UDC 669.013.5:502.174

Practical aspects of utilization of the radioactively contaminated metal in metallurgical plants

Valeriy Balakin

D.Sc. in engineering

Victor Mashinistov

PhD in Technical Sciences

Oleg Galkin

The National metallurgical academy of Ukraine, Dniepropetrovsk

Abstract
The aspects of utilization of the radioactively contaminated metal in metallurgical plants had been considered. Utilization had been carried out in terms of proposed technology using the influence of the heat process on the radioactivity of the final products.
It is shown that radioactively pure metal can be got in melting the radiatively contaminated metal in electrical arc furnace according to the common,"classic" technology. The furnace is to be equipped with reliable and effective system for filtration of emissions (ejections) into atmosphere. The production personnel needs to have the permit to the work with the sources of ionizing radiation, and it is expediently to locate the plant on the territory of alienation of the nuclear electric power station of Chernobyl.
Key words: RADIOACTIVELY CONTAMINATED METAL, SOLID RADIOACTIVE WASTE, SELF-DECONTAMINATION, UTILIZATION OF THE RADIOACTIVE METAL

Introduction

The wide use of ionizing radiation in economic activity leads to ingressing of the big quantity (of a lot) of radioactive waste into environment. The radioactively contaminated metal (RCM), which is the part of this waste becomes the source of potential danger for biologic objects. In this case a lot of metal is withdrawn from economic turn-over. All this makes the problem of utilization of the huge volume of accumulated RCM utterly actual.

The technology of the RCM utilization had been considered in [1]. It is proposed to use RCM as a charge in metallurgical furnaces without preliminary decontamination of this metal. In the process of melting the radionuclides being on the surface of contaminated metal penetrate into the volume of the melted metal and are distributed evenly in it. Under such conditions ionizing radiation (IR) of a major portion of elementary isotrope sources (this part is played by radionuclides) is totally absorbed with metal itself, that means that in the process of melting takes place the self-decontamination.

In accord with proposed approach protected with a patent [2], the quantity of radioactivity, which could be brought into the melting furnace should not exceed some maximum permissible value calculated beforehand. This ensures the not-exceeding of permissible level of IR off the surface of articles made of the melted metal. The additional clearing of metal products of sources of IR takes place in the process of melting at the expense of evaporation of the radioactive substances, which have the temperature of boiling lower than the temperature in furnace. As a result we have the metal with such level of residual radioactivity, which allows using this metal later on without any restrictions.

The process of RCM utilization by means of the proposed technology includes operations connected wirth putting the scrap of RCM in storage, transportation and processing this scrap in metallurgical plants.

Earlier the evaluation of the radiation situation had been carried out, this situation being formed on all the stages of handling RCM, which is intended for charging into metallurgical furnace. It was shown that while doing this the necessary level of the radiation safety is ensured, which excludes any unjustified irradiation of production personnel.

In the present paper possibilities have been considered as to the practical realization of technology of RCM utilization proposed in [1].

Characteristic of the radioactively contaminated metal intended for using as charge

A high quantity of RCM, which falls into the category of the solid radioactive waste (SRW) is accumulated and continues to be accumulated in the environment. In conformity with [4]. SRW is classified by heat release for low-active, mean-active and high-active waste. Such waste contaminates air, water, soil and plants with radioactive substances (RS). This contaminants raise the level of the natural radioactive background, what correspondingly leads to additional external irradiation of humans as well as to their internal irradiation, when RS penetrate the human organism with air, water and food. The internal irradiation is more substantial.

In conformity with data presented in [6], in 2006 more than 1,000,000 tons ferrous metal have been accumulated in the area of alienation of the nuclear power station (NPS)of Chernobyl. This metal could be used in metallurgy. The most of this RCM (90-95%) fall into the category of low-active waste. 20 years after disaster the radioactive contamination in the area of alienation of the NPS of Chernobyl had been determined mostly with caesium-137 (83%), strontium-90 (14%) and insignificant quantity of isotopes of plutonium and products of their disintegration.

In many branches of industry, a high quality of metallic waste is accumulated, which is contaminated with natural radionuclides (radium, thorium, sodium): pipelines, fittings, the basic equipment of gas- and oil-processing plants and so on. Such metal is forcely located in depositories or on the open areas, since the operative norms and rules do not allow using it for its direct designated purpose as well as in capacity of metal scrap.

In installations of nuclear energetics the elements of the nuclear reactors work over a period of tens of years under conditions of a strong neutron irradiation. Powerful streams of neutrons are capable penetrating in metal, which is contiguous to nuclear fuel for a few centimeters. Such action leads to appearance of induced radioactivity in metal showing the diversity of created radioisotopes being the sources of kinds of IR. As a result, utilization of constructions of reactors, which worked out their service life becomes a great problem, because they are the radioactive waste.

In conformity with existing classification, RCM is the open type source of IR, what means that the RS from this source can find their way into environment. These RS are located on the surface of metallic object. Fixing of RS on this surface occurs usually by the way of holding the particles on the rough, porous, uneven surface and also at the expense of physico-chemical interaction with metal, diffusion deep into the surface of metal and so on. This surface contamination is extremely uneven at the expense of action of numerous factors.

IR created by RS, which are located on the surface of the RCM, is potentially dangerous for biologic objects falling under action of IR. The cause of this is the possible external and internal irradiation of these objects additionally to the basic (background) one. The level of this additional irradiation can exceed the allowable norms of radiation safety [6]. To return RCM in the economic turn-over it is necessary that the level of IR off the surface of articles made of this metal does not exceed allowable norms. One of ways for solving this problem is the use of RCM in the capacity of charge in metallurgy. But in this case it is necessary to ensure that the quantity of activity to be put into the furnace with charge does not exceed the certain value A_{max} determined beforehand.

Justification of the design technique as to the quantity of radioactivity in the charge

The quantitative measurement and identification of the radioactive elements are to be done by intensity of IR created by these elements [7]. The only available method for evaluation of contamination on the open surfaces is measuring the power of expositional dose **P** (R per hour) with subsequent determination of density of the radioactive contamination on the surface A_{surf} (Bk per sq.m), since these values are connected between them with the linear dependence according to relationship:

$$A_{surf} = K_{rec} \cdot P ,$$

where K_{rec} is the coefficient of recalculation.

In practice the scale of recording device is calibrated already in units of measuring the specific activity, that is activity referred to the unit of the surface area (Bk per sq.m). On the basis of measurements of the specific activity A_{surfi} on the i-th section of contaminated surface and its area S_i it is possible to calculate activity of this section of surface:

$$A_i = A_{surfi} \cdot S_i .$$

Metallic constructions, facilities, equipment at the conversion in metal scrap are divided in fragments to ensure the possibility of transportation to metallurgical plants and subsequent charging into the melting furnace. Different fragments differ substantially from each other by the degree of contamination. A mutual screening of IR created by these fragments, which takes place under chaotic location of the fragments of metal scrap on the storage yard or in the vehicle, distorts the results of measurements. That is why it is practically impossible to determine the objective value of the summary quantity of activity in the corresponding lot of metal scrap.

It is proposed to perform evaluation of the summary activity of RCM (which is intended for using as a charge) before its fragmentation. With this end in view, the value of power of emission (radiation) P_i is determined on the i-th section of the object intended for conversion in metal scrap, and evaluation of the area S_i of contaminated surface of this section is made as well as evaluation of mass M_i of this section. In consequence, the summary activity of the object divided in N sections is

$$A_{об.} = \sum_{i=1}^{N} A_i \cdot S_i .$$

Accordingly, the mass of the whole object is:

$$M_{об} = \sum_{i=1}^{N} M_i .$$

By means of obtained data it is possible to evaluate the average level of radiation off the surface of the object:

$$P_{av} = A_{об} \cdot K_{rec} .$$

While charging the radioactive metal scrap into the furnace it is important that the quantity of activity charged into the furnace does not exceed the maximum allowed value A_{max}. If the mass of radioactive scrap is less than the capacity of the furnace, the non-radioactive scrap is added into the furnace to its full capacity.

Behavior of the radioactive substances in the furnace in the process of melting metal

The RS put into the furnace with charge are distributed in the process of melting evenly by all the volume of liquid metal. In consequence a source of radiation arises, and emission (radiation) off its surface into environment is formed by the set of elementary isotrope radiators being in its volume. All the articles produced of this metal are closed type sources of IR; in such sources radiators are rigidly fixed and can't go outside their limits. This excludes for these radionuclides the possibility of penetrating inside living organisms, and, consequently, the production personnel is not subjected to internal radiation.

So, the potential danger of such source for biologic objects can be attributed only to the possible external action of radiation created by this source. The use of the proposed technology ensures obtaining of the radiation pure metal what excludes for biologic objects the possibility of irradiation exceeding the norms.

The side product of metal production is the slag, which is composed of non-metallic components of the charge. In the process of melting these inclusions and RS, which have the density less than the density of metal, rise to the surface and are concentrated in the slag. Results of measuring the radioactivity of products of the blast furnace pig iron heat are presented in [8]. They show that the equivalent natural radioactivity of slag exceeds by several fold the level of pig iron radioactivity. Concentration of radionuclides in slag during melting favors additional (at the expense of the self-decontamination process) clearing of metallic articles to be produced from these radionuclides.

Fumes with suspension of fine-dispersed particles of different charge components, which are carried outside the furnace arise in the process of melting metal. Among the radionuclides, which can be put into the melting furnace there are such substances that have the temperature of boiling t_k lower than the temperature in the furnace 1600˚C. This is, in the first place, caesium-137 (t_k =685˚C), strontium-90 (t_k =1367˚C), potassium-40 (t_k =753°C). Taking into account that the mass of all the radionuclides being in the furnace is a few fractions of gramm, they all can be evaporated from the melted metal in the period of melting. It is shown in [8] that the major part of radionuclides of the natural origin being in the furnace in the process of melting pass into the dust-fume phase, what reduces their quantity in the smelted pig iron too.

Evaporated radionuclides can ingress into the atmosphere and settle down on the ground increasing the risk of additional internal radiation of humans with these RS. Prelininary evaluation shows that this does not lead to exceeding the allowable levels of penetration of the radionuclides into the human organism as well as allowable concentrations in air and drinking water. To prevent the possible abnormal emissions into the atmosphere in the process of melting metals, it is necessary to equip the furnace with reliable and effective system of filtration of emissions removed in the atmosphere.

During the heat, IR created by radioactive substances, which are found in liquid metal are also acting on the lining of furnace. The neutrons of all the kinds of IR can penetrate deep into the lining from the layer of melted metal being in contact with it. This radiation ionizes the substance of lining, but, since the intensity of it is small (insignificant), such action does not lead to the change of lining properties.

Beside ionization, the action of neutrons leads to creation of induced radioactivity in the layer of lining situated near the surface, of width to 10 cm. As a result, the radioactive isotopes of the chemical elements, which enter in composition of the lining substance, arise in this layer, and their quantity can be accumulated in the process of the furnace service. Induced activity does not influence the properties of lining and the metal to be smelt. The radioactivity accumulated in the lining can create IR with intensity exceeding the prescribed norms. That is why the repairing works in the furnace are to be carried up by the personnel, who has the permit of working with the sources of IR (category A).

The above-considered technological cycle is ending with making radiation pure metal, which can be used later without any restrictions. The radioactivity of this production does not increase at any kind of working (processing).

In accordance with given technology, the charge with elevated level of radiation is charged into the melting furnace. Consequently, the side-products of manufacture including slag and a fume-dust component, can have the level of radioactivity exceeding the allowable ultimate values.

Conclusions

Results of investigation on the possibility of utilization of the radioactively contaminated metal, presented in [1,3] and the given paper showed, that the proposed approach can be realized with using the electric arc furnace. Smelting can be performed according to the usual “classic” technology. The only additional requirement is the necessity of equipping the furnace with reliable and effective system for filtration of the fume-dust component of the heat products.

Since on all the stages of the technologic cycle it is necessary to handle the sources of IR, these works are to be performed by the personnel of category A [6]. Proceeding from above-stated, it is expedient to place the plant for utilization of the radioactively contaminated metal in the area of alienation of the NPS of Chernobyl.

Beside performing of the main task this will give possibility to carry out the natural investigations in purpose of the further improvement of proposed technology and extending its scope for utilization of the radioactively contaminated metal.

References

1. Mashinistov V.Ye., Galkin O.F. Technology for utilization of the metal contaminated with radioactivity at the enterprises of metallurgy. Metallurgical and Mining Industry, 2015, №2, P.277-281.
2. Zayavka na izobreteniye №a201306522 ot 27.05.2013 “Sposib utilizatsii radioaktivno zabrudnenogo metalobrukhtu”. Avtory: Mashinistov V.Ye., Galkin O.F.. Zayavitel NMetAU, Dniepropetrovsk, Ukraina. Resheniye o vydache patenta ot 06.04.2015.
3. Osnovni sanitarni pravyla zabezpechennya radiatsiynoi bezpeky Ukrainy №54 vid 02.02.2005 r.

4. Doklad “Otsenka riskov oblucheniya naseleniya Rossii”. Kuznetsov V., Ostretsov I., Toponov A., Shingarkin M. http://.seu.ru/projects/metal/report_version_5[0].doc.
5. Normy radiatsiynoi bezpeky Ukrainy (NRBU-97). Derzavni gigiyenichni normartyvy. Kuyiv, 1997.-121 s.
6. Maksimov M.T., Odzagov G.O. Radioaktivnyye zagryazneniya i ikh izmereniye: Uchebnoye posobiye.- Energoatomizdat, 1989.-304 s.
7. Gasik M.I. i dr. Prirodnaya radioaktivnost shikhtovykh materialov i produktov plavki ferrosplavov. Materialy mezhdunarodnoi nauchno-prakticheskoi konferentsii. NMetAU, Dniepropetrovsk, “Sistemnuye technologii”, 1999.-s.448.