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EXPERIMENTAL RESEARCH OF ENERGY EFFICIENCY OF FURNACE OPERATION FOR WELDING ELECTRODES COATING HEAT-TREATMENT

The paper considers and analyses main problems dealing with operation of the furnace intended for drying and sintering of welding electrodes with rutile coating. Complex of measures aimed at energy saving has been developed.

Key words: *drying agent, electrode, furnace, recirculation.*

Introduction

Welding electrodes are widely used in various branches of industry. Heat treatment of electrodes is carried out to provide sufficient mechanical strength to the coating and maintain the content of humidity within the limits that promote normal course of welding process, provide preset chemical composition and properties of surfaced metal and welded joints. Strength of a weld depends of the quality of the electrode, its humidity[1].

The process of drying and sintering of electrodes takes place in furnaces of special types, as a rule these are electric furnaces.

Due to constant price increase for energy resources, the need to develop measures, aimed at energy saving in various branches of industry, including electrodes manufacturing arises. For decades the problem of power resources economy remains urgent.

Industrial research of energy consumption in various furnaces (F-232, ППТК-15, ЦРМЗ) used for drying and sintering of electrodes, has been carried in [2, 3], the authors underlined main problems of these furnaces operation, revealed the reasons of high level of energy consumption and suggested a number of measures, aimed at energy saving.

The authors of the paper performed a cycle of investigations of energy efficiency of continuously operating furnaces for drying and sintering of the electrodes with rutile coating at the enterprise.

The aim of the paper: study the reason of inefficient operation of furnaces, high level of energy consumption and elaboration of measures for elimination of the revealed faults.

Main part

Sphere of application of rutile electrodes – welding of constructions, made of low-carbon, low-alloy steels in construction and machine -building. Final moisture content of such electrodes must be u_f=0.1..0.3 %.

The process of drying and sintering of electrodes occurs in two stages the duration of the first stage is $\tau_1 = 0...40$ min, temperature of drying agent (air) t_{air1}= 25…120 °C, duration of the second stage is – $\tau_2 = 40$ min, t_{air2}= 120…150 °C.

Electric power of the furnace is 150 KW, calculated mass of charged electrodes – 750 kg. Technological process provides dry. of electrodes, that is, prior to placing in the furnace they pass through the thermo tunnel and initial humidity decreases (from u_i=7.7 – 9.3 % after pressure test to 7.25 % after thermo tunnel). Rather often the drying at the enterprise takes place by holding the electrodes in the shop at ambient temperature or by blowing of the electrodes in the furnace.

Internal construction of the furnace is shown in Fig. 1 and system of air supply and extraction is shown in Fig. 2.

Fig. 1. Internal construction of the furnace

In order to study the efficiency of furnace operation the investigation was performed during furnace operation in production conditions.

The complete cycle of heat treatment includes prior drying, drying, sintering and cooling. In the given type of furnaces the processes of drying and sintering occur. Prior drying takes place in thermo tunnel and cooling takes place in the shop. Three fans of ДЕ – 190 type are located in the upper part. Fans discharge under pressure fresh air into distributive duct, where 30 electric heaters, rated for 5 KW each, are located. Foul humid air is ejectivelly removed through the system of holes in the upper part of the furnace (in Fig. 2 the pipe line of yellow colour).

As a result of unsuccessful reconstruction of the furnace various problems arise: non-uniform drying of electrodes (final humidity at different frames may vary in wide range). The existing system of air extraction removes humid drying agent inefficiently. That is why at the enterprise during furnace operation the doors open several times, after that hot humid air enters the shop. This results in heat losses.

The results of furnace operation for three charges, which took place during one day (from 12^{05} – 18^{10}) are shown in Fig. 3. During the experiment such parameters were measured: temperature in the furnace, relative humidity of the air, temperature of air at the air hole, dew point temperature, power consumption of the furnace, humidity of electrodes coating. Measurements were carried out by the laboratory instruments of the enterprise, producing electrodes. Mass of electrodes and frames was weighted prior to charging. In the process of drying the electrodes were charged in the furnace on the frames of two types: ordinary and lightened. Lightened frames were manufactured by means of elimination of certain elements.

First charge (Fig. 3 a)

Temperature in the shop - 25 ºC. Frames are lightened (weight 2,25 kg) (Fig. 4). Electrodes passed through the tunnel. Weight of dry electrodes on one frame is 4.5 – 4.8 kg. Moisture meter is placed in the rear part of the furnace. Weight of the electrodes, charged in the furnace is approximately 1041 kg. Electrodes are tightly placed in 1 – 2 rows. In the process of treatment they are stuck in so-called "dry shortcakes" and are dried irregularly. The study showed that the electrodes on lightened frames are dried faster than on ordinary frames, after 60 min of sintering content of humidity of electrodes is 0.19 % on lightened frames and 0.8 % on ordinary frames. Power consumption of the furnace in the process of electrodes sintering is 93.6 KW. After 60 min of sintering electrodes had the humidity content 0.16 – 0.19 %, that corresponds to standard value (standard $u_e \leq 0.7$ %), content of humidity on ordinary frames is 0.21 %.

Fig. 2. System of air supply and extraction of sintering furnace

Second charge (Fig. 3 b)

Electrodes are charged on large frames (Fig. 4). Start of the furnace takes place at the temperature in chamber +57 °C. Electrodes passed through thermal tunnel. Thermal processing took place in two steps: drying at the temperature up to 120 °C, duration 50 min and sintering at the temperature 140 °C, duration 50 min. If the air is heated to 120 °C, the heating elements by means of temperature regulator are disconnected. If the furnace is cooled to 115°C, the heating elements are switched on and the air is heated to needed temperature. The electrodes on the frames are placed in two, three rows, that results in non-uniform sintering of electrodes.

Part of electrodes are sintered with high quality (humidity content 0.39 %) and other part contains the excess of humidity of more than 1.5 %. Electrodes on large frames are stuck in "dry shortcake" as they are poorly blown through by drying agent. In the process of sticking longitudinal cracks appear almost along the total length of the electrode. The weight of sintered electrodes on one frame is 6.5 – 7.12 kg. Weight of one charge is approximately 1523 kg. Power consumption of the furnace in the process of electrodes calcinations is 88.8 KW. The weight of large frame is (2.88 kg). After 85 min of sintering the humidity of electrodes was 0.39 %, this corresponds to normative value (standard $u_e \leq 0,7$ %). Proceeding from the research performed it is seen that it is possible to reduce energy consumption decreasing the process of electrodes sintering by 5.6 KW.

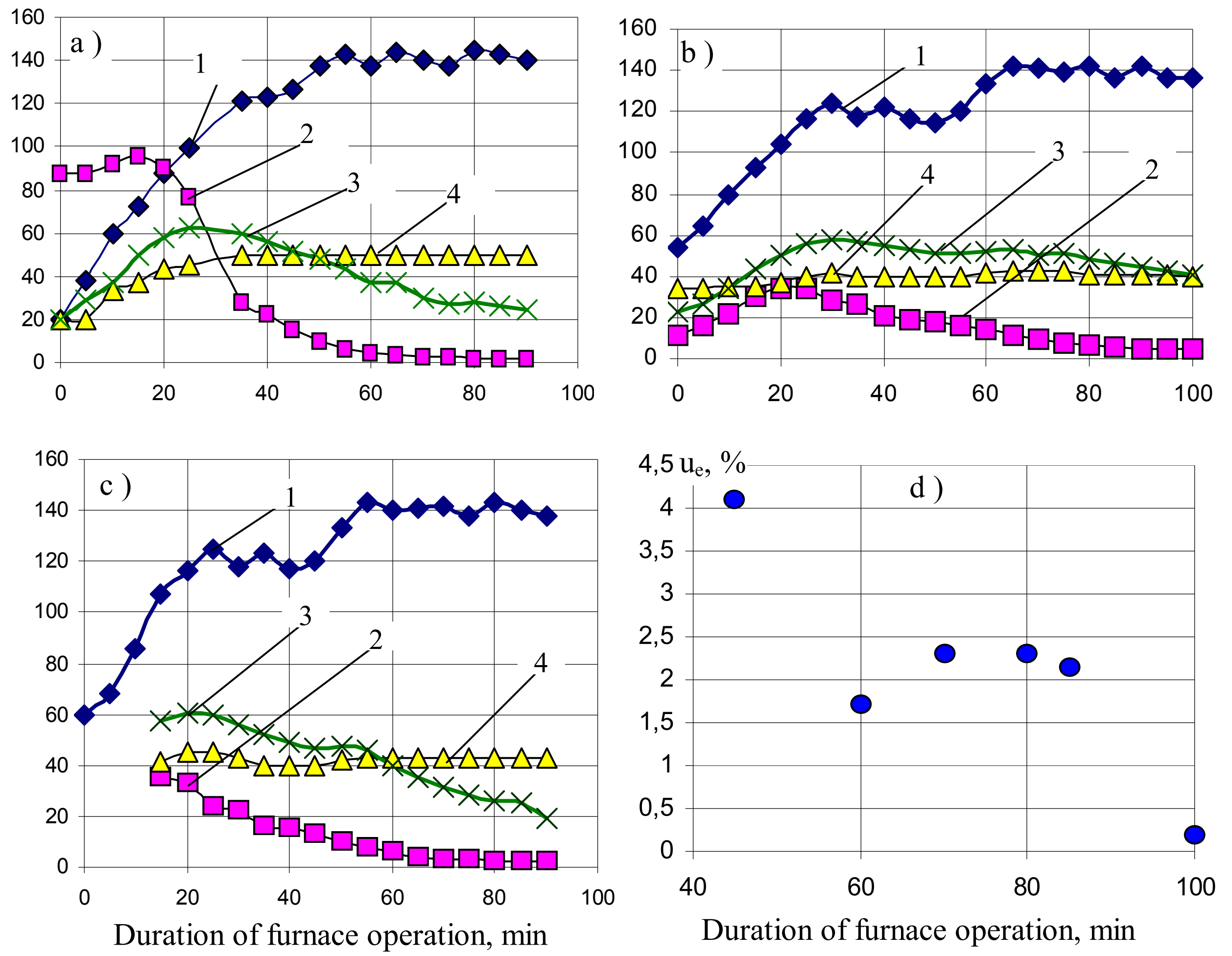


Fig. 3. Results of furnace operation study: a) first charge; b) second charge; c) third charge; d) change of electrodes coating humidity for the second charge.
1 – temperature in the furnace, °C; 2 – relative humidity of air, %; 3 – temperature of the dew point, °C; 4 – air temperature on the air hole, °C

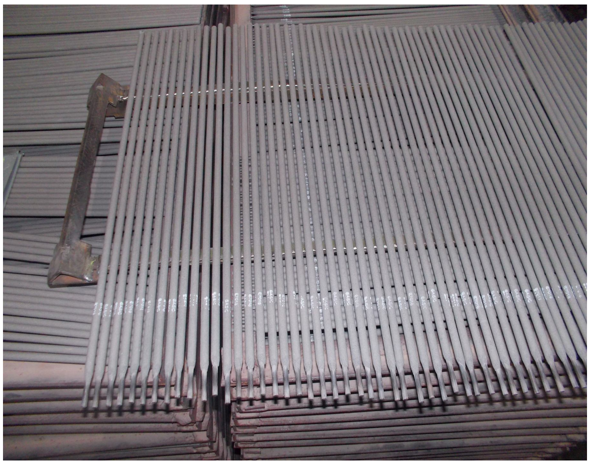
Third charge (Fig. 3 b)

Temperature in the shop is 25 ºC. Electrodes are placed on small frames, weight is 2.25 kg. Electrodes are after thermotunnel. The weight of dry electrodes on one frame is 4.5 – 4.8 kg. Moisture meter is located in the rear wall of the furnace. Electrodes were placed on the frames of two types: lightened and ordinary. The weight of charge is 1040 kg. Electrodes are placed tightly in 1 – 2 rows, on certain frames they are stuck in "dry shortcakes", electrodes are dried non-uniformly. Electrodes on lightened frames are dried faster than on ordinary frames. After 60 min of furnace operation content of humidity of the electrodes is 0.21 % on lightened frames (weight 2.25 kg) and 0.28 % on ordinary frames. Power consumption of the furnace is the process of sintering – 80 KW. After 60 min of sintering the content of the humidity in electrodes was 0.16 – 0.19 % , that corresponds to normative value. As a result of research performed, it is determined, that energy consumption can be reduced as a result of reduction of electrodes sintering process by 11.2 KW.

Analysis of furnace operation (Fig. 3) shows that start of the furnace at temperature 57 °C and 60 °C (for the second and third experiments correspondingly) allows to obtain the temperature of 120 °C in the furnace factor: of 25 min for the second experiment and 22min for the third experiment. As it was stated above, electric heaters are disconnected by means of automatic device. In its turn, this allows to save electric energy. If for the first charge power consumption of the furnace was 93.6 KW, for the second and third charges it was 88.8 and 80 KW correspondingly.

Other indices of furnace operation, shown in Fig. 3, are necessary fore further study of the kinetics of drying process of welding electrodes coating.

a)



b)

Fig. 4. Location of the electrodes on a) ordinary and b)lightened frames

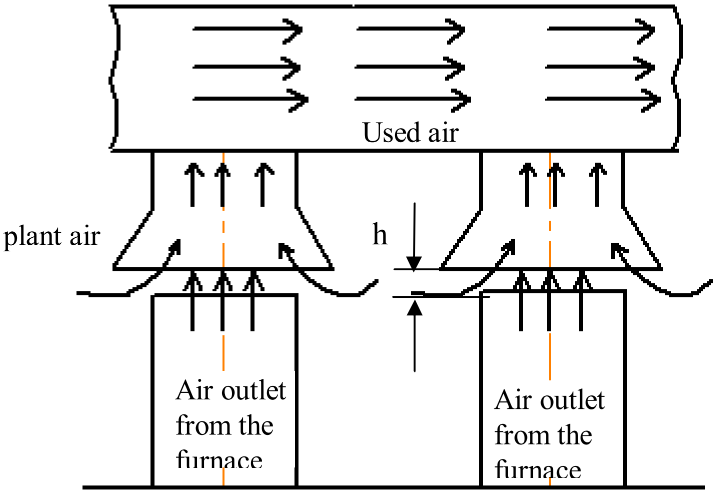


Fig. 5. Scheme of humid air extraction from the furnace

Duration of heat treatment for the second experiment is the longest, as the mass of charged electrodes is almost 1.4 limes greater than for the first and third charges. Sharp change of electrodes coating humidity (Fig. 3 d) at 60^{th} min of furnace operation was observed. At increased temperatures of drying (rigid modes of drying) gas formation reactions can be appear in organic components of coating. The formed gases leave the coating along capillaries, pushing the humidity of macro and micro capillaries. Certain increase of humidity content of the coating while transition to higher temperatures of electrodes coating drying can be explained by this after thirty min of the experiment considerable volume of humid air has been accumulated, the existing system of ventilation (Fig. 5) removed in efficiently. Fans on the line of air supply operated in full power but the doors of the furnace had to be opened to remove humid air. That is why increase of furnace productivity is impossible without reconstruction of exhaust system.

The authors performed aerodynamic calculation of existing exhaust system, recommendations regarding its reconstruction in case of furnace operation on increased capacity are developed. We should note that it is necessary to install additional fan on exhaust system. That will perform the function of humidity regulator of drying agent and will be switched on automatically if considerable volume of humid air is accumulated in working space of the furnace. This, in its turn, requires the refitting of the existing system of automation. Also it is necessary to adjust the height *h* (Fig. 5) for better removal of air.

It should be noted that the design output of the furnace is 150 KW, but only 70 % of the design output is used in the process of heat treatment. That is, much is to be done to improve the performance.

Mass of charged metal pieces (frames and charging cars) is approximately 400 kg. For heating up of such mass of metal 10 – 13.5 KW of electric energy is used. If lightened frames are used, energy can be saved (3.5 – 5 KW/h). Ten furnaces of such type are located at the enterprise, during a day five chargings of electrodes are performed, annual saving of cost may be considerable. Volume of spoilage, as a result of non-uniform drying of electrodes can be reduced. As it is seen from Fig. 4a ordinary frames cover electrodes from both sides and hot air dries them non-uniformly. After removal of certain elements of the frames, their mass reduced and the level of electrodes coating uniformity increased.

As energy losses depend on many factors [3], then the reduction of energy losses is possible only when the most important factors, influencing the volume of energy saving are concentrated.

Conclusions

1. It is necessary to follow design norms of charged electrodes mass.

2. In order to obtain better heat exchange in the furnace it is necessary to install bumper plates, which will direct air flow from the fan directly to electrodes; This will provide better circulation of the air around charging cars with electrodes.

3. To avoid worsening of the quality of electrodes, they should be evenly distributed on the framers (hot in bulk).

4. To reduce heat losses for heating of frames and charging cars (transport facilities) frames of special construction, developed by the authors, should be used, this will allow to save 3 – 5 KW/h of electric energy per one charge. To reduce intervals between charges it is necessary to manufacturer several sets of such frames.

5. In order to save electric energy intervals between charges must be minimal, this reduces losses of heat in the environment.

6. For qualitative and uniform drying of electrodes it is necessary to improve ventilation system of the furnace and additionally install the fan, that will perform the function of regulator of drying agent humidity. It is necessary to install modern automation system on the furnace to provide better control over main production indices.

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