

Magneto-inductive systems as a method to reduce the environmental risks of the existing systems of incoming quality control of metallurgical raw materials

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Abstract. The advantages of automated systems for magnetic inductive incoming quality control of raw materials of large metallurgical enterprises are demonstrated. Environmental risks under the existing visual control system were assessed.

1 Introduction

In the "Fundamentals of State Policy in the Field of Environmental Development of Russia for the Period up to 2030", approved by the President of the Russian Federation on April 30, 2012, the strategic goal of state policy in the field of environmental development was defined – the solution of socio-economic problems, providing environmentally-oriented economy growth, conservation of a favorable environment, biodiversity and natural resources to meet the needs of present and future generations, realization of the right of every person to a favorable environment, strengthening the rule of law in the field of environmental protection and environmental safety [1].

The use of secondary mineral resources in industry allows to solve not only set problems, such as resource conservation and environmental protection, but also becomes the reserve for increasing the Russian economy efficiency.

European countries also do not stand aside from the set problems. Thus, the European policy in the Waste Framework Directive (WFD) [2] sets as a priority goal the prevention

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and reduction of waste production and its harmfulness. This can be achieved by optimizing the use of primary resources, introducing technologies that minimize waste generation, developing environmentally friendly products and appropriate technologies for the final processing of hazardous substances contained in waste, and recycling waste, through recycling, reuse, enhancement or other processes that aim to produce secondary raw materials.

A significant part of secondary resources are recycled ferrous metals, which serve as a feedstock for steelmaking, production of ferroalloys, steel and iron castings. As the Government of the Russian Federation emphasizes in the “Strategy for the Development of the Russian Ferrous Metallurgy for 2014-2020 and for the Prospect until 2030”, the ferrous scrap industry is strategically important for the socio-economic development of the country [3]. The use of secondary raw materials in metallurgical production will reduce the cost price of final metallurgical products, while simultaneously solving the problem of hazardous waste disposal. Compared to steel production from mineral raw materials, steel production from recycled metals consumes 74% less energy and 40% less water, and reduces pollutants in water by 76% and in air by 86% [4].

As it is indicated by a number of researchers [5 - 7], the recycling of scrap metal and waste in the world economy has recently occupied a significant place. The amount of scrap and waste ferrous metals used as raw materials in global metallurgical production increases every year.

The system for processing scrap and waste metals can be divided into the following stages: collection, sorting, cutting raw materials, decontamination, remelting [8, 9].

The scrap metal supplied by scrap metal recyclers comes from various sources and is heterogeneous in composition and quality. The main quality indicators of scrap as charge material for steelmaking furnaces are: bulk density, chemical homogeneity, the content of non-metallic impurities (earth, sand, oil, organic materials, etc.) and nonferrous metals.

As noted in a number of papers [10, 11], the quality of used scrap is gradually deteriorating, the proportion of lightweight scrap containing impurities of nonferrous metals is increasing, the amount of plastic, glass and other impurities is increasing.

The procedure of reception, storage and methods of testing of scrap and waste ferrous and nonferrous metals are regulated by current standards, respectively, GOST 2787-75 “Ferrous secondary metals. General technical conditions”. Scrap metals may contain various inclusions such as sand, paint, ground, rubber, plastic, nonferrous metals, refractories, wood. Scrap contamination is on average 3 - 5% [12]. Although this value seems small, but in the end it leads to the formation of hundreds of thousands of tons of waste, for transportation along with scrap and disposal of which huge funds are spent. The issue of reducing the impurity level in secondary metal legitimately arises.

In practice, many scrap metal suppliers neglect this requirement, using the difficulties encountered by the buyer in unloading of railway gondola cars due to stringent rules to limit downtime of rolling stock regulated by the Federal Law “The Charter of Rail Transport” [13] and the requirements of instructions of the USSR Gosarbitrazh dated June 15, 1965 No. P-6

and dated April 25, 1966 No. P-7 [14, 15] for acceptance of goods in quantity and quality, which are still applied in disputes arising between suppliers and buyers. The main method of falsification is the hidden loading of massive non-metallic cargoes into railway gondola cars, such as stone and concrete blocks, construction waste, earth, scrub, scale, rubber, plastic, and household waste.

Clogging inclusions give the railway gondola car additional technologically useless mass, fixed on the scale car, the report of which serves as the basis for mutual settlements with the Supplier at prices established for conditioned raw materials. As a result, the loss caused by clogging of railroad gondola cars to large metallurgical enterprises is more than 7 billion rubles a year of direct financial losses, not including the cost of unloading, sorting and disposal of contamination.

2 Materials and methods

As methods for assessing the contamination of scrap metal, a visual assessment of car contamination was used by specialists of the Quality Control Department of a large city-forming parent enterprise of a metallurgical holding (hereinafter – “LME”). This method of assessing the scrap metal contamination is used, so far, at all metallurgical plants in Russia. Visual assessment of car contamination is based on the visual presence of earth on the surface of scrap metal and waste on the bottom of gondola car.

As a reference method, the developed specialized means of express control UKNV-2 “Induktomass”, based on the magnetic principle of measurements, was used.

Based on the data obtained from measuring system and scale car, speed sensors and gondola car dimensions, the automatic analysis system plotted the distribution of magnetic mass along gondola car length. In the calculations, correction factors or functional dependences of the speed of movement and the gondola car dimensions were used.

In the UKNV-2 modification, instead of spiral-screwed magnetic coil, the blocks of which cover a railway car and an operating mainline, the installation of a system of magnetoresistive and magneto-inductive sensors (magnetic field transducers) in the amount of from 5 to 15 pcs in accordance with the patent [16].

The system of two lidars with specially developed software, installed at a height of 5.0 m from the level of the rail top of the railway track, is used to simultaneously measure the integral bulk density of cargo, the overall characteristics of the cargo and railway gondola car, the car, instant and average speed, the car serial number in rail transport. The magnetic transducer system is used to measure the level of magnetic field fluctuation in the area of railway gondola car passing near the supports of existing railway infrastructure (supports of contact network and bridge crossings).

The fundamentals of method for magnetic detection of nonmagnetic impurities are described in [17].

The mass of waste was determined by studying the contamination of 20 cars with scrap, randomly selected from the trains arriving by rail to the LME's site.

3 Results and discussion

Currently, when accepting a batch of scrap and waste metal, control of the degree of scrap contamination at metallurgical plants is determined visually. Let's make some calculations that characterize the method capabilities.

Bulk density of scrap metal in gondola cars is 550-750 kg/m³. The bulk density of ground is 1600-2500 kg/m³. The monolithic metal density is 7850 kg/m³. The net weight of a fully loaded car is 50-70 tons. The average metal thickness in scrap metal is 3 mm. The gondola car volume is 76-88 m³. The gondola car area is about 25-35 m².

Let's calculate the ground layer on the surface of a railway car, corresponding to 5 – 7% of contamination.

Taking as input data for assessment of the average values of the above we get:

The ground mass with a contamination of 7% in a car with a net mass of 60 tons is 4200 kg. Which corresponds to $4200 : 2000 = 2.1 \text{ m}^3$.

The ground mass with a contamination of 5% in a car with a net mass of 60 tons is 3000 kg. Which corresponds to $3000 : 2000 = 1.5 \text{ m}^3$.

The surface area of 1 m³ of scrap metal will be $1 : 0.003 \times (650 : 7850) \approx 28 \text{ m}^2$.

The scrap metal surface area in the car will be $28 \times 80 = 2240 \text{ m}^2$.

Thus, the contamination of 7% corresponds to the visual presence of ground layer on the metal surface, on average, with a thickness of $2.1 : 2240 = 0.0009 \text{ m}$, i.e. less than 1 millimeter (including “waste on car bottom”).

The contamination of 5% corresponds to the visual presence of ground layer on the metal surface, on average, with a thickness of $1.5 : 2240 = 0.00066 \text{ m}$, i.e. less than 0.7 mm (including “waste on car bottom”).

It is quite difficult to distinguish such a contamination visually from the height of car view from the trestle (5-6 m) by QCD specialists of metallurgical enterprises, and, therefore, the contamination percentage will be determined with a large margin of error.

Comparison of carried out results of the UKNV's measurements and QCD's assessments, based on visual observations and signs of metal, passed shredding showed that, on average, according to the contamination assessment of UKNV, each car contains 5 – 10 % more contamination, determined visually by enterprise's QCD. The monitoring results are illustrated in Table 1.

Table 1. Monitoring results.






Photocontrol	QCD's data, contamination, %	UKNV-2's data, contamination, %
	5.8 %	11.5 % The ground thickness – at least 0.3 m, the density – at least 1 t/cubic meter (dry soil). Car area 25 sq.m. Total – at least 10 tons. Or at least 11 %.
	5.1 %	14.6 % The ground thickness – at least 0.5 m, the density – at least 1 t/cubic meter (dry soil). Including metal – 50% of the volume Car area 35 sq.m. Total – at least 8 tons. Or at least 13%.
	4.3 %	7.5 % The ground thickness – at least 0.1 m, the density – at least 1 t/cubic meter (it is not clear from the photo, the soil may be wet). Car area 35 sq.m. Total – not less than 3.5 tons. Or at least 6% for dry soil and at least 8-9% for wet

Table 2. Continued.

	4.3 %	9.6 % The ground thickness – at least 0.3 m, the soil is thoroughly mixed with metal (50-60% of the volume), the soil density – at least 1 t/cubic meter (it is not clear from the photo, perhaps the soil is wet, then – up to 2.5 t/cubic meter). Car area 35 sq.m. Total – at least 4 tons. Or at least 7% for dry soil and at least 9-10% for wet soil.
	8.2 %	4.7 % The car does not contain any visually distinguishable blockages. The main part of contamination according to UKNV is water (the car is heavily watered) 3-4%.

4 Conclusion

As you can see from the table above, the magneto-inductive system gives a more objective result than the visual system. The incoming scrap metal inspection by the magnetic-inductive method will give great savings in LME's funds, which, among other things, can be directed to measures that reduce the damage from storage and disposal of slag dumps and emissions of harmful gases generated from the processing of ballast material that clogs metallurgical raw materials. The introduction of magnetic inductive systems will reduce the amount of environmentally hazardous pollution at the stage of supplying raw materials for large metallurgical enterprises.

References

1. *Fundamentals of state policy in the field of environmental development of the Russian Federation for the period up to 2030* (2012)
2. Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives
3. Order of the Ministry of Industry and Trade of the Russian Federation dated May 5, 2014 No. 839. On approval of the Strategy for the Development of the Ferrous Metallurgy of Russia for 2014 - 2020 and for the long term until 2030 and the Strategy for the Development of the Nonferrous Metallurgy of Russia for 2014 - 2020 and for the prospect until 2030
4. *Bureau of International Recycling (BIR). The Industry* (2021)
5. V. V. Smirnov, *Auditing*, **5(4)**, 30 (2018)
6. X. Hu, C. Wang, M. K. Lim, S. C. L. Koh, *J. of Cleaner Production*, **243**, 118576 (2019)
7. K. E. Daehn, A. Cabrera Serrenho, J. M. Allwood, *Environmental Science & Technology*, **51(11)**, 6599 (2017)
8. E.V. Rastyannikova, *Innovation and investment*, **7**, 81 (2019)
9. A. Damgaard, A.W. Larsen, T. H. Christensen, *Waste Management & Research*, **27(8)**, 773 (2009)
10. E. A. Popov, *Business strategies*, **9(2)**, 35 (2021)
11. A. O. Andrianov, O. A. Mednikov, *Scientific almanac*, **1-1(27)**, 19 (2017)
12. GOST 2787-75, Secondary ferrous metals. General specifications
13. Federal Law "Charter of Railway Transport"
14. Instruction on the procedure for accepting industrial and technical products and consumer goods by quantity (approved by the decree of the State Arbitration of the USSR dated June 15, 1965 N P-6)
15. Instructions on the procedure for accepting products for industrial and technical purposes and consumer goods in terms of quality (approved by the Decree of the State Arbitration of the USSR dated April 25, 1966 N P-7)
16. V. A. Kochemirovsky, A. G. Kuzmin, M. A. Malygin, Patent of the Russian Federation. RU 2717286 C1 System for determining bulk density and non-magnetic contamination of scrap metal in gondola cars in railway vehicles. Bul. 8 (2020)
17. V. A. Kochemirovsky, S. V. Kochemirovskaia, M. A. Malygin, A. G. Kuzmin, M. O. Novomlinsky, A.A. Fogel, L.S. Logunov, *Applied Sciences*, **9(10)**, 2001 (2019)