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Analysis of the heat affected zone in plasma jet cutting process of the aluminium alloy EN AW 5083

ABSTRACT

Plasma jet cutting process is a well-known nonconventional thermo-electrical manufacturing process that is widely used in metal and shipbuilding industry. It uses the energy of highly ionized gas to cut various types of metal materials. Cutting process is determined by technological parameters whose values define the final cut quality results. Cut quality can be defined considering different characteristics such as: kerf width, bevel angle, surface roughness, dross height and heat affected zone. In this paper, a research on the influence of variable process parameters on the heat affected zone (HAZ) was conducted. An investigated material was aluminium alloy EN AW 5083. HAZ analysis was done by measuring hardness changes on the specimen cross sections and by microscopic observation of the material structure.

Keywords: *plasma jet cutting, heat affected zone, aluminium, EN AW 5083, hardness, material structure.*

1. INTRODUCTION

Plasma jet cutting process alongside laser cutting process is the most common non-conventional thermo-electrical manufacturing procedure today. In this process, the injection of the gas into electrical arc creates a high intensity plasma jet that has sufficient amount of energy to melt the workpiece and to blow the molten metal away from the cut. This process can be used to cut various types of materials such as mild steels, stainless steels, aluminium alloys, copper alloys, titanium alloys etc., at various thicknesses [1]. The main advantages that position this technology in front of laser cutting process are lower investments, long consumables life, lower production costs per part and high productivity [2]. Beside the production costs, the main objective of this cutting process is to obtain the best possible final cut quality. According to that, many authors have investigated the influence of the process parameters on the cut quality characteristics aiming to find an optimal cutting area [3-10].

One of the most important cut quality characteristics is the heat affected zone. It can be defined as a part of material where the structure changes can be expected because of the heat input during the plasma jet cutting process. In this paper, an investigation of the influence of process parameters such as cutting speed and arc current on the heat affected zone was conducted. The heat affected zone was analysed by hardness measurements on the specimen cross sections. Metallographic analysis of the material structure was done as well. The material used for experimental work was aluminium alloy EN AW 5083.

2. EXPERIMENTAL WORK

In this paper, the heat affected zone was analyzed. The analysis was conducted on samples (cuts) of 3 mm thick sheet, cut with different process factor values (Table1).

For heat affected zone determination purposes, micro-hardness testing of the samples cross-section was done, as well as the microstructure analysis. The complete analysis was conducted at the Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, University of Split.

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Table 1. Samples for heat affected zone analysis

Tablica 1. Uzorci za analizu zone utjecaja topline

No. of specimen	Cutting speed, v (mm/min)	Arc current, I (A)	Cutting height, H (mm)
1	2000	45	1
2	2000	65	1
3	2000	85	1
4	4000	45	1
5	4000	65	1
6	4000	85	1
7	6000	45	1
8	6000	65	1
9	6000	85	1

Figure 1. OPTON Axioskop optical microscope
Slika 1. OPTON Axioskop optički mikroskop

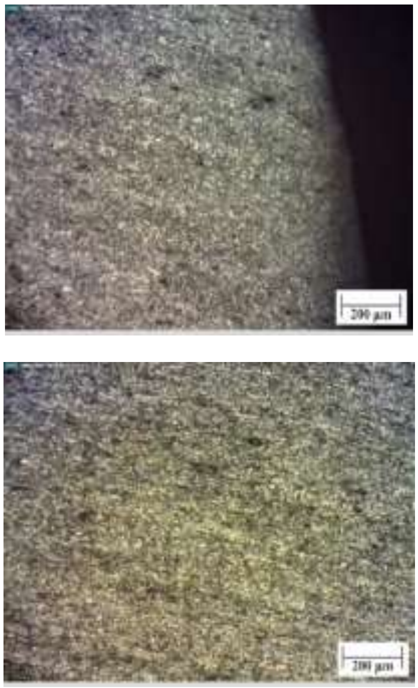
Testing samples were taken from the sheet parts that were cut by plasma jet process at certain values of the input factors. The process of gathering samples was conducted by cutting process, with the use of appropriate cooling agent. The samples were then grinded by the use of abrasive paper sheets with different granulation, and polished. For metallographic analysis, samples were etched with etching agent ordinarily used for microstructure development purposes of the aluminium alloys. It consisted of 0,5 mL of 40% HF (Hydrofluoric Acid) dissolved in 100 mL of water, at room temperature.

The metallographic analysis was done on optical microscope OPTON Axioskop with connected DinoEye digital camera (Figure 1).

3. RESULTS AND DISCUSSION

The metallographic analysis results for chosen samples are presented on Figures 2 and 3.

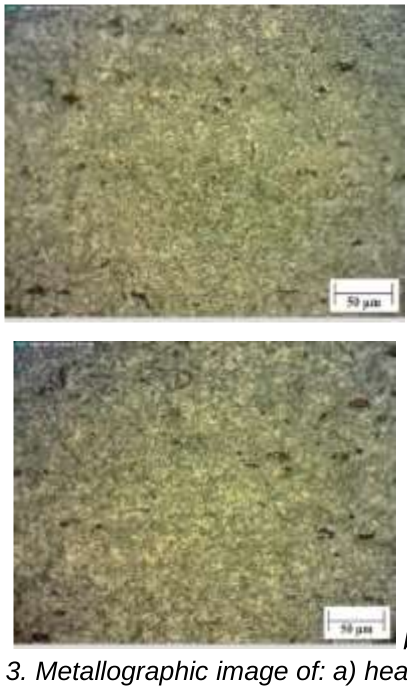
Hardness testing was carried out on micro-hardness tester Shimadzu HMV-2T (Figure 4), with testing load of 9.8 N (HV1), in distances of 0.3 mm from the cutting edge towards center of the samples. For each of the gained hardness values, 3 measurements were done (Figure 5).



a) b)

Figure 2. Metallographic image of: a) heat affected zone and b) base material for the sample No. 9

Slika 2. Metalografske slike: a) zone utjecaja topline i b) osnovnog materijala za uzorak br. 9



a) b)

Figure 3. Metallographic image of: a) heat affected zone and b) base material for the sample No.6

Slika 3. Metalografske slika: a) zone utjecaja topline i b) osnovnog materijala za uzorak br. 6

The average values of measured hardness are given in Table 2. Based on obtained results, the histogram diagrams of micro-hardness values change dependency on distance of the cutting edge (Figure 6.1. - 6.9) and different cutting process input parameters (Figure 6.1. - 6.9, 7 and 8), are presented.

Figure 4. Micro hardness tester Shimadzu HMV-2T

Slika 4. Mikrotvrdomjer Shimadzu HMV-2T

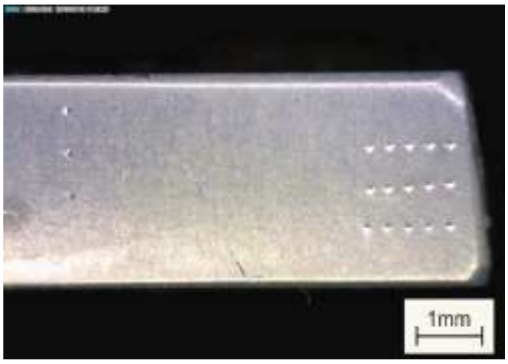


Figure 5. Micro-hardness testing positions

Slika 5. Pozicije mjerenja mikrotvrdoće

The difference between maximum measured hardness at 0.3 mm distance from the cutting edge and the hardness measured at the center of the sample is also shown on Figures 6.1. - 6.9.

Table 2. Micro hardness testing results on various distances from the cutting edge

Tablica 2. Rezultati mjerenja mikrotvrdoće na različitim udaljenostima od ruba reza

Specimen No.	Distance from the cutting edge, (mm)					
	0.3	0.6	0.9	1.2	1.5	Center of specimen cross section
	Hardness HV1					
1	80.1	79.9	79.7	79.7	79.5	79.5
2	83.0	81.0	80.9	80.6	80.2	80.2
3	87.5	84.9	81.2	79.6	77.6	77.5
4	79.5	78.4	78.0	77.5	77.3	77.3
5	82.1	81.4	81.0	80.1	80.0	80.0
6	87.8	83.3	80.7	80.6	78.1	78.0
7	81.5	80.7	80.5	79.8	78.9	78.4
8	81.9	80.3	79.1	78.0	77.7	77.7
9	83.8	81.7	80.4	79.8	79.5	79.4

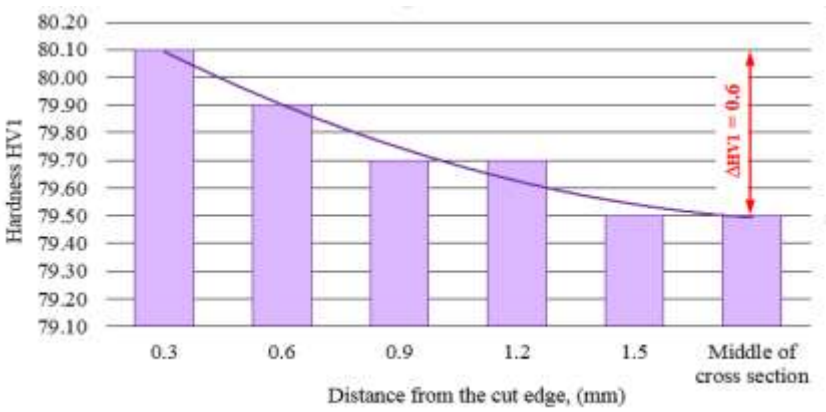


Figure 6.1. Diagram of micro-hardness value change dependency on the increase of distance from cutting edge - sample No. 1

Slika 6.1. Dijagram promjene mikrotvrdoće u ovisnosti o povećanju udaljenosti od ruba reza – uzorak br. 1

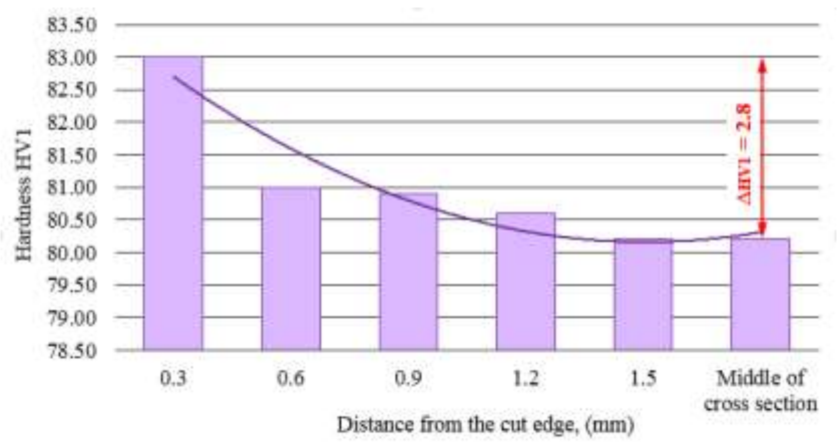


Figure 6.2. Diagram of micro-hardness value change dependency on the increase of distance from cutting edge - sample No. 2

Slika 6.2. Dijagram promjene mikrotvrdoće u ovisnosti o povećanju udaljenosti od ruba reza – uzorak br. 2

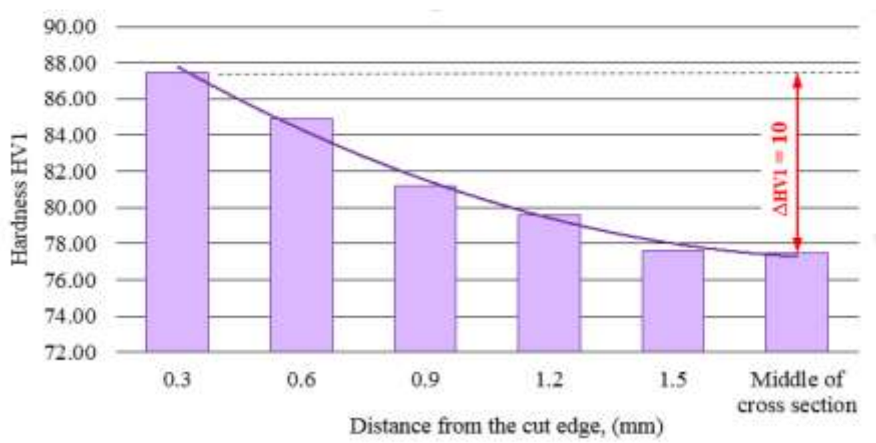


Figure 6.3. Diagram of micro-hardness value change dependency on the increase of distance from cutting edge - sample No. 3

Slika 6.3. Dijagram promjene mikrotvrdoće u ovisnosti o povećanju udaljenosti od ruba reza – uzorak br. 3

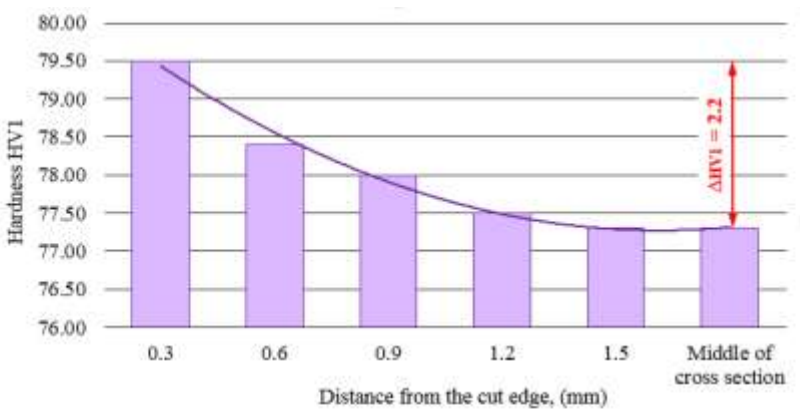


Figure 6.4. Diagram of micro-hardness value change dependency on the increase of distance from cutting edge - sample No. 4

Slika 6.4. Dijagram promjene mikrotvrdoće u ovisnosti o povećanju udaljenosti od ruba reza – uzorak br. 4

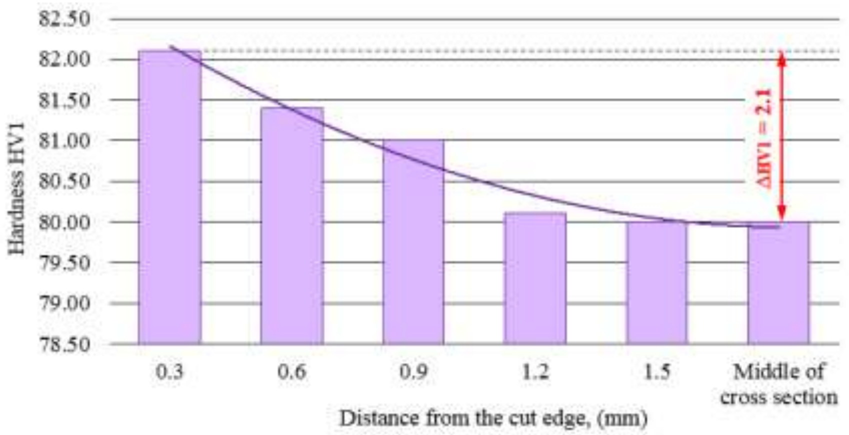


Figure 6.5. Diagram of micro-hardness value change dependency on the increase of distance from cutting edge - sample No. 5

Slika 6.5. Dijagram promjene mikrotvrdoće u ovisnosti o povećanju udaljenosti od ruba reza – uzorak br. 5

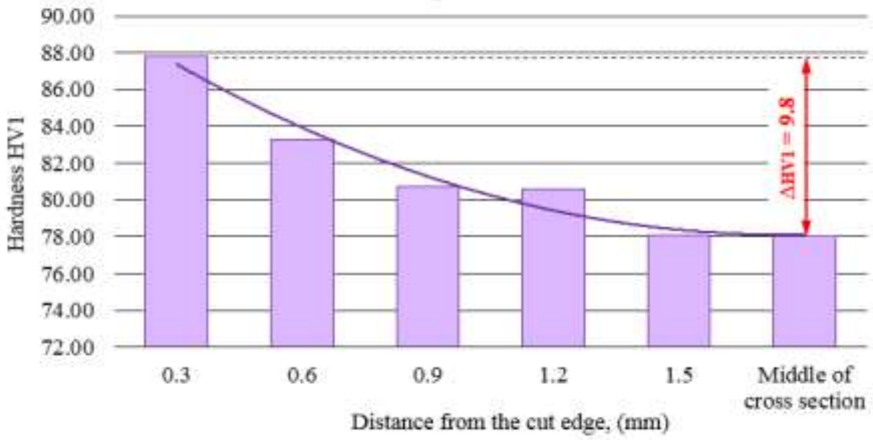


Figure 6.6. Diagram of micro-hardness value change dependency on the increase of distance from cutting edge - sample No. 6

Slika 6.6. Dijagram promjene mikrotvrdoće u ovisnosti o povećanju udaljenosti od ruba reza – uzorak br. 6

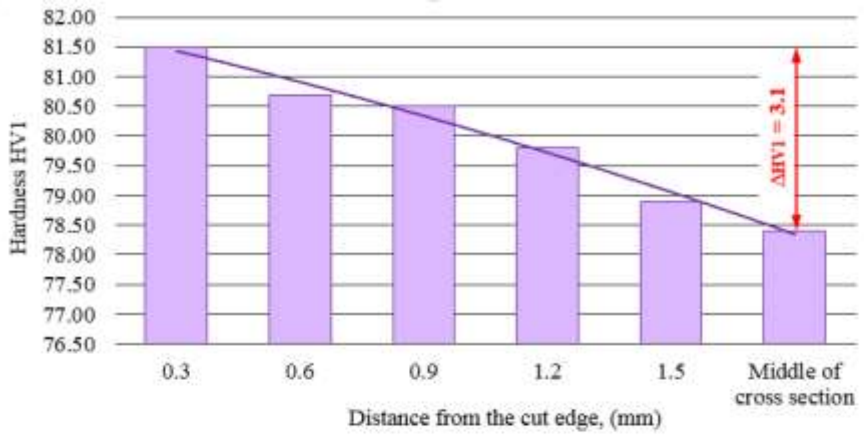


Figure 6.7. Diagram of micro-hardness value change dependency on the increase of distance from cutting edge - sample No. 7

Slika 6.7. Dijagram promjene mikrotvrdoće u ovisnosti o povećanju udaljenosti od ruba reza – uzorak br. 7

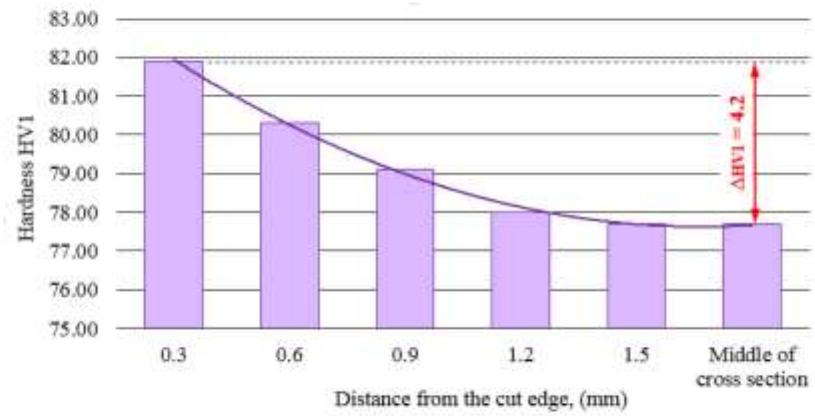


Figure 6.8. Diagram of micro-hardness value change dependency on the increase of distance from cutting edge - sample No. 8

Slika 6.8. Dijagram promjene mikrotvrdoće u ovisnosti o povećanju udaljenosti od ruba reza – uzorak br. 8

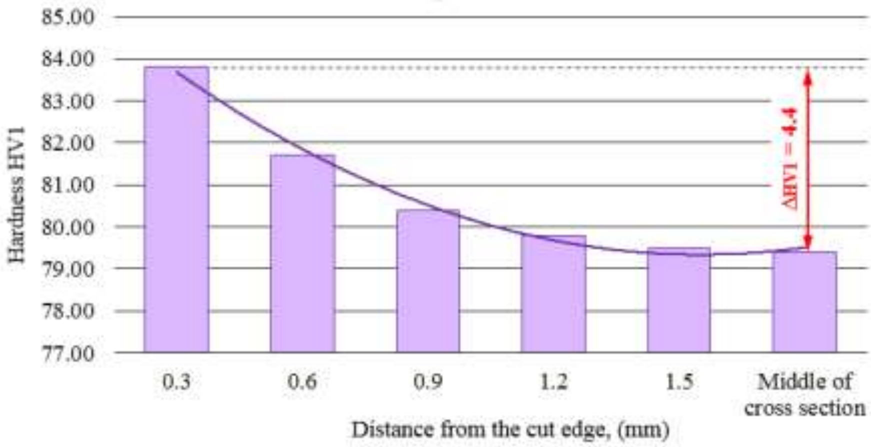


Figure 6.9. Diagram of micro-hardness value change dependency on the increase of distance from cutting edge - sample No. 9

Slika 6.9. Dijagram promjene mikrotvrdoće u ovisnosti o povećanju udaljenosti od ruba reza – uzorak br. 9

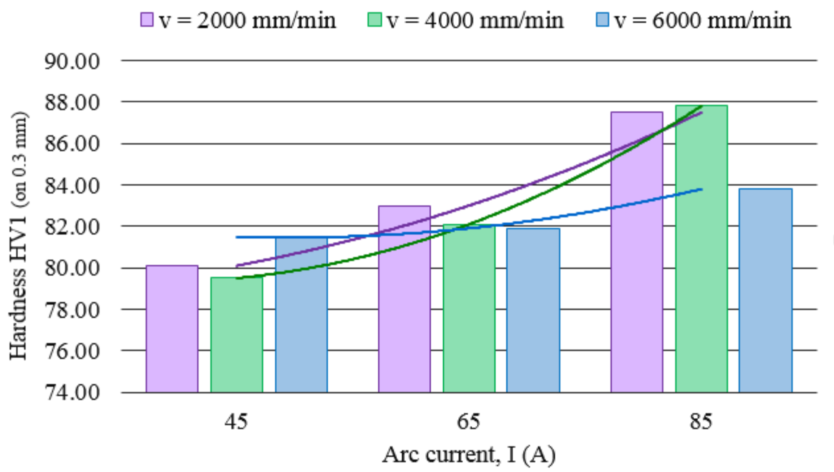


Figure 7. Diagram of micro-hardness value change dependency on electric current change for different values of cutting speed

Slika 7. Dijagram promjene mikrotvrdoće u ovisnosti o promjeni jakosti struje za različite vrijednosti brzine rezanja

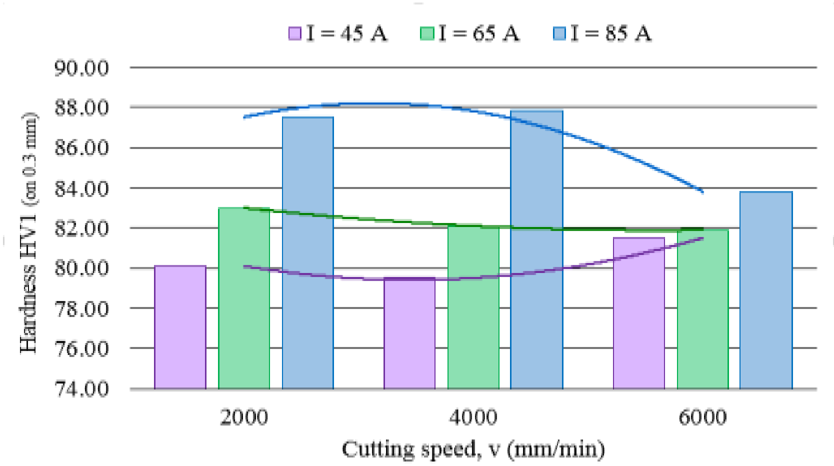


Figure 8. Diagram of micro-hardness value change dependency on cutting speed change for different values of electric current

Slika 8. Dijagram promjene mikrotvrdoće u ovisnosti o promjeni brzine rezanja za različite vrijednosti jakosti struje

On all of the metallographic images obtained, beside usually expected phases in the material structure, the existence of dark areas (inclusions), was noticed. For the purpose of properties analysis of the mentioned structural features, micro-hardness testing was conducted with 98.07 mN load applied (HV 0.01), figure 9. In this figure, the indentation mark of micro-hardness measurement for usual phases was noted with a circle, with obtained values of 78 HV0.01. On the same figure, the indentation marks of micro-hardness measurements for dark areas were noted with squares. Obtained values were 95 HV0.01. The results have showed that dark areas do not represent any form of porosity in the material structure. It is possible that these areas imply certain precipitates. For more precise definition, SEM analysis ought to be conducted.

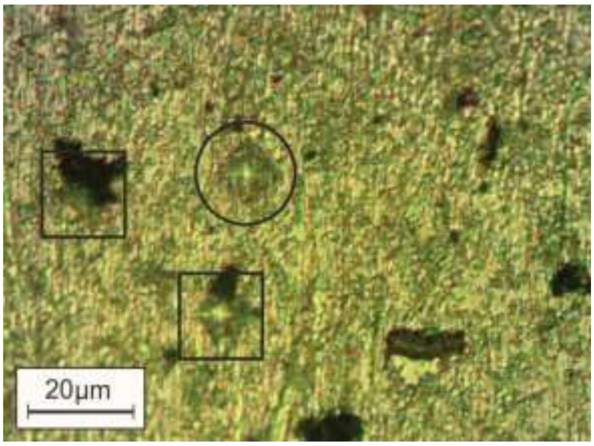


Figure 9. Micro-hardness testing of different phases in material structure

Slika 9. Mjerenje mikrotvrdoće različitih faza u strukturi materijala

4. CONCLUSION

Based on the obtained results of the micro-hardness analysis, as well as microstructure analysis, it can be concluded that significant structural changes in the heat affected zone did not occur. In fact, here is the case of non heat-treatable aluminum alloy, which is not sensitive to the heat input during plasma jet cutting process, therefore significant hardness changes did not occur. Significant structural changes are expected to occur during cutting process, particularly during welding process, of the heat-treatable alloys. In the heat affected zone of these alloys, heat treatment effects would be undone, for the reason of the intermetallic compound precipitates grain size going larger, which would eventually lead to hardness and material strength values decrease.

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IZVOD

ANALIZA ZONE UTICAJA TOPLINE KOD PLAZMA REZANJA NA LEGURI ALUMINIJA EN AW 5083

Rezanje plazmom je poznati nekonvencionalni termo-električni proizvodni postupak koji se ponajviše koristi u metalnoj i brodograđevnoj industriji. Postupak koristi energiju visoko ioniziranog plina za rezanje različitih tipova metalnih materijala. Postupak rezanja je definiran tehnološkim parametrima čije vrednosti određuju kvalitetu završnog reza. Kvaliteta reza može se definirati različitim karakteristikama, kao što su: širina reza, kut nagiba, površinska hrapavost, visina srha i zona uticaja topline. U ovom radu provedeno je istraživanje delovanja različitih parametara procesa na zonu uticaja topline (ZUT). Ispitivani materijal je bila legura aluminija EN AW 5083. Analiza zone uticaja topline izvršena je merenjem promene tvrdoće po poprečnom preseku uzoraka i mikroskopskom analizom strukture materijala.

Ključne reči: *plazma rezanje, zona uticaja topline, aluminij, EN AW 5083, tvrdoća, struktura materijala.*

Naučni rad

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