not affected at all. Owing to slag foaming with the use of injection of dust-coal mixture, the consumption of coal and an oxygen consumption were considerably decreased in comparison to injection powdered by coal only. Summing up, the pneumatic injection has in this case both ecological and economic aspects and very interesting results of its use.

3. **FERROALLOYS PNEUMATIC INJECTION INTO MELTING FURNACE**

The commonly used powdered materials being introduced into furnaces in foundries are carburizers and various alloy additions. The carburizers are often added in large quantities (hundreds of kilograms) so the method with lance submerged into liquid bath is preferred but the alloy additions are often added in really small quantities and then the non-submerged lance can be employed. Although, because of many technological problems, the pneumatic injection of powdered ferroalloys for increasing its content in liquid alloy e.g. cast iron is still only a margin. The reason is that conventional methods of alloy additions introducing give good enough results, too. However, it should be emphasized that fine particles of ferroalloys are considered waste material in production of lump ferroalloys. From this point of view industrial application of pneumatic injection for alloy additions is reflection worth, because the producers sell the finest ferroalloys fractions much cheaper than lumpy ones. Significant is a short introduction process duration time too, that last few minutes or less with small temperature drop what is the next advantage of the method. But the problems still to be solved are the best lance design and process pneumatic parameters values. The new lance proposal along with the technological parameters analysis were published in previous Metal Conferences proceedings [6 and 7]. In this paper some further experiments with the diphase stream force analysis (using the new lance) are presented.

When the injection process is carried out into induction furnace with use of non-submerged lance, one of the biggest problems is achieving the proper gas-particles stream range in liquid before the particles dissolve completely and do not reach the bath's bottom. When the stream energy is not proper it is not easy to obtain homogenous chemical compositions in liquid bath volume in furnace or ladle and it is necessary to stir it mechanically. When you use an inductive furnace you have an assistance of the electromagnetic stirring what greatly improves homogenization. The problem does not exist with use of submerged lance because you have to regulate stream range by depth of lance submersion and mixing is much better because bubbles of introduced carrier gas “boil” the bath significantly. But the problems connected to temperature drop are visible much more and after injection process you have to deliver new portion of heat energy to compensate lost temperature.

To achieve the proper diphase stream range in liquid metal it is necessary to ensure that its dynamics and force which impact the dense liquid metal surface are large enough. If so, the diphase stream range inside the liquid metal is large (sometimes down to the furnace bottom) and the particles injected are efficiently assimilated by the liquid alloy. The experiments on the special experimental setup were carried out to measure this force value and to combine it with the achieved process results. Preliminary results of the experiments were presented on previous Metal Conferences [6 and 7] where the experimental installation along with the methodology were described. In this paper the final analysis were briefly presented in some examples of experimental equation obtained.

The average value of stream force in stable (during the stable cycle period) was calculated, the experimental equations were formulated and graphs were made. On the next page there are presented some of the formulas for the parameters analogical as on the stream force's time-changing graphs, see Fig. 2 as an example.
\[
F = -0.785 + 0.032 \cdot w_k + 0.019 \cdot \mu \quad [1]  
\]

where: \(w_k\) – gas velocity, \(\mu\) - mass mixture concentration.

The next is a dependence between diphase stream force and pressure values.

\[
F = -0.063 + 0.809 \cdot p_1^2 + 1.831 \cdot p_4^2 \quad (2)  
\]

where: \(p_1\) – carrier gas pressure, \(p_4\) – pressure in the feeder.

The described (and others not mentioned in the paper) 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 and mostly influences the diphase stream force value.
2. Diphase stream force value increases with pressures increasing (especially pressure in powder feeder \(p_4\) which increase cause mass concentration increasing) and decreases with increasing of distance between lance outlet and measuring surface (liquid metal bath). For distances above 40mm the value was so small that impossible to measure with used equipment.
3. The proper period of injection cycle for industrial conditions is in the middle of the process, when the stream force is of good stability. The peak visible in the end of the injection process is a response for the quite considerable volume of carrier gas blown-out with the last portion of powder injected.
4. Mass concentration of the diphase mixture and velocity of carrier gas in the lance outlet decisively influence the analyzed force. But the value of mass concentration should not be above 20-30kg/kg because the higher values cause high instability of conveying process.

**4. PNEUMATIC INJECTION FOR UTILIZATION THE ELECTRODES SCRAP**

The next group of materials possible to utilize mostly in cast iron foundries are: steel scrap, crushed graphite electrodes and dust wastes from electrodes manufacturing process [8-13]. In many foundries cast iron melting process is based mainly on a pig iron and process scrap (returns). It gives an assurance of proper carbon content in liquid metal bath without necessity of its further introduction in carburizers. Steel scrap for the sake of its low carbon content (0.1-0.2% C) is for many foundries an uninteresting material from production point of view. However, it contains a low sulphur and phosphorus content too, what enables to use it even in ductile cast iron production. The fact of steel scrap introduction instead of pig iron is of great importance for the production of which consumes much quantities of energy and is very harmful to the environment. The steel scrap is much cheaper charge material than pig iron. But the problem of carbon deficit in liquid cast iron appears when we replace the pig iron with the steel scrap. So we have to recarburize the liquid metal bath by use of various methods but one of the best is pneumatic injection of carburizers. The method itself is widely known and described in some previous Metal Conference...
Proceedings [7] and in previous papers [14]. In the paper the clue is to emphasize that pneumatic powder injection method can be considered both as an efficient method of the cast iron recarburization and waste utilization.

The experiments indicate possibility of obtaining a significant carbon content increase by use of pneumatic injection technique both in cast iron and cast steel and makes possible cast iron production with no share of pig iron. In that case a considerable amount of the carburizer is added with solid charge material on the furnace bottom and then the injection process is conducted to correct slightly the carbon content in liquid. As a result the heat time is decreased and costs are less in comparison to method with injection of the whole amount of required carburizers.

The elements of the setup on the Fig. 3 are: 1-pressure container, 2-control switchboard, 3-feeder’s mixing chamber, 4-reducer, 5-extensometric scales, 6-slide damper, 7-silo, 8-screening sieve, 9-compressed air supply, 10-main valve, 11-pipe, 12-lance manipulator, 13-injection lance, 14-EAF.

The usage of the steel scrap and the carburizers from crushed electrodes reveals that the pneumatic injection is an important method for environmental protection. The properties of the made alloys are the same or even better than without this technique in production and with pig iron in solid charge.

Fig. 3. Recarburization setup.

4. CONCLUSIONS

In the paper the usage of pneumatic powder injection method for solid metallurgical and foundry wastes utilization was presented. The experiments in this field have been made in the Department of Foundry, Silesian University of Technology for many years. These several experimental examples as well as industrial applications show how this technique can be employed to utilize furnace dusts from various kinds of furnaces, fine ferroalloys fractions into liquid bath introduction, liquid ferrous alloys recarburization and used moulding sand reclamation. The results of author’s experiments proved effectiveness of this method in every of the mentioned processes. The ecological and economic parameters of industrial application are very promising so the interest of the industry continuously increases. To develop further the theory of diphasic stream movement from the powder injection process point of view the next researches have been just launched. Their goal is to examine stream flow with use of the high speed camera to catch the real particular powder particle movement. Both model experiments and real injections into liquid metal are planned to observe how the gas-powder stream really enters the liquid metal surface. The results of the mentioned experiments will be published later.

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REFERENCES


