Engineering Guidelines for the recovery of fast wearing parts of process equipment of beet sugar plant by plasma spraying with fusing

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Abstract. The paper considers the possibility of the recovery of fast wearing parts of process equipment of beet sugar plants and provides a brief description of the recovering technology of these parts by plasma spraying with coating fusing. Technological parameters of plasma spraying with fusing of wear-resistant coatings are considered. On the base of the research work the Engineering Guidelines of recovery of fast wearing parts of process equipment of beet sugar plant by plasma spraying with fusing is provided.

1. Introduction
The real strategy of fail-safe control of process equipment of beet sugar plant is the recovery of fast wearing parts. The recovery of these parts is stated as the one of key propriety areas of cost-effective use of resources. For the wide range of parts the cost price of their recovering is equal to 30…70% of the new one. But the service life of the recovering part is higher due to hardening plasma technology usage [1]. The cost reduction is achieved because the recovering part is considered as the blank with necessary shape with some wear on the working surface. The application of the advanced plasma technologies makes the recovering parts quite similar with the new parts. This fact blurs the line between primary and secondary resources and turns them into alternative ones.

2. Materials and methods
The process of the recovery of equipment part is a complex constructive and technological task which characteristics could be changed during its fulfillment. While designing technological process the analysis of technical, economical, ecological and resource saving aspects should be considered. The surface of the part of the equipment of the beet sugar plants is covered with fat films and other impurities. So recovering parts should be thoroughly cleaned. Usually the synthetic detergents and solvents are used for cleaning. After cleaning equipment part should be inspected. The parts with unacceptable defects or wear should be recovered for further using. The material for plasma spraying should be dried and screened before use. Drying should be performed with periodical mixing at the temperature from 100 to 200 °C over the period of 1 or 2 hours immediately prior to powder injector filling. The powder thickness on the sheet pan should not be more than 20 mm thick. Maximum period of time between the drying and spraying is 60 min. After the drying the powder should be put through the sieves type 016 or type 004 made from the square meshed woven wire cloth in accordance with
GOST 6613-86. Remainder left the on the sieve type 004 should be used for plasma spraying. For coating material selection the special software is recommended [2]. Data dialogue system “Barion 1.0” gives the possibility for optimal choosing of wear resistant material. Prepared powder can be stored outdoors at the temperature plus 25°C and relative humidity 70% up to eight hours. If it is necessary to store powder for a longer period of time it should be dried before using in accordance with the above mentioned process.

3. Results
Coating adhesion to the base material and its operational characteristics depend heavily on cleanliness, configuration and roughness of the surface. Mechanical treatment should be performed to make the necessary geometric shape of the detail and to remove wear patterns. Abrasive blasting should be performed to provide the necessary roughness of the detail surface. Such treatment allows to remove the oxide film from the surface. It activates the surface and provides the chemical bonding between the surface and coating particles. It is recommended to use the aluminium oxide grades 13A or 14A with grain size from 30 to 100 microns (GOST 3647-71) or white cast iron shot grades D4K1 or D4K1,5 with grain size from 0.8 to 1.5 microns (GOST 11964-66) as the abrasives for all types of details. Abrasive blasting should be performed in accordance with next working conditions:

- air pressure: from 0.5 to 0.6 MPa;
- abrasive jet impact angle: from 75° to 80°;
- treatment period of one area: not less than 40 seconds;
- distance from the surface to the nozzle: from 35 to 40 mm;
- compressed air flowrate: from 3 to 4 m³·min⁻¹.

After the abrasive blasting the surface should be blown with compressed air to remove small abrasive particles. Compressed air should be free of oil and moisture in accordance with GOST 9.010-73. The prepared surface should be matte and have no shiny areas. It is recommended to use the thermo-abrasive device for the surface preparation before the plasma spray coating application. Nowadays the thermo-abrasive treatment of the metal surface is considered to be the most effective. Formed at the combustion chamber the gas-flame torch heats the abrasive particles to 200…250°C. So moisture and organic compounds are removed from the compressed air and abrasive material. Removal of different surface contaminations is performed under the high temperature and with high energy impact on the surface layer and low oxygen environment [3].

![Figure 1. Large surface abrasive treatment with the thermo-abrasive device before the plasma spraying.](image)

The period between surface treatment and spraying should be as minimal as possible and should not exceed two hours because the surface is active and easily oxidizes. During the storage after abrasive treatment attention should be paid to avoid surface contamination. It is not permitted to touch the detail by hands and recommended to use degreased tools and instruments. Uncovered areas of the
detail located near the spaying zone should be protected by metal screens. The screens should be installed at the distance a bit greater than thickness of coating surface.

Coating should be applied at the special production area with the ambient temperature not less than plus 10°C and humidity not more than 70%.

It is reasonable to use the portable multifunctional plasma unit [4]. Condition of the plasma torch electrode (nozzle, electrode) should be controlled before using. Local wear of jet surface could be not more than 2 mm. Set-up procedure of the portable multifunctional unit should be provided in the following sequence:

- pour prepared powder into the injector dosing device;
- set values for the pressure of gas and cooling liquid and their starting flowrate in accordance with the manual;
- turn on the unit with switched off power supply source, check the correct supply of plasma gas and the oscillator.

Start-up of the portable multifunctional unit is performed in accordance with the procedure shown at the cyclogram (figure 2). Composite powder is spraying.

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**Figure 2.** Cyclogram of operation mode of a plasma multifunctional plasma unit in a mixture of compressed air with hot hydrocarbons from the internal combustion engine: $t_0$ – start of the spraying process, switching on the gas supply system and the free-standing cooling unit; $t_0 + t_1$ – pause for 2...10 seconds (adjustment of gas and coolant flowrates); $t_1 + t_2$ – starting of the operation of the power supply; $t_2$ – switching on the second plasma-forming gas and the powder feeding; $t_2 + t_3$–time of coating; $t_3$ – turning off the powder feeding; $t_3 + t_4$ – pause for 2...5 seconds (cleaning the service lines from powders); $t_4$ – switching off the plasma arc and the supply of the second plasma-forming gas; $t_4 + t_5$ – pause for 2...5 seconds; $t_5$ – switching off the gas supply system and the free-standing cooling unit; $t_5 + t_6$ – period of part replacement.

It is necessary to turn up the plasma torch while setting up the equipment so that the angle between the jet nozzle and the detail surface would be from 60 to 90 degrees. As the unit switched on the spraying process data should be installed.

During the coating process:
- arc current rate: 170 A;
plasma-forming gas flowrate: 2.7 m$^3$ per hour, under the pressure: 0.2 MPa;
- spraying distance: 150 mm.;
- plasma torch speed: 40 cm per minute.

Plasma torch speed relative to the coating surface should be determined in a way that one pass coating thickness should be not more than 200 microns. It is recommended to apply an intermediate layer with the thickness not more than 0.05…0.15 mm in one pass to achieve the hard adhesion between the coating and the detail surface. The necessity of the intermediate layer application should be determined separately for the specific case and depending on the detail recovery specification [5].

Depending on the ratio of the compressed air and hot hydrocarbons from the combustion engine in the plasma-forming mixture plasma spraying of powdered materials is performed in reducing, oxidizing or neutral environment that is determined by the $\alpha$ value calculated by formula (1):

$$\alpha = 0.0827 \times \frac{Q_v}{Q_{gu}}$$

where:
- $Q_v$ – quantity of the compressed air supplied to the mixing unit before the plasma torch, m$^3$ per hour;
- $Q_{gu}$ – quantity of hot hydrocarbons from the combustion engine supplied to the mixing unit before the plasma torch, m$^3$ per hour;
- if $\alpha=1$ (stoichiometric composition), neutral environment;
- if $\alpha>1$ oxidizing environment;
- if $\alpha<1$ reducing environment.

Main coating should be applied layer by layer up to required thickness (figure 3). The thickness of layer to be applied in one pass should not exceed 0.2 mm. Overall temperature of detail during the spraying should not exceed 200°C. In case of specific oxidation tints appeared on the surface spraying should be stopped and detail should be cooled. To prevent the detail overheating the blowing of detail during the spraying with the compressed air in accordance with GOST 17433-80 is allowed. In case of the drop-shaped laps, accidental point-like inclusions (from the plasma torch) forming on the coating the spraying should be stopped. The formed defects with the diameter more than 2 mm should be removed with the sharp knife or scraper.

**Figure 3.** Plasma spraying of wear-resistant coating.

Depending on the surface shape and the detail size the coating application may be performed mechanically or manually. During plasma spraying first one or two passes are performed without the powder injection in order to heat the detail surface up to 70... 200°C. If the surface is preliminary blasted with the thermo-abrasive device this operation is skipped.
To improve adhesion between the coating and the base material and to reduce residual stresses in coatings appeared as a result of the detail heating with plasma jet, the coating fusing with plasma jet without the spraying material supply is used. Applied coating fusing is performed with the same plasma torch (figure 4). After the unit starting at the beginning of the process the fusing modes should be set:

- arc current of plasma torch: 200 A;
- plasma-forming gas flowrate: 2.7 m$^3$/hour at the pressure of 0.2 MPa;
- fusing distance: 40... 50 mm;
- plasma torch speed: 15... 18 cm per minute.

The detail is preliminary heated to the temperature of 300...500°C with plasma jet, and then the plasma torch is stopped on the small area of the coating, which is heated to fusing. The moment of fusing to be detected by shiny mirrored surface appearance, which reflects the plasma jet, after that the plasma torch should be quickly moved to the next area. The coating quality to be controlled visually, there should not be any chips, blisters, peeling, piling and oxidation tints. The presence of cracks should be determined with the ten-power magnifying glass. In case of unsatisfactory coating determination it should be removed by mechanical treatment. The recoating should be performed in accordance with the recommendations mentioned above.

4. Conclusion

As a result of the performed researches the sustainable modes of the plasma spraying with the fusing with the powdered hard alloys were reasoned and determined, which allows to use it for the development of specific technological processes of recovery of worn details of process equipment of the beet sugar plant.

References

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