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Prognosis of effects of remelting performed by means of plasma arc

A. Dudek [a,]*, Z. Nitkiewicz [b]
[a,b] Institute of Materials Engineering, Częstochowa University of Technology
*Corresponding author. E-mail address: dudek@mim.pcz.czest.pl

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Abstract
Selection of remelting parameter is performed mainly by trial and error method, which is time-consuming and expensive. The performed investigations are aimed to create the method for fast prognosis of remelting effects and their purpose was to propose a research method for diagnostics and determination of temperature and shape of plasma arc used for surface treatment of 40Cr4 steel with TiO_2 coating. The diagnostics was performed by means of the high-resolution visible light and thermovision camera.

Keywords: Heat Treatment, Remelting, Arc Plasma, Diagnostics

1. Introduction

The requirements imposed on materials by modern, ever-developing technology can be met due to e.g. application of surface treatment which enables formation of surface layer [1÷20].

The values for the parameters (arc power, current, power voltage, chemical composition, gas pressure, feed rate, nozzle diameter, distance to the surface of the processed part), depending on the source, depends on the physical and chemical properties of the remelted material.

Selections of the abovementioned parameters is often made on the basis of trial and error method which is usually time-consuming and expensive. Therefore, in-depth analysis of e.g. parameters which characterize the source will be very useful in creation of the method which would enable fast prognosis of the parameters of used source with effects of remelting. This will enable wide application of the technology.

One of the most important parameters which determine plasma arc is a temperature which has direct influence on all remaining parameters of the process, which is proved by numerous papers [1, 9÷13].

2. Methodology and description of the investigations

Steel (for toughening and surface treatment -40Cr4) with ceramic 100 and 200 μm coating of TiO_2 (performed by means of plasma spraying) was used for investigations.

The surfaces of the samples were remelted by means of arc plasma using the following current and voltage parameters: remelting current of 10-140 A, source feed rate 220-580 mm/min, blowpipe distance from the sample surface 3 mm. Fig. 1 presents the picture of arc column.

The obtained layers were subjected to microstructure tests in order to optimize and separate current and voltage parameters which were analyzed later. The obtained picture of the zones which appeared after the process of remelting is presented in the Fig. 2.

Knowing that the electrical energy in the arc is transformed into the heat, the arc power and the amount of the heat were calculated and expressed as energy input per unit fusion length. The results are presented in the Fig. 3.

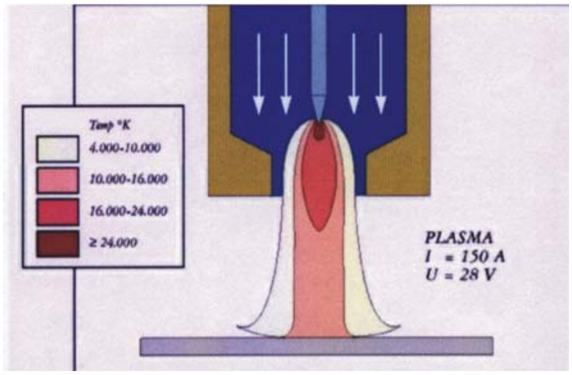

Fig.1. Arc with the temperature fields

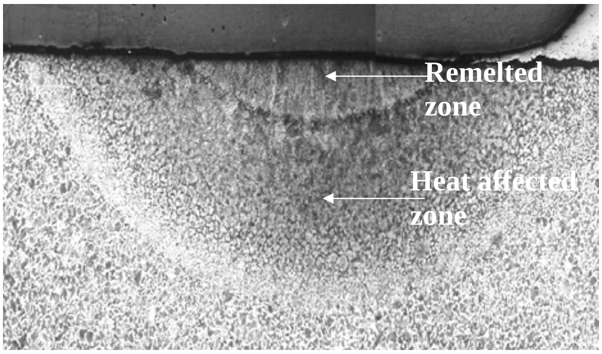

Fig.2. Picture of the zones created in material as a result of remelting of the surface.

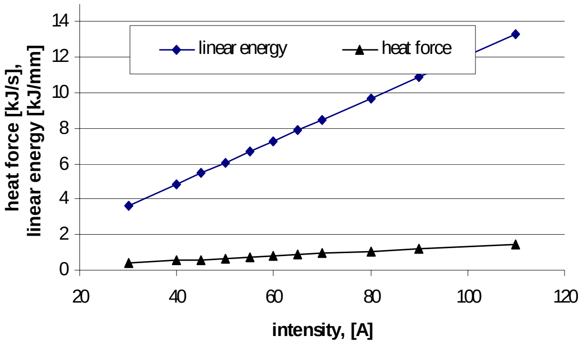

Fig.3. Change in heat force and linear energy depending on the applied current intensity

Thermovision camera Therma Cam P65 has some temperature range which is insufficient for measuring the plasma arc. The picture of the arc obtained during the experiments using thermovision camera is presented with the fig. 4. The central part of arc column, which is over the range of the camera, is visible as a bright area, which is a 70% of the whole volume of the arc column.

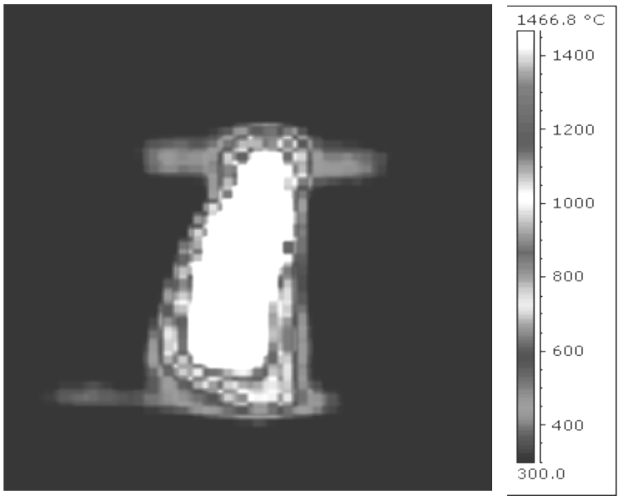

Fig.4. Picture of the arc received from thermovision camera

While making the measurements of the temperature along two perpendicular lines which cross the arc, the temperature distribution along these directions were obtained. The results are presented in the Fig. 5. Two geometrical values of the arc have been marked on the chart – its length (a) and width (b). These measurements were used for further correlations.

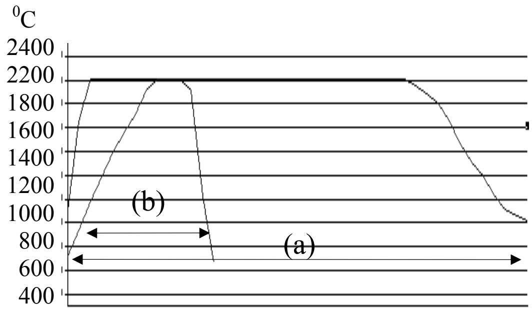

Fig.5. Temperature distribution in two perpendicular directions of the arc [14]

During next step of the investigations the measurements of width of the arc which was created for some current and voltage parameters. The obtained results were correlated with the width of structural changes which occurred on the surface of remelted sample. The results are presented in the Fig. 6. As results from the analysis performed for the obtained chart, the width of the material of the melted 'tear shape' corresponds to the arc width.

While trying to create a method of fast prognosis of remelting effects and considering the data from previous investigations, the surface area of the zones which are created in material as a result of remelting with arc plasma were calculated and approximated by means of ellipse equation.

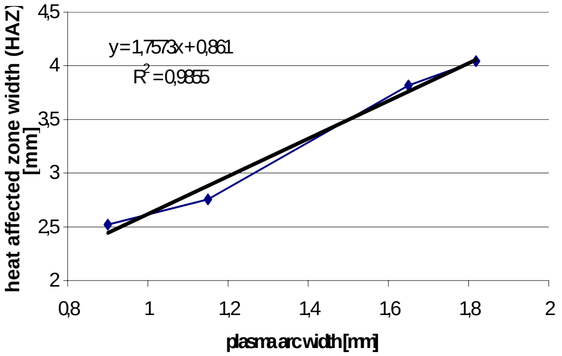

Fig.6. The width of the plasma arc as a function of the heat-affected zone width

Surface area of the zones can be calculated from the dependence:

$$P = \int_{-\frac{s}{2}}^{\frac{s}{h}} \left[\frac{h}{s} \left[(s)^2 - 4x^2 \right]^{0,5} \right] dx \qquad (1)$$

where:
s – width of heat-affected zone
h – depth of heat-affected zone

The experimental results and analytical results, obtained after application of the equation (1) is presented in the Fig. 7.

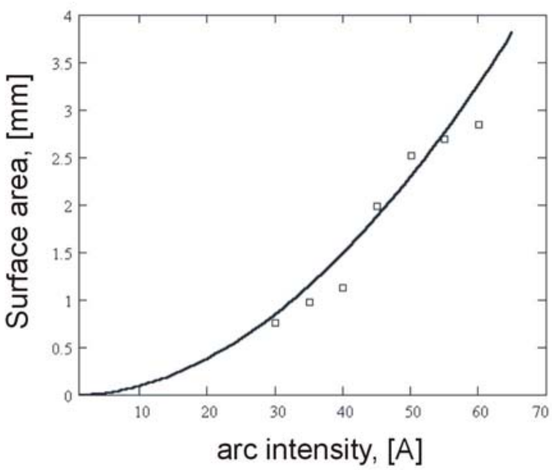

Fig.7. Changes in surface area of SWC -h – as a function of plasma arc current

4. Results

Remelting of plasma arc sample surfaces has resulted in obtaining wide modification of the surface layer, depending on used current and voltage parameters.

Thermovision camera application enabled determination of geometrical parameters of the plasma arc including its width.

Comparison of geometric dimensions of heat source and structural changes which occurred on the surface of the remelted samples enabled to assume that the width of plasma arc corresponds to (Fig. 6) the width of heat-affected zone in the processed material.

As a result of analytical tests several data which describe the geometry of plasma arc and the zones created in the melted material have been obtained.

The mathematical description presented in the paper enables prognosis of effects of melting for the material taking only planned parameters of plasma arc into consideration.

References

[1] J.H.Lee, S.J.Na, An analysis of volumetric radiation heat flux and experimental comparison with arc light sensing in GTA welding process, Journal of Materials Processing Technology, 110, (2001) 104-110.

[2] A.Grabowski, B.Formanek, M. Sozańska, M.Nowak, Laser remelting of Al.-Fe-TiO_3 composite powder incorporated in a aluminium matrix, Journal of Achievements in Materials and Manufacturing Engineering, 18, (2006), 95-98.

[3] W.Serbiński, B.Majkowska, Microstructure and corrosion properties of the laser treated superston alloy, Journal of Achievements in Materials and Manufacturing Engineering, 18, (2006), 415-418.

[4] A.Zieliński, M.Jażdzewska, A.Narożniak, W Serwiński, Surface structure and properties of Ti6Al4V alloy laser melted at cryogenic conditions, Journal of Achievements in Materials and Manufacturing Engineering, 18, (2006), 423-426.

[5] L.A.Dobrzański, E. Jonda, A. Polok, Effect of laser treatment on changes of the surface layers properties of the hot work alloy tool steels, Journal of Achievements in Materials and Manufacturing Engineering, 18, (2005), 42-46.

[6] A.M.Camacho, M.Marin, L.Sevilla, R.Domingo, Influence of strain hardening on forces and contact pressure distributions in forging processes, Journal of Achievements in Materials and Manufacturing Engineering, 15, (2006), 166-174.

[7] R.Filip, Alloying of surface layer of the Ti-6al.-4V titanium alloy throuhg the laser treatment, Journal of Achievements in Materials and Manufacturing Engineering, 15, (2006), 174-180.

[8] M.H.Majzoobi, A.Ghomi, Optimisation of autofrettage in thick-walled cylinders, Journal of Achievements in Materials and Manufacturing Engineering, 16, 132-144, 2006.

[9] M.Węglowski, The determine of the arc themperature in GTA and GMA method, Wyznaczanie temperatury łuku spawalniczego metody GTA i GMA, Biuletyn Instytutu Spawalnictwa, 4, 51-59, 2004.

[10] Nitkiewicz Z.,: Wykorzystanie łukowych źródeł plazmy w inżynierii powierzchni. Wyd. PCz, Częstochowa, 2001.

[11] Dudek A., Nitkiewicz Z., Stokłosa H.: Analiza kształtu łuku podczas procesu przetapiania. Inżynieria Materiałowa. 5, 2005.

[12] Burakowski T., Wierchoń T. Inżynieria powierzchni metali. WNT, Warszawa, 1995.

[13] Dudek A., Nitkiewicz Z.: The structure properties of surface layers wich was obtained by alloying process, Acta Metallurgia Slovaca, 8, 2002, s. 339-343.

[14] Dudek A., Nitkiewicz Z.: Diagnostics of plasma arc during the process of remelting of surface layer in 40Cr4 steel, Achievements in Mechanical and Materials Engineering, (2007) (in press).

[15] Wendler B.: Wytwarzanie pojedynczych i kompozytowych warstw węglikowych, węglikoazotków i azotków tytanu na podłożach stalowych metodą pośrednią. Obróbka Powierzchniowa, Częstochowa, s. 149-153, 1992.

[16] Smolik J., Miernik K., Walkowicz J., Bujak J.: Eksploatacyjne własności powłok TiN, TiC i Ti(C,N). Obróbka powierzchniowa, Częstochowa, s.149-153, 1992

[17] Singh Sidhu B., Puri D., Prakash S.: Mechanical and metallurgical properties of plasma sprayed and laser remelted Ni–20Cr and Stellite-6 coatings. Journal of Materials Processing Technology 159, 2005.

[18] Orłowicz A., Trytek A.: Susceptibility of iron castings to heat absorption from electric arc and to hardened-layer shaping. Metallurgical and Materials Transactions A, t. 34A, z. December, s. 2973-2984, 2003.

[19] Orłowicz A., Trytek A.: Structural and operating aspects of rapid solidification of surface layer of spheroidal graphite iron castings. International Journal of cast metals research, t.16, z.5, s.496-504, 2003

[20] Orłowicz A., Mróz M.: Structure and operational characteristics of castings of LM25 with surface layer refined by rapid solidification. International Journal of cast metals research, t.15, s.85-92, 2002