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The Influence of Alkali Metal Chlorides on the Manufacturing Process and Steel Properties in Aluminothermic Reduction of Iron

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Metal production by remelting of ferrous and nonferrous scrap is economically and technologically substantiated. Technologies aimed at a decrease in the fraction of metals obtained by conventional remelting in the total volume of cast product are very promising. Economical efficiency is achieved owing to the use of metal reduced from mechanical engineering wastes by exothermic melting. Such wastes are scale, ferrous and non-ferrous metals chips [1].

Manufacturing process of steel production from mechanical engineering wastes consists of several stages. At first, refractory graphite mold is filled with thermite mixture composed of wastes. This thermite mixture is ignited, and exothermic oxidation-reduction reaction is started. This reaction produces melt of metal and dross. Molten metal fills casting mold, and dross comes to the surface [2 – 5].

It has been found experimentally that (1) the completeness of chemical element reduction depends on the temperature of the exothermic reaction; (2) the intensity of the exothermic reaction is influenced by the proportion of the thermite mixture; (3) high intensity of aluminothermic melting accompanies short-time emission of gaseous phase and splashing of dross and metal melt.

Moreover, increasing the reaction temperature decreases the extraction of reduced metal owing to melting loss of its main components and has a negative influence on metalware structure. As a result, there occur gas inclusions and porosity.

A decrease in chemical reaction temperature and aluminothermic melting intensity is possible by using thermite mixture components involving alkaline metals, for instance, Na and K. These metals make it possible to produce steel of high quality at low temperatures. They also affect the fluidity of dross generated in oxidation-reduction process.

Thus, the aim of this investigation was to study KCl and NaCl impact on steel manufacturing process and steel properties in aluminothermic reduction of iron from mechanical engineering wastes.

There were two problems stated. The first problem was to determine the influence of alkaline metals chlorides on the intensity of oxidation-reduction process and metal extraction. The second one was to study the impact of these chlorides on the properties of obtained alloys.

It has been found experimentally that the mass content of NaCl in the thermite mixture more than 11% results in inhibition or full stop of thermochemical process of Fe reduction and interaction between accompanying components. The quality of obtained metal considerably deteriorates, and consequently, such content proves to be inappropriate. In the same way, the maximum permissible content of KCl in the thermite mixture comes out to be 13 %.

The analysis of relationships between chloride content in thermite mixture and mass metal extraction as a result of aluminothermic process shows that the maximum efficiency is accomplished when NaCl content constitutes 3.5 % or when KCl content constitutes 4 %.

When used NaCl and KCl in small amounts, mass metal extraction is more than estimated value (50 %) and experimental value (47 %) of metal extraction at thermite mixtures combustion without these chlorides. When NaCl and KCl content exceeds 7 % and 7.25 %, respectively, mass metal extraction becomes less than foregoing experimental value.

Using NaCl and KCl prolongates combustion time. This may lead to a more complete interaction between mixture components, as well as to better separation of reaction products, i.e. surfacing of dross.

Steel produced with the use of previously mentioned chlorides chemically corresponds to steel St3 [6]. We carried out the analysis of structures for specimens produced by aluminothermic melting. We also determined the hardness of steel specimens.

The investigation of specimen fracture showed that the use of KCl results in a slight increase in the grain size of the cohesive fracture areas. In both cases, the prevalence of cohesive fracture areas is typical of the chlorides under study. This indicates that they sufficiently affect generation of steel plasticity.

We carried out microstructure contrast analysis of St3 specimens produced by various manufacturing techniques, generation conditions being the same. It was found that during exothermic melting of thermite mixture components, as contrasted to the conventional ferrite-pearlite structure, two-phase microstructure consisting of α-phase Fe_3Al and $FeAl_2$ (ξ) in the shape of slag is formed. Taking into account the value of hardness, from the result obtained, we can conclude that the oxidation-reduction process has high intensity; the temperature gradient of metalware production has high value as well.

The action of chlorides on the microstructure generation of St3 specimens at exothermic melting of thermite mixture components is obvious. In this case microstructures with ferrite-pearlite phase composition and with grain size similar to conventional St3 are formed. The resulting structures are characterized by lack of clearly defined interface of ferrite phases, and therefore, they are similar to ferrite-pearlite gray cast iron. In addition, KCl results in the generation of spherical graphitic inclusions in steel structure with decrease of pearlite phase content. The similarity with gray cast iron also follows from their hardness values.

In conclusion, effective influence on exothermic reaction behavior is possible if the thermite mixture contains chlorinated components such as NaCl and KCl. Their content in the thermite mixture less than 7 % and 7.25 %, respectively, permits one (1) to improve the efficiency of the aluminothermic process by increase in the bulk of obtained metal melt, (2) to decrease the number of nonmetallic inclusions in steel structure owing to the reduction of the exothermic process intensity, 3) to control the physical-mechanical properties of the produced steel.

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