Anti-penetration coatings for foundry molds and cores based on slag of secondary aluminum metallurgy

I.O. Leushin, A.N. Grachev
Nizhny Novgorod State Technical University named after R. E. Alekseev (Russia)
lmps@nntu.nnov.ru

Developing a concept for recycling byproducts generated during re-melting of secondary metals in order to meet the needs of supplying industries (i.e., those industries which supply products, articles and components for further use by other industries) is one branch of research (among others) of the Chair of Foundry-Metallurgical Processes and Alloys at Nizhny Novgorod State Technical University named after R.E. Alekseev.

Within the framework of this branch the problem of recycling the slag generated during aluminum scrap re-melting (aluminoslag) is being solved. This slag is abundant at the enterprises of secondary metallurgy, as well as at the foundry shops of the machine-building, automotive, tool-making and instrument-making industries. In particular, one of the possible ways of recycling of this aluminoslag is its application as a filler in anti-penetration coatings for foundry molds and cores in steel and iron casting.

This work is rather urgent due to several reasons. First, it is of interest to owners and operators having such waste, since its reuse allows:

— to lower the cost of purchasing and maintaining the disposal sites;

— to reduce the penalties imposed by regulating bodies;

— to remedy the state of environment;

— to avoid landscape altering.

Secondly, this work is attractive for supplying industries, especially the foundry-metallurgical one, because using such byproducts will provide a solution to the problem of introduction of new and inexpensive materials.

Thirdly, still unsolved is the penetration problem in steel and iron casting, despite a considerable amount of existing anti-penetration coatings, the majority of which, even at high prices, are ineffective on account of various reasons.

According to the stated above, the principle objective of this work is to broaden the sources of raw materials for mold anti-penetration coatings for ferrous alloys along with a substantial decrease in their cost, yet retaining a guarantee of satisfactory result as to the castings' surface quality, using aluminoslag as a filler.

This objective can be achieved by developing effective anti-penetration aluminoslag coating compounds for foundry molds, as well as by developing their application techniques.

At the very beginning of this work one set the following main tasks:

1. Examination of aluminoslag as a mold coating material.

2. Theoretical evaluation of the performance of an aluminoslag-based coating.

3. Development of the technology of manufacturing and application of aluminoslag mold anti-penetration coatings.

4. Realization of the worked-out techniques in practice.

Prior to begin doing the set tasks, one evaluated aluminoslag as a molding material. In this connection aluminoslag's following properties (under laboratory conditions, according to the standard procedures adopted in Russia) were determined: chemical composition and grain size distribution; change of mass on firing; true density; moisture; pH of aqueous extracts. In addition, aluminoslag - liquid melt interface was tested.

As a result, the degree of applicability of aluminoslag as a filler for mold/core anti-penetration coatings was estimated as high, the prerequisites for this being: presence in its content of Al_2O_3 with high refractoriness; relatively constant chemical composition; sufficiently stable grain-size distribution which assures the obtaining of the necessary fines and powder fraction up to 30 % of the material's mass (without crushing); high percentage of pure aluminum in the slag; low slag wetting by liquid steel melt.

Next steps in the research were detection and analysis of all existent working mechanisms, materials and compounds of mold/core anti-penetration coatings in steel and iron casting, those utilizing industrial byproducts inclusive. Particular attention was paid to the analysis of the existing experience in utilization of metallurgical wastes.

As a result, the conclusion about the novelty of the development was drawn; it was connected first of all, with the peculiar working mechanism of aluminoslag-based anti-penetration coatings which are based (apart from other things) on the "gas lock" and the "gas phase activation" effects [1].

While fulfilling this work's first task, one examined such properties of aluminoslag as porosity, gas permeability, shape of grains, specific surface, surface properties, as well as the properties of aluminoslag-based coatings (gas generating capacity and flow of chemical reactions under contact with melt. Physical-chemical and thermodynamic aspects of aluminoslag coatings for mold use were substantiated.

In the end, a practically important conclusion was drawn about the all-round effect of aluminoslag coatings which prevent the formation of all three kinds of penetration.

Decrease in thermal penetration is reached via the presence in aluminoslag's content of high–refractory oxides Al_2O_3 and SiO_2; by formation, under contact with steel melt and gas phase, of Al_2O_3 with high refractoriness; by forma-

tion of high-refractory compounds - silicates (sillimanite and mullite), and aluminum nitride.

A decrease in mechanical penetration is obtained by:

1) use of aluminoslag of fine and powder fraction;

2) non-wetting of a mold coating by liquid melt;

3) formation, under contact of liquid steel melt with aluminoslag, of Al_2O_3 and AlN in the form of hard high-refractory inclusions in the silicate layer, which contributes to clogging the mold's pores and to imparting an additional hardness to the surface layer;

4) high crystal-chemical affinity of the formed silicates with the mold's material;

5) formation of a gas space (during the coating thermo-destruction), which acts as a "gas lock" or a heat-insulating gas cushion hindering penetration by the first hot streams of the melt the mold pores and opposing, at the first stages of pouring (in conjunction with the initial skin), the liquid metal pressure acting on the working surface of the mold.

Additional contribution to the struggle against penetration is made by formation of silicates in the sand mold's pores. An advantage here is a crystal-chemical affinity of similar silicates in the coating and the mold; this guarantees the coating will not be eroded during interaction with the steel melt.

Reduction of chemical penetration is possible due to:

1) steel deoxidation by the coating's aluminum;

2) activation of chlorine-bearing gas phase which induces formation, at first on the initial skin and later on the casting's skin, of an easily removable protective layer of ferrous chlorides (in the form of a shell) , which becomes an obstacle to gases' moving into the casting;

3) N_2O and K_2O oxides which turn the penetration shell glassy and easily removable;

4) a gas space or a "gas lock" which hinders contact of the liquid melt with the mold's material and lessens the probability of low-wetting silicates formation (of fayalite type).

While performing the second task one described, using results of the coating experimental testing, the working mechanism of aluminoslag coatings with consideration of the heat, fluid-gas-dynamic and chemical aspects of the "gas lock" and the "gas phase activation" effects; a physical and a mathematical model of aluminoslag-based coatings' operation were suggested, as well as a computing pattern, the parameters of which are a coating's thickness, slag's particle-size distribution and heat transfer coefficient. The above parameters were given an approximate evaluation.

The technique of a coating's thickness evaluation envisaged a consecutive analytical solution of a series of boundary problems with a rising extent of formulation complexity (an iterative correction of evaluation results).

Evaluation of the slag's particle-size distribution for anti-penetration coating applications has been carried out, bearing in mind simultaneous implementation of two conditions:

1) melt penetration into the mold pores no deeper that the coating's thickness for the period of the casting's wall solidification;

2) assurance by the slag's particles of an optimum value of gas permeability, the magnitude of which was set.

Fulfillment of the third task allowed a technologically strict (as applicable to shaped castings) execution of procedures intended for aluminoslag preparation for use as a filler in mold/core anti-penetration coating compounds with immediate manufacturing of these coatings. In this case the indispensable procedures for transforming aluminoslag into an aluminoslag filler were the following: its preliminary crushing; drying to constant mass; sieving through a 0.063-mm mesh riddle.

In this segment of research the working mechanism of aluminoslag anti-penetration coatings underwent corrections linked with the presence of metallic aluminum in the form of a framework in the original aluminoslag, among the "branches" (i.e., structures) of which the rest of aluminoslag's constituents are located. Aluminoslag crushing leads to separation of these constituents from the metallic aluminum, yet does not assure its turning into powder. Therefore, the role of the metallic aluminum in the working mechanism of mold/core aluminoslag anti-penetration coatings has ceased to be considered in practice. Yet, this fact has not diminished the aluminoslag coatings' all-round effect on foundry molds in iron and steel casting.

The same stage of research, development of pilot systems of aluminoslag mold anti-penetration coatings based on water and organic solvents is located. While examining their main properties (density, viscosity, sedimentation stability, covering ability), one sought an optimum combination of the coating's components. The techniques of aluminoslag coatings' application in steel and iron casting, as well as the techniques and patterns to control the interaction between melt and mold's materials were developed.

While carrying out the fourth task, one examined aluminoslag coatings' release issues, estimated the economic effectiveness of the work, accomplished environmental expert testing which demonstrated the acceptability of these technical solutions to the conditions of running facilities.

The suggested development has passed industrial approbation with a positive economic effect at Nizhny Novgorod Machine-Building Plant Ltd. and several other plants of the city of Nizhny Novgorod. Over thirty scientific papers have been published, one degree of PhD (metallurgical engineering) has been earned, one Russian patent for an anti-penetration coating filler has been taken out on the base of results obtained by this work.

REFERENCES

1. *Leushin I. O., Grachev A. N.* Development of effective anti-penetration coatings for foundry molds based on aluminoslag fillers. Liteynoe proizvodstvo. 2002. № 4. p. 13–15.