Surface quality provision of laser welding using plasma cleaning

R R Rakhimov, R R Saubanov, V V Zvezdin, R M Hisamutdinov
Kazan (Volga) Federal University (KFU), Naberezhnye Chelny, Russia

E-mail: rafisih88@mail.ru, saubanov@mail.ru

Abstract. The features of laser welding technology with the help of hard-nose powders on the cutting edge of the mill with plasma cleaning of the mill surface are described here. It is shown that the quality of weld deposition technological process depends on the processing modes, the energy characteristics of the laser technological system (LTS), as well as on the purity of the router bit.

1. Introduction
In modern technologically advanced production laser technologies for surface hardening are becoming more and more popular, since they provide the highest quality of the hardened layer and do not create difficulties in automation and robotization. Compared with traditional technologies of surface thermal hardening of parts and tools, laser hardening technology shows higher technical and economic indicators.

The technological process (TP) of laser thermal hardening (tempering, weld deposition) of the surface layers has a number of advantages compared with traditional heat treatment technologies, by which there is no need to carry out the technological operation of tempering; there are minimal residual deformations and minimum heat supply to the work piece; it is the terrain impact on the hardened surface, which allows you to process locally only the necessary parts of the tool or part [1-3].

However, in spite of all the advantages, the technology of laser heat-hardening of steels has some disadvantages, which impose certain restrictions on its scope. The main disadvantages of laser technology of thermal hardening include the following: the hardened surface must be cleaned; the depth of the hardened surface depends on the thermal characteristics of the steel; there are tempering zones in overlaps of the hardened surface tracks; high cost of laser technology systems [4-7].

The absorption coefficient of laser radiation and the quality of the hardened surface layers obtained depend on the surface finish of the parts. When exposed to the metal surface of the stream of laser radiation is reflected, the remaining part is absorbed. The energy of the absorbed laser radiation is converted into heat, called effective thermal power.

The purpose of the study is to analyze the methods and experiments to improve the quality of TP, using the results of experimental work on the restoration of the router bit from tool steel R18K5F2 with increased resistance. The deterioration of tool edges is a consequence of changes in operating conditions, which is characterized by an increase in cutting and cutting forces at high temperatures.

In order to obtain the specified quality indicators of TP, modern hardening technologies require the provision of parts surface cleanliness at the preparation stage [1, 3-7]. One of the trends in the development of modern blank production in mechanical engineering is the widespread use of
automated plasma technological systems (PTS), as an effective method of surface cleaning with complex automation of TP [1, 2]. Considering this, research is being conducted on the development of PTS with stabilization of operating modes and surface treatment methods by laser radiation, aimed at changing both the surface cleanliness and the microstructure of metals [4].

The relevance of metal surface cleaning is explained by low energy and time costs. Combining the functions of plasma surface cleaning and laser hardening of metals leads to an increase in the efficiency of the TP. To evaluate the results of plasma cleaning, a series of experimental studies on the deposition of BoroTec - Eutalloy® 10009 powder on a worm milling cutter made of steel R18K5F2 was carried out.

2. **Theoretical analysis and experimental studies**

Based on the conducted patent information review on plasma technologies and TP purification, a three-electrode AC plasma torch was developed (Pat. No. 2558713, a device for a pulsed plasma alternating current generator) (Fig. 1). An experimental installation of a PTS based on a three-electrode alternating current plasma torch was developed, which allows cleaning the surface of metals in a short period of time, which leads to an increase in the efficiency of the TP [2-4].

The performance characteristics of parts are largely determined by the state of the surface and its physicochemical properties. Studies on the treatment of the metal surface with a pulsed plasma flow show a change in the purity of the surface layer, which leads to an improvement in the quality indicators of heat-strengthened surfaces [4]. The deviation of the PTS parameters from the optimal values contributes to the intense erosion of both the main electrodes and the nozzle insert, which leads to the destruction of the structural elements of the plasma torch.

Technological characteristics of the plasma cleaning process in pulsed modes depend on the energy parameters of the plasma torch, pulse duration, processing schemes, type of material being processed and other factors [8-9].

The design of a three-electrode plasma torch with alternating current is shown in Figure 1.

![Figure 1. The design of a three-electrode plasma torch with alternating current.](image)

The design (Fig. 1) includes a preliminary gas treatment unit 1 with a screw nozzle of variable section 8, a discharge chamber 2 in which three electrodes 3 are fixed, an auxiliary pulse source of arc start 5, ceramic bushings insulators 6, fittings 7 for supplying cooling water and plasma gas. The electrodes of the plasma torch 3 form a funnel-shaped three-beam shape and are arranged at an angle of 2° to the axis of the plasma torch.

During the development of PTS, studies were conducted to identify the dependence of the quality indicators of cleaning and heat treatment of the surface of parts on the flow of nitrogen in the plasma torch. Figure 2 shows the state of the treated surface after exposure to plasma in a nitrogen atmosphere.
Figure 2. The treated surface area of steel 45 plasma in a nitrogen atmosphere in a pulsed mode.

It can be seen from the figures that plasma flow impact zone differs sharply from contaminated sites, both in appearance and in the chemical composition of the surface layer.

As part of the study, laser deposition of BoroTec - Eutalloy® 10009 powder on R18K5F2 steel was performed using flux of the AN-43 brand. A number of changes in the structure of the metal and phase transformations occurring in the process of heating and subsequent cooling occurring during heat treatment, characterized by the type of thermal cycle, were identified. The initial heating of a certain volume element up to the temperature $T_{c}$, with the subsequent rapid cooling to a temperature below $T_{a}$ is necessary for the process of steel surfacing (according to the Chernov diagram). This process takes place when the melting temperature is reached in the processing zone of the temperature of the powder and metal [1-5]. Restoration of the teeth of the cutter and obtaining other structures takes place while simultaneously deteriorating the surface quality. Figure 2 shows an axial pitch fragment with a leading edge defect.

Figure 4 shows an axial pitch with a LI thermal influence contour. The deposited layer has a thickness of less than 0.1 mm, with a depth of thermal influence of about 0.4 mm. The microhardness at the surface is HV0.05 885 and reaches the value HV0.05 769, at a distance of 0.1 mm from the surface.

The weld overlay consisting of BoroTec - Eutalloy® 10009 powder and flux is clearly visible. The optimum content of alloying elements, silicon and manganese, as well as limiting the content of phosphorus and sulfur in the layer of weld metal is ensured by the use of flux brand AN-43 [1, 10].

Figures 3-4 show axial pitch fragments with a deposited layer. Figure 5 depicts the state of the router bit surface after laser deposition of BoroTec - Eutalloy® 10009 powder without prior plasma cleaning of the surface, and figure 6 shows the rob surface after plasma cleaning.

Figure 3. Axial pitch fragment after surfacing of BoroTec - Eutalloy® 10009 powder without prior plasma surface cleaning.  
Figure 4. Axial pitch fragment after surfacing of BoroTec - Eutalloy® 10009 powder after plasma surface cleaning.
Such gases in the atmosphere as $\text{N}_2$, $\text{O}_2$, $\text{H}_2$, and carbon dioxide, released on oxygen and carbon at high temperatures, which penetrate into the liquid metal during the deposition of a TP laser, are known to degrade the quality and protect the zone affected by the flow of energy from of them. In addition to all this, the presence of contaminated sites on the surface of the material at high temperatures contributes to the release of gases and vapors, which also degrades the quality of laser deposition of TP. Therefore, the use of plasma surface cleaning and the use of neutral gases (argon, helium) as a protective atmosphere in the process of laser deposition give good results.

3. Conclusion

The results of the experiments showed that the physicochemical properties of materials (quality of the surface layer of the material being processed) of the tool, powder and medium of the technological process, the quality of processing and its stability affect the process of laser surfacing of high-strength coatings with increased wear resistance $[8,9]$. The reasons for this are different chemical activity and thermal properties of the surface and powder, leading to different distribution of the thermal field. The specific contribution of the energy source energy and all types of interaction between the medium and the metal characterizes the temperature dependence of the deposition and ascent zones. Therefore, the main task is to develop methods for stabilizing the parameters of the PTS and LTS rows $[8–10]$.

References

[1] Zvezdin V V, Rakhimov R R, Saubanov R R, Israfilov I H, Akhtiamov R F 2017 Management of laser welding based on analysis informative signals IOP Conference Series: Materials Science and Engineering Volume 240, Issue 1 Article number 012073.

[2] Zvezdin V V, Hisamutdinov R M, Rakhimov R R, Israfilov I H, Akhtiamov R F 2017 Method of control position of laser focus during surfacing teeth of cutters IOP Conference Series: Materials Science and Engineering Volume 240, Issue 1 Article number 012072.

[3] Israphilov I H, Israphilov D I, Bashmakov D A, Galiakbarov A T, Samigullin A D 2014 Numerical analysis of temperature distribution in bottom electrode of DC arc furnace in process Contemporary Engineering Sciences Volume 7, Issue 25-28 Pages 1483-1491.

[4] Gabdrakhmanov Az T, Israphilov I H, Galiakbarov A T, Samigullin A D, Gabdrakhmanov ALT 2016 Improving the efficiency of plasma heat treatment of metals Journal of Physics: Conference Series Volume 669, Article number 012014.

[5] Valiev R A, Bochkov V E, Bashkirov Sh Sh, Romanov E S and Chistjakov V A 1991 Mössbauer study of surface layers of high-speed steel after laser treatment Hyperfine Interactions 69(1-4) Pages 589-92.

[6] Khafizov A A, Valiev R I, Shakirov Yu I and Valiev R A 2014 Steel surface modification with plasma spraying electrothermal installation using a liquid electrode Journal of Physics: Conference Series Volume 567, Article number 012026.

[7] Shakirov Y I, Valiev R I, Khafizov A A, Valiev R A and Khakimov R G 2016 Erosion of electrode metal in the electric discharge under the exposure of the electrolyte stream Journal of Physics: Conference Series Volume 669, Article number 012064.

[8] Rakhimov R R, Saubanov R R and Israfilov I H 2017 Analysis of the impact of informative heat treatment parameters on the properties of hardening of the surface layers Journal of Physics: Conference Series Volume 789, Issue 1 Article number 012040.

[9] Saubanov R R, Zvezdin V V, Israfilov I H, Haybullin I I and Rakhimov R R 2014 Synthesis of oxidic powder in nonequilibrium low-temperature plasma with increase of indicators of quality of process Journal of Physics: Conference Series Volume 567, Issue 1 Article number 012034.

[10] Zvezdin V V, Hisamutdinov R M, Rakhimov R R, Israfilov I H, and Saubanov R R 2018 Technology of overlay laser welding of durable powdery into blade edge of miller IOP Conference Series: Materials Science and Engineering Volume 412, Issue 1 Article number 012083.