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INVESTIGATION OF THE SURFACE QUALITY ALLOYING WITH THE ELECTRODES OF CHROMIUM-NICKEL STEEL

Abstract

The paper presents a brief study of electro-discharge mechanical machining with an elastic, discrete electrode. The factors causing the chemical composition and surface roughness of superficial layer have also been taken into consideration. Attention has also been given to the relation between the material of electrode and the superficial layer composition.

The superficial layer obtained by BEDMM consist of several layers. At the top, a molten and resolidified layer, called recast layer, is observed. This layer is usually present because material removal in BEDMM is mainly based on melting process of the workpiece material. In the recast layer in machining condition the mixing and diffusion of the material hot electrode and the workpart can occur.

Keywords: electroerosion, flexible electrode, alloying, superficial layer

1. Introduction

due to the present trend in constructing machines, alloys of special properties are often used. These materials are characterised by mechanical durability and high resistance to abrasion and corrosion. Cutting such materials may prove difficult because most of them are hard to cut. The process is made even more difficult by the fact that parts made of these alloys are of complex shapes. In these circumstances it is advisable to use BEDMM as the surface finishing process.

BEDMM involves gradual removal of the extra material from the surface of the part being machined by electro-erosive, electro-chemical and mechanical processes [10]. Apart from the removal of the material, mass exchange processes between the hot electrode and the machined part take place, being the result of the mixing of the partially melted electrodes and diffusion processes. As a result of those processes the chemical composition and geometrical structure of the superficial layer of the part is formed. Consequently, the resulting layer exhibits new properties [2, 5, 7].

2. Experimental investigations

The investigations aim to explain the phenomena occurring in the process of electrodischarge mechanical machining with the brush electrode as well as to determine the influence of the machining conditions on the surface layer conditions.

The following factors (Fig. 1) influencing the machining results have been examined:

– kinematics parameters (v_0 – rotational speed of the brush electrode, v_f – feed-rate),
– electric parameters (U – voltage, E – impulse energy, τ – impulse time duration),
– material of brush electrodes (tungsten, molybdenum, chromium-nickel steel) and diameter of wires,
– value of the deflection (Δ) of the hot electrode components.

The layer is shaped by the energetic effect of the discharge on the electrodes and the following phenomena are caused by such a discharge:

– superficial melting of the anode and cathode,
– expulsion of the material into the inter-electrode area and its consequent solidification,
– transfer of the melted material from the hot electrode onto the part surface,
– mixing and diffusion of the particles of the transferred material into the workpiece material,
– temperature increase of the surrounding layers,
– very fast cooling of the superficial layer due to

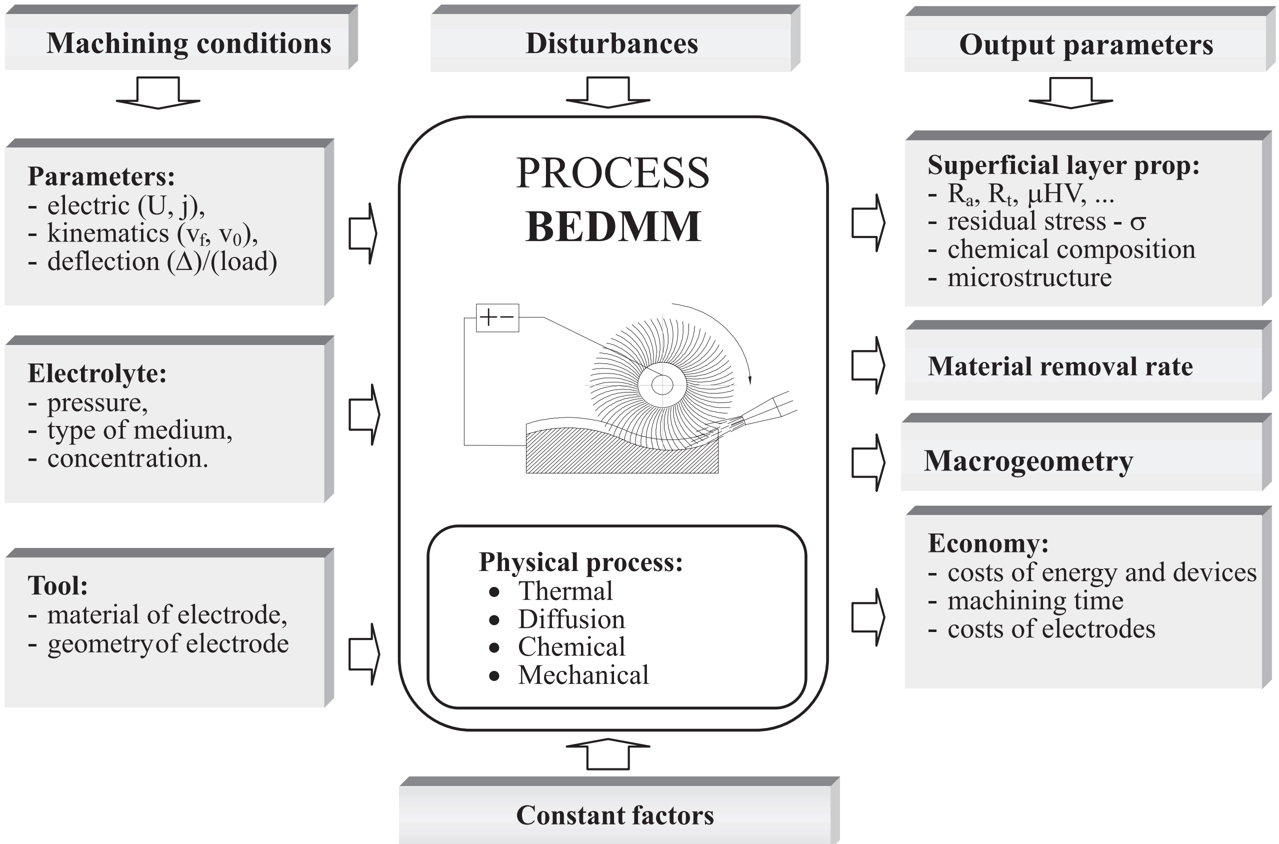

Fig. 1. BEDMM process as a subject investigation

the heat transfer through the part core.

The above factors have influenced the following output parameters:

– productivity
– parameters describing the geometry of the surface layer (R_a, R_t, S_m, D_q, W_a, W_t, W_{sm})
– surface texture
– metallographic structure of the superficial layer
– superficial layer chemical composition
– microhardness distribution in the superficial layer.

In the BEDMM process [2] a rotating metal brush is used as a tool and the process is performed in the presence of a machining fluid, which is water-glass in water solution with composition ratio lower than that used in erosion-mechanical cutting (< 10%). The position of the brush should be properly chosen, as shown in Figure 2a to ensure deflection (Δ) of the tool components big enough to allow mechanical rupture of the anodic layer

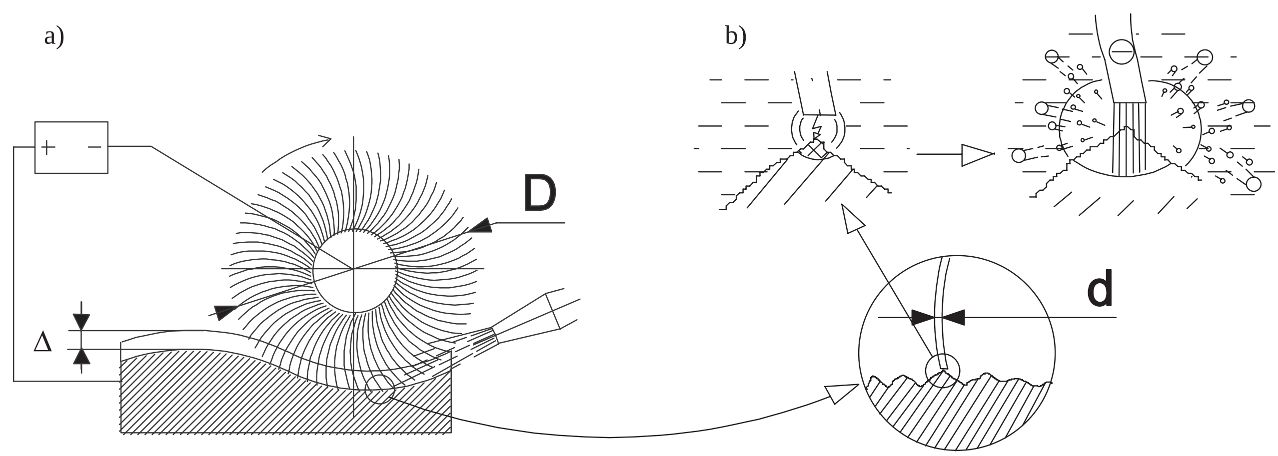

Fig. 2. Electrical discharge occurs in BEDMM process

on the surface of the workpiece and an initiation of an electrical discharge. After the initiation is achieved and the plasma channel is built a rapid local increase in temperature occurs on the peak of roughness which causes melting, evaporation and metal removal. Figure 2b shows the principle of this process. Electrochemical, electro discharge and mechanical phenomena and their interaction can be found in BEDMM.

In electrical discharge machining spark discharges are the main factor influencing the formation of the superficial layer [10, 11]. As a result of single discharges local melting and material evaporation occur, resulting in roughening of the surface in the form of craters. They are determined, but as the craters overlap and are randomly distributed their structure must be random in nature.

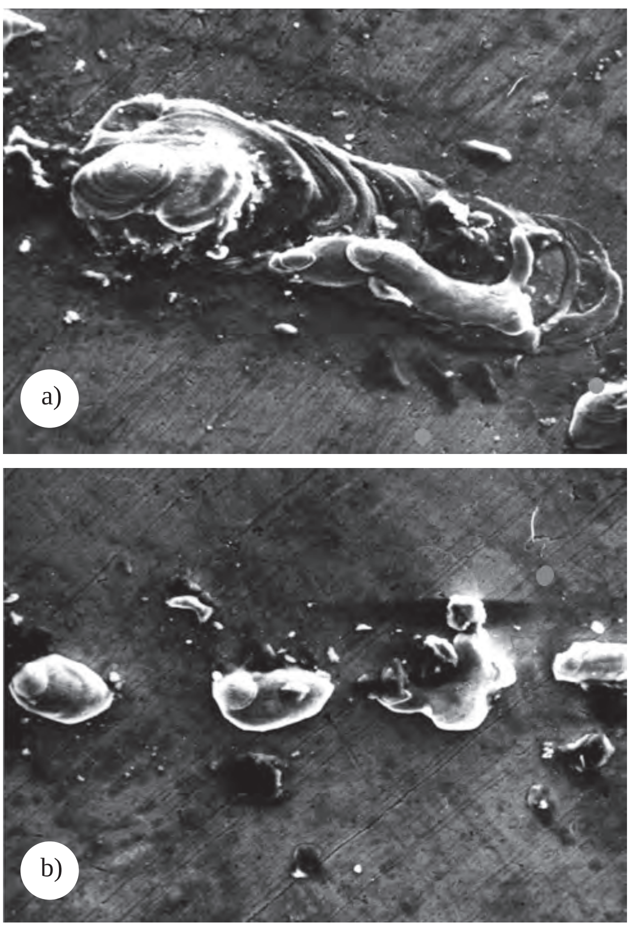

Fig. 3. SEM photograph of the BEDMM machined surface with a visible trace of the discharges, single wire d = 0.185 mm (the diameter of the wire), v_o = 0.7 m/s, a) U = 8 V, magnification 300x, b) U = 4 V, magnification 300x.

With typical parameters of machining the mechanical contact of the brush with the melted metal can cause the liquid metal to spread over the machined surface, as a result of which the peaks of roughness are flattened. An increase in pressure, with low voltage applied, can cause the depassivated layer to be torn off. Eventually, it leads to a direct contact of the electrodes and the fading of the discharges. That, in turn, changes the nature of the process to electromechanical. In these circumstances the main process that forms the geometrical structure of the surface layer is furrowing the surface with each part of the brush.

Detailed examinations of the superficial layer carried out by means of X-ray diffraction microanalysis have shown that apart from the removal of the material from the machined surface, particles of the hot electrode are transferred to the machined part. As a result of these processes a 5–10 μm thick modified layer is created. When molybdenum, tungsten or chromium nickel steel electrodes are used, the concentration level of these elements in the superficial layer increase up to 10%.

Some wires affect the surface by electrical discharges and by the above-described process of mass transfer from the cathode to the anode and thermochemical modification of the superficial layer. Other wires affect the surface in an electromechanical way [1]. The mechanical contact of the wires with the machined surface is accompanied by an electric current without any discharges. This electromechanical influence results in smoothing the roughness peaks created by the electric discharges and in the temperature increase of the machined surface.

The electrical erosion phenomena, which occur during machining with the brush electrode, are accompanied by a mechanical contact of the elastic brush wires, which are pressed against the machined surface and move at high speed. It results in removing the machined part particles, which do not adhere closely to the surface and cause surface smoothing.

The surface texture is random and consists of micro-craters covered by micro-irregularities resulting from the dynamic effects of the melted metals particles transfer, thermocapillary waves, etc. with the distinct summit levelling due to the mechanical effect of the brush elements.

The final effect of the process is shown in Figure 4a. It is a surface machined with voltage applied U = 12 V. The results of the research have been supplemented by the profilogram of a surface machined in the BEDMM process. Its analysis shows that removal of material occurs mainly at the peaks of the roughness.

On closer inspection [5] the profile (Fig. 4b) of the surface appears to be asymmetrical. Two structures

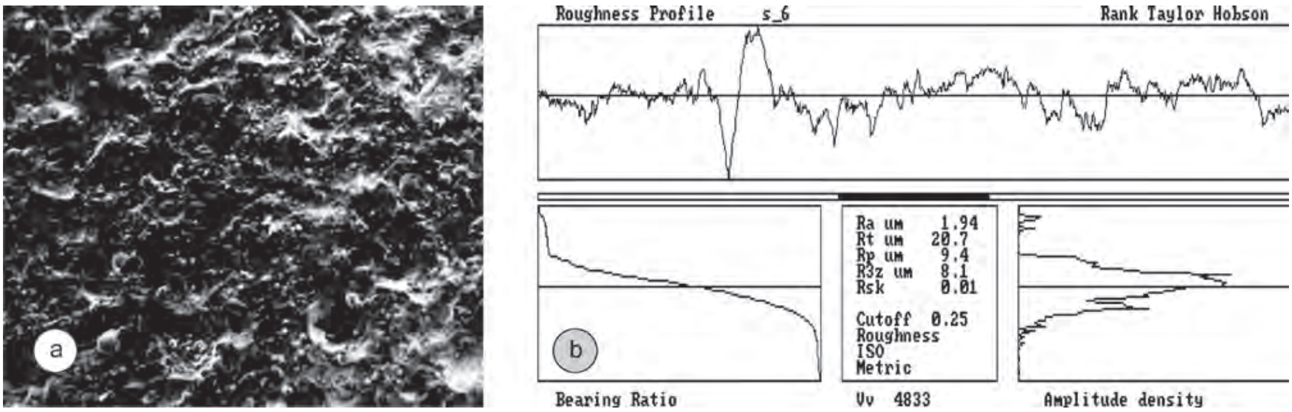

Fig. 4. SEM photograph of a surface: a) and profilogram of a layer, b) after being BEDMM machined, the voltage applied U = 12V, d = 0.3 mm (the diameter of a single wire), v_o = 3.6 m/s (tangential velocity), v_f = 12 mm/min (feed rate)

can be distinguished, the primary one, being the result of spark discharges and seen as craters in the shape of spherical caps, and the secondary one, being the result of mechanical and electrochemical processes, mainly seen at the peaks of roughness. The peaks being flat, the roughness of the layer has an advantageous profile.

The range of roughness produced by the process (Fig. 5) is R_a = 0.5–5 μm, the lower values being comparable to the values produced by grinding.

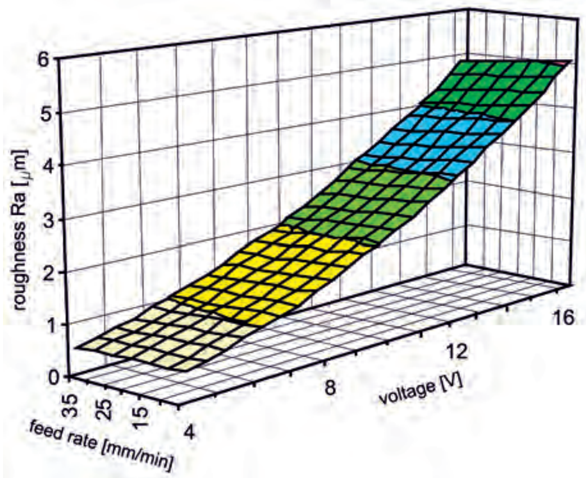

Fig. 5. The effect of the voltage and tangential velocity of the hot electrode on R_a, with chromium cast-iron being the machined alloy, d = 0.3 mm (the diameter of a single wire), deflection Δ = 0.4 m/s, v_f = 12 mm/min (feed rate)

Residual stresses in the superficial layer usually occur as a result of the melting and solidifying of the superficial layer. Examinations carried out using the Philips-Weisman method have demonstrated that the stresses are positive. They occur at a depth of no more than 100 μm. After BEDMM roughening machining (U = 16 V) maximum tensile stress achieved is 1500 MPa. Applying mechanical machining with a rotating brush to a part that has been BEDMM-machined creates compressive (negative) stresses in the superficial layer about 500 *MPa*. Some result of the investigation shows Figure 6.

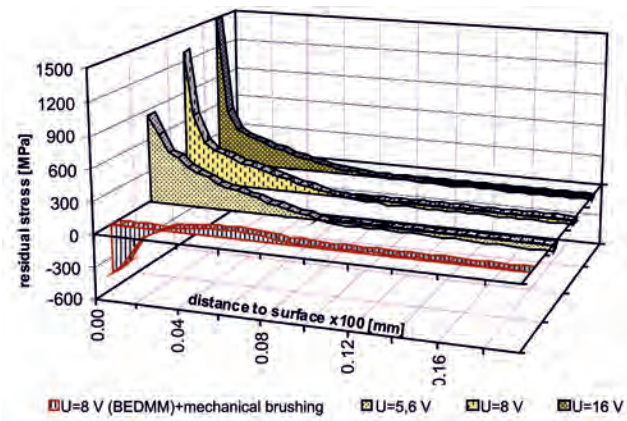

Fig. 6. Residual stresses BEDMM machined workpieces U = 5.6, 8, 16 V, parameters of machining Δ = 1 mm, v_0 = 3.6 m/s, v_f = 12 mm/min, material of workpiece carbon steel (0.45%C)

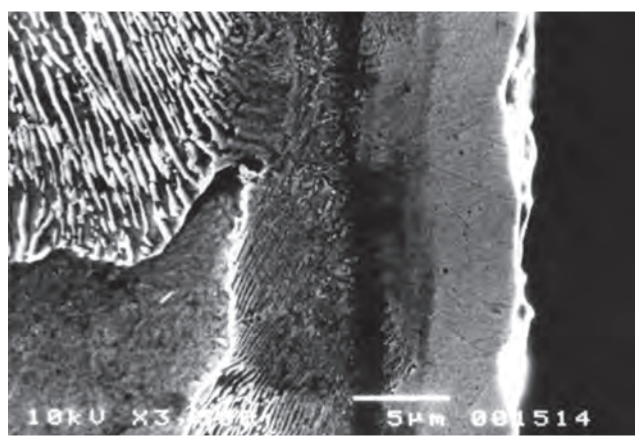

Fig. 7. SEM photographs of the metallographic microstructures of the surface layers after the machining process (U = 8 Vb) using the made of chromium nickel steel (1H18N9) electrode; material of workpiece carbon steel (0.45%C), magnification 3500x

The metallographic structure Figure 7 shows features typical of a surface machined by BEDMM. Superficial layer has a gradient structure with an increase of chromium and nickel content. At the top, a molten and resolidifier layer, called recast layer, is observed. This layer is usually present because material removal in BEDMM is mainly based on melting process of the workpiece material. In the recast layer in BEDMM condition mixing and diffusion of material working electrode and workpart can occur due to temporary, directly contact electrodes. Below the recast layer a heat affected zone is present. This zone comprises the workpart material which has undergone an influence by heat and has not been molten. In the case of steel, usually hardened [3].

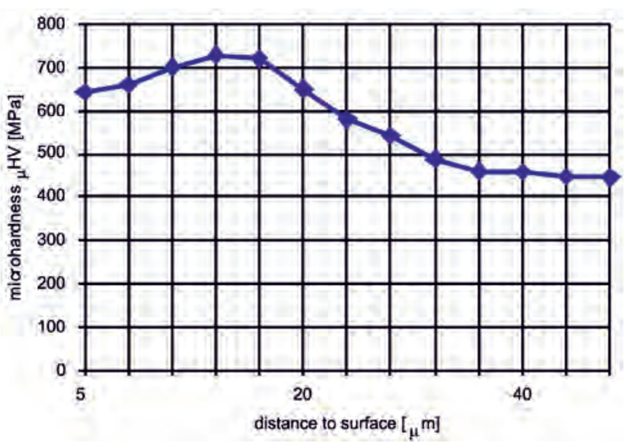

Fig 8. Microhardness distribution in a crossection of the surface layer after the BEDMM process (U = 16 V), hardened steel (NC 10)

Microhardness distribution in a cross – section of the surface layer after the BEDMM process (U = 16 *V*) is shown in Figure 8, material of workpiece – hardened steel (NC 10).

X-ray diffraction pattern obtained from the surface layer after the BEDMM process using a chromium nickel steel electrode shows Figure 9. The chemical composition of the superficial layer after the BEDMM process (U = 8 V, DC current generator) using a chromium nickel steel (1H18N9) obtained by an X–ray diffraction analysis:

a) workpiece – native material (steel 0.45% C) Cr 0.09%, Ni 0.08%
b) superficial layer machined by 1H18N9 – steel electrode Cr 9.91%, Ni 5.25%
c) chemical composition hot electrode (1H18N9 – steel) electrode Cr 18.0%, Ni 9.0%

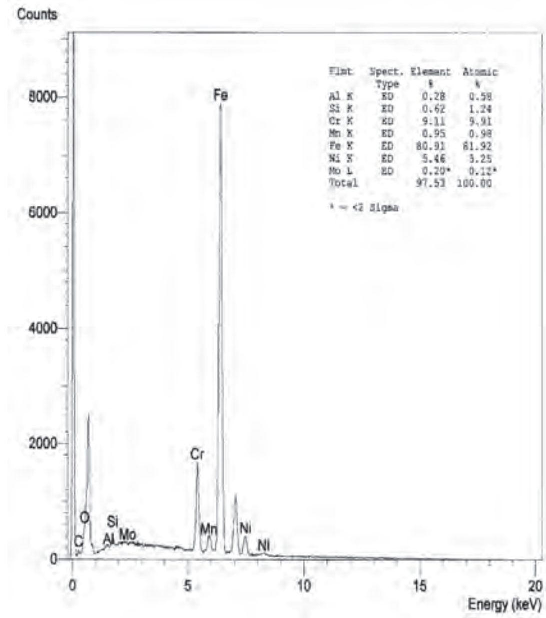

Fig. 9. X–ray diffraction pattern obtained from the surface layer after the BEDMM process using a chromium nickel steel (1H18N9) electrode (U = 8 V)

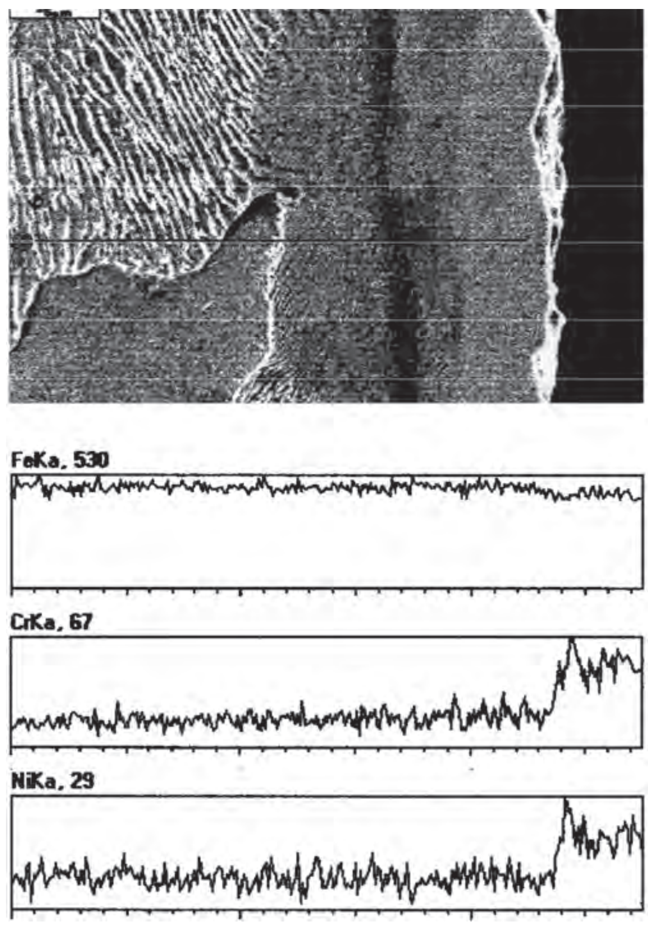

Fig. 10. X-ray line scan of the superficial layer after the BEDMM process (U = 8 V) using a chromium nickel steel (1H18N9) electrode – a (magnification 3500x); chemical elements distribution in the sub-surface layer – b

Figure 10a shows microstructure and line scan of X-ray diffraction microanalysis of the surface layer after the BEDMM process using a chromium nickel steel electrode. Figure 10b shows chemical elements distribution in the superficial layer with an increase of chromium and nickel content.

3. Conclusions

The investigations into electro-discharge machining with rotating brush electrodes have shown that:

– the surface layer subjected to the BEDMM process contains chemical components of the hot electrode (cathode);
– analysis of the molten and resolidified layer shows an increase of chromium (up to 10 %) and nickel (up to 5%) content;
– thickness recast layer achieved about 5 – 10 micrometers;
– the metallographic structure of the superficial layer reveals properties that are typical of electroerosion discharge machining;
– the physical properties of the hot electrode and level of voltage significantly influence the machining process and its results;
– if the process is well controlled higher hardness, higher wear resistance of the superficial layer can be achieved.

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„The work is co-financed from the means of the European Social Fund within the Project „Invention – the key areas of Świętokrzyski region economy supported by young scientists' potential as well as by the knowledge and innovation transfer", with the identification number WND-POKL 08.02.01-26-020/1".

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Badania stanu warstwy wierzchniej stopowanej elektrodami ze stali chromowo-niklowych

1. Wstęp

W budowie maszyn coraz częściej stosuje się różnego rodzaju stopy o specjalnych właściwościach. Materiały te charakteryzują się wyższą wytrzymałością mechaniczną, odpornością na ścieranie oraz odpornością korozyjną. Metody obróbki konwencjonalnej takich materiałów może okazać się trudne, lub nieopłacalne ekonomicznie. W tych okolicznościach, zaleca się stosowanie obróbek niekonwencjonalnych, takich jak obróbka elektroerozyjna, obróbki hybrydowe w tym BEDMM.

BEDMM polega na stopniowym usuwaniu naddatku materiału z powierzchni części obrabianej w wyniku oddziaływań elektroerozyjnych, elektrochemicznych i mechanicznych. Oprócz usuwania materiału, procesowi towarzyszy wymiana masy pomiędzy elektrodą a częścią obrabianej powierzchni. W wyniku tych procesów zmienia się skład warstwy wierzchniej.

2. Badania doświadczalne

Badania mają na celu wyjaśnienie zjawisk zachodzących w trakcie obróbki elektroerozyjno-mechanicznej elektrodą szczotkową, jak również określenie wpływu warunków obróbki na stan warstwy wierzchniej obrabianego przedmiotu.

W procesie BEDMM [2], jako narzędzie stosowana jest obracająca się metalowa szczotka, jako dielektryk zastosowano roztwór szkła wodnego. W procesie obróbki elektroerozyjno-mechanicznej wyładowania elektryczne są głównym czynnikiem wpływającym na modyfikowanie warstwy wierzchniej [10, 11]. W wyniku pojedynczych wyładowań następuje lokalne topnienie i odparowywanie materiału, skutkiem tych oddziaływań są kratery na powierzchni obrabianej, co zostało przedstawione na rysunku 3. W przypadku oddziaływań mechanicznych szczotki następuje redystrybucja ciekłego metalu na powierzchni materiału obrabianego, w wyniku tych oddziaływań wierzchołki chropowatości są wygładzane. Wzrost nacisku elementów elektrody roboczej, przy niskiej wartości napięcia zasilającego może spowodować zerwanie warstwy pasywnej i bezpośredni metaliczny kontakt elektrod.

Szczegółowe badania warstwy wierzchniej wykonanego za wykorzystaniem techniki dyfrakcji rentgenowskiej wykazały, że oprócz usuwania materiału z obrabianej powierzchni, cząstki elektrody roboczej są przekazywane do powierzchni obrabianej. W wyniku tych procesów około powstaje warstwa wierzchnia zmodyfikowana na grubości 5–10 µm.

Część drucików elektrody szczotkowej oddziałuje na powierzchnię obrabianą poprzez wyładowania elektryczne i przenoszenie masy, część natomiast oddziałuje elektromechanicznie [1]. Mechanicznemu kontaktowi drutu z obrabianą powierzchnią towarzyszy przewodzenie prądu bez wyładowania. Wpływa to na wygładzania pików chropowatości powstałych podczas wyładowań elektrycznych, ponadto następuje wzrost temperatury obrabianej powierzchni.

W skutek nacisku elementów elektrody na powierzchnię obrabianą oraz ruchu obrotowego elektrody szczotkowej z dużą prędkością następuje usuwanie cząstek roztopionego materiału z obrabianych części. Opisywany sposób oddziaływań elektrody roboczej powoduje dodatkowe wygładzanie powierzchni.

Efekty finalnego procesu możemy zaobserwować na rysunku 4a, przy napięciu U = 12 V. Podczas bliższego przyjrzenia się profilowi [5] powierzchnia (rys. 4b), wydaje się być asymetryczny. Wyróżnić można tutaj dwie struktury, główną spowodowaną wyładowaniami, drugą będącą wynikiem oddziaływań mechanicznych oraz elektrochemicznych.

Struktura metalograficzna została przedstawiona na rysunku 7 dla powierzchni po typowej obróbce BEDMM.

Skład chemiczny (rys. 9) warstwy wierzchnich po obróbce BEDMM (U = 8 V, generator prądu DC), przy użyciu stali niklowo chromowej (1H18N9) otrzymanego w wyniku mikroanalizy rentgenowskiej:

- przedmiot obrabiany –materiału (stal C45, 0,45% C) Cr 0,09%, 0,08% Ni
- WW obrabiana przez 1H18N9 – elektroda stalowa Cr 9,91%, 5,25% Ni
- skład chemiczny rozgrzanej elektrody (1H18N9 – stal) elektroda Cr 18,0%, 9,0% Ni

3. Wnioski

Badania obróbki elektroerozyjnej z zastosowaniem obrotowych szczotek, pokazują, że:

- warstwa powierzchni poddana procesowi obróbki BEDMM zawiera składniki chemiczne elektrody (katoda);
- analiza roztopionej i zakrzepłej warstwy wykazuje wzrost chromu do 10% i nikielu do 5%;
- grubość zmodyfikowanej warstwy może osiągnąć około 5–0 mikrometrów;
- struktura metalograficzna warstwy wierzchniej posiada właściwości, które są typowe dla obróbki elektroerozyjnej;
- właściwości fizyczne elektrody roboczej i poziom napięcia znacząco wpływa na proces obróbki i jego wyniki;
- właściwy dobór warunków procesu stopowania umożliwia osiągnięcie wyższej twardości oraz większej odporność na ścieranie zmodyfikowanej warstwy wierzchniej.

„Praca współfinansowana ze środków Europejskiego Funduszu Społecznego w ramach Projektu „INWENCJA – Potencjał młodych naukowców oraz transfer wiedzy i innowacji wsparciem dla kluczowych dziedzin świętokrzyskiej gospodarki” o numerze identyfikacyjnym WND-POKL 08.02.01-26-020/1”.