The influence of the arc plasma treatment on the structure and microhardness C120U carbon tool steel

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Received: 26.02.2010; accepted in revised form: 30.03.2010

Abstract

The examination of the structure and microhardness of surface layer of C120 U carbon tool steel after arc treatment are presented in the paper. They are compared with the properties obtained after conventional hardening. The GTAW (Gas Tungsten Arc Welding) method was used. The remelted zone consists of dendritic cells and columnar crystals. Inside the columnar crystals dependent to current arc plasma intensity the martensite or lower bainite was observed. The cooling rate of the remelted zone is similar to the cooling rate obtained in the classical heat treatment. The maximum hardness 650 HV0,1 was measured in material after treatment with a smaller current intensity of arc plasma – 60A. Increases of the current intensity of arc plasma from 60 A to 110 A (for fixed speed rate of source) lead to increases the depth of the remelted zone from 1,2 to 3,1 mm. Thickness of the heat affected zone in the all specimens was similar (1,9 to 2,1 mm).

Keywords: carbon tool steel, arc plasma treatment, structure, microhardness.

1. Introduction

Carbon steel C120U grade is largely used on the tools for cutting, for dies and knives, for stamping and drawing tools, hobs, thread rolling tools and in many other applications due to her typical properties - high hardness, good toughness and compressive strength. The surface of the steel can be modified by using surface engineering's techniques. Remelting of the surface layer by the source of concentrated energy is promising technique to improve properties of the materials [1-6]. Laser or electron beam use to melting of the surface of tool steels aims to obtain a modified layer with increased microhardness and abrasion resistance [7,8]. The surface remelted layer has usually a finer and more homogenous structure than its original base material. The remelting with the arc plasma (TIG- tungsten inert gas or GTAW - gas tungsten arc welding) used as an economical and easily available method is considered as an alternative for laser and electron beam [1,2]. The aim of the present work is to study the changes in the structure, microhardness of surface layers of C120U tool carbon steel after arc plasma electric treatment.

2. Material and methodology

The material used in this study was C120U steel. Chemical composition of this steel is presented in Table 1. Specimens as cuboids about dimensions 7,5 x 30 x 30 mm were conventional hardened (temperature austenitization – 770 °C, quenching in oil) and tempered (in temperature 250 °C). Temperatures hardening and tempering were chosen on the basis EN ISO 4957:1999 norms to obtain a structure with a relatively high toughness. Remelting surface was carried out using gas tungsten arc welding method. The surface of the samples were remelted by means of
arc plasma using the following parameters: source speed rate – 0.2 m/min, remelting current of 60, 80, 100, 110 A, distance from the sample surface – 2 mm. After remelting, cross section was prepared.

Vickers' microhardness was measured along the axis of the melted zone using a Hannerman Microhardness Tester with an applied load of 100 g for 10 s. Microstructural characterizations were conducted using optical and scanning electron microscopy (SEM). For optical and SEM microscopy, the samples were sectioned, polished and etched in 2% solution Nital.

3. Results

The required properties of tool carbon steel are achieved by complex heat treatment comprising annealing, hardening and tempering leading to spheroidal cementite in a matrix. After conventional heat treatment, the matrix structure consists of tempered martensite and bainite. The matrix possessed an fine grain structure. Diameter of the grain former austenite was 20 µm. The martensite spines were several micrometers long. The carbides have relatively regular oval-shape. Structure of C120U steel prior to arc plasma treatment is shown in Fig.1.

![Figure 1. Structure of the C120U steel after conventional heat treatment, spheroidal cementite inside martensitic matrix](image1)

After arc plasma electric treatment on the cross section of the surface layer was distinguished two areas with the different microstructure were observed in respect to the parent material. The first area – remelted zone (RZ) and second area – heat affected zone (HAZ). Optical microscopic images of a single track are presented on Fig. 2. The influence of current intensity of the electric arc plasma on the dimensions of RZ and HAZ are shown in Table 2. With increased current intensity (for fixed speed rate of source = 0.2 m/min) the depth of the RZ increased too.

![Figure 2. Optical image of the cross section of the C120 steel after arc plasma treatment. RZ – remelted zone, HAZ - heat affected zone, SUB – substrate](image2)

The thickness of the HAZ was similar for all examined probes and average approximately 200 µm. The remelted zone consists of cells crystals and dendritic cells. The interdendritic space is failed secondary cementite. In the specimens treated with 60 A and 80 A current intensity, the plate martensite was observed inside central columnar crystals. The martensite plates were to 20 µm long. Inside the columnar crystals in the vicinity of the grains boundaries lower bainite was remarked (Fig.3.). Between plates of the martensite and lower bainite there is visible retained austenite.

![Figure 3. Remelted zone of the probes after treatment with current intensity of arc plasma – 60 A, cell crystal, in the grain boundaries the secondary cementite is visible](image3)
Figure 4. Remelted zone of the probes after treatment with current intensity of arc plasma – 100 A, lower bainite, retained austenite and secondary cementite

Because the secondary cementite was isolated in the solid state, the cooling rate in RZ on the CCT diagram basis we can define. CCT diagram show in Fig.4. The cooling rate of the remelted zone is on the level 10 °C/s.

Figure 5. CCT diagram for a carbon steel similar to C120U [9]

In the specimens after treatment with current intensity arc plasma equal 100 and 110 A, in the structure of RZ lower bainite was observed, (Fig. 4). Below the RZ in the HAZ, three areas were distinguished. The first area – zone of material heated above $A_{cm}$ temperature and hardened. This area is shown in Fig.6. The plate martensite and large quantity retained austenite we see. The second area – zone of material heated to temperature in range $A_{cm}$ – $A_1$. Structure of the zone consists of martensite, bainite, retained austenite and secondary cementite. We can perceive the speroidal cementite, which locally in a matrix is dissolved (Fig.7.). The third area – zone of material heated to temperature bellow $A_1$ and tempered. Structure of the zone is similar to the structure of the substarte (core) of materials examined. Microhardness tests showed gradual hardness profiles in the cross section of surface layer, (Fig. 8, 9.). Microhardness of RZ is dependent to on arc plasma treatment parameters. The maximum hardness of RZ approx. 650 HV0,1 was obtained by remelting the steel with smallest value of current intensity of the arc plasma – 60 A.

Figure 6. HAZ of the probes after treatment with current intensity of arc plasma – 60 A, zone of material heated above $A_{cm}$ temperature and hardened

Figure 7. HAZ of the probes after treatment with current intensity of arc plasma – 60 A, zone of material heated bellow $A_1$ temperature and tempered

Figure 8. Microhardness HV0,1 of the C120 steel after arc plasma treatment with current intensity of arc 60 and 80 A
Increase of the current arc plasma from 60 to 110 A lead to the decrease of cooling rate. The smaller cooling rate was reason to create of structures about smaller mikrohardness (retained austenite, appear bainite). In the HAZ the microhardness decrease continuously to the level 300 HV0,1 was observed.

![Microhardness HV0,1 of the C120 steel after arc plasma treatment with current intensity of arc 100 and 110 A](image)

Figure 9. Microhardness HV0,1 of the C120 steel after arc plasma treatment with current intensity of arc 100 and 110 A

The microhardness around 300 HV0,1 on the bottom of the HAZ measured, where the materials was tempered. The width (approx. 0,5 mm of area tempered is similar in the examined probes.

4. Conclusions

Surface of C120 steel after arc plasma treatment showed tracks have multizone microstructure composed of the remelted zone, heat affected zone and substrate, which can have diversifified microhardness. Structure (particularly precipitation of martensite, bainite retained austenite and secondary cementite) in the remelted zone is dependent on the arc plasma treatment parameters. The cooling rate obtained during the treatment by arc plasma of the steels is compared to the cooling rate of the steels during conventional heat treatment. This cooling rate can be estimated on the basis of the standard CCT diagram for C120 steel. Increased of the current intensity of arc plasma lead to of grater areas of materials remelting and it decreases of the cooling rate of the treatment zone. When the remelted zone is shallow microhardness is high and structure consists with martensite, retained austenite and secondary cementite. The maximum hardnes of remelted zone approx. 620 HV0,1 was obtained by remelting the steel with 60A – current intensity of arc plasma, The average hardness decreases together with increases of he current intensity of arc plasma.

References