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Microhardness and tribological wear of the steels remelted with an electric arc

S. Adamiak
Institute of Technics, University of Rzeszow, ul. Rejtana 16a, 35-111 Rzeszow, Poland
e-mail: sadamiak @univ.rzeszow.pl

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Summary

This study presents results of a research on the surface strengthening of the C15, C45 and C90U steels by application of concentrated heat stream with the GTAW methodology. Utilizing the GTAW methodology remelting of the surface layer of the sampled steels was performed by a welding head moving at a speed ranging from 200 mm/min to 800 mm/min and the current intensity of the electric arc ranging from 50A to 300A. Measurements of hardness, frictional coefficient and intensity of tribological wear were performed in the remelted surface layer. Correlation between the intensity of the electric arc versus microhardness and tribological wear resistance under conditions of dry-friction was established. Following the treatment an increase in hardness as well as increase in the tribological wear resistance could be observed in steel samples. The best results were achieved during remelting of the surface layer with electric arc at 100A intensity and the speed of the welding head in relation to treated sample of 200 mm/min.

Keywords: steel, remelting of a surface layer, hardness, tribological wear, GTAW method

1. Introduction

Ever-growing quality demands for machinery and construction components, along with the energy-saving requirements at their manufacturing, call for application of high-energy heating methods. One such methods is a concentrated heat stream application based on the GTAW (Gas Tungsten Arc Welding) technology. Its advantages are: relatively easy application and low-cost equipment requirements.

Ability to achieve greater effective working area with a single heat stream pass, as compared to a laser or electron technologies, also adds to GTAW method's advantages. The resulting material structures can be easily controlled with such basic technological parameters like current intensity, speed of the heat source and the composition of the plasma-generating gases [1-9].

Knowledge of those issues allows to choose technological parameters that are optimal for the surface layer shaping during the surface-refinement of machine elements.

This study analyses influence of parameters of the GTAW treatment on the geometry of the surface layer and microhardness of C15, C45 and C90U steel samples.

2. Methodology and materials used for the study

Test samples were 200x50x20 mm cubicoids made of C15, C45 and C90U steel (Fig. 1).

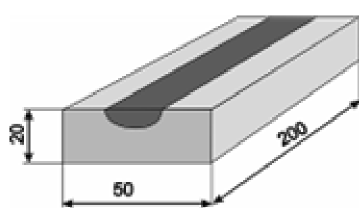

Fig. 1. Shape and dimensions of test sample

Test samples were surface-remelted with the electric arc using a FALTIG 315AC/DC apparatus. Samples were remelted at a constant speed of the electrode of 200 mm/min and varying intensity of the electric arc of 50, 100, 200 and 300A, as well as at a constant intensify of the electric arc and varying speed of electrode of 200, 400, 600 and 800 mm/min. Argon was used as a plasma-generating gas. The study was conducted in the Founding and Welding Department of University of Technology in Rzeszow. Measurements of microhardness were performed on the surfaces perpendicular to the treated surface using Hannemana mph 100 apparatus. Analysis of changes in microhardness in relation to current intensity of the electric arc and the speed of the electrode were performed. Tribological analyses were conducted under conditions of dry-friction using the TM-01 tester working in pin-on-disc configuration. Relationship between changes in the intensity of tribological wear and the intensity of the electric arc was established. The intensity of the wear was calculated according to the following formula (1).

$$I = \frac{\Delta M}{s \cdot A} \qquad \left[g / m^3 \right] \tag{1}$$

where: ΔM – mass of the sample before abrasion and after,
s – distance of friction, A – surface of friction.

Distance covered by friction was 1000 m, force applied by the sample on the anti-sample was 2,8 MPa and speed of slippage was 0,17 m/s . Anti-sample was made of high-speed HS 6-5-2 steel, treated with a conventional heat-treatment, hardness of anti-sample was 63 HRC. The surfaces created as a result of tribological wear were inspected using a Tesla BS-340 electron microscope.

3. Results description

Structural changes during crystallization and the subsequent rapid cooling down to the ambient temperature had a substantial influence on the hardness of the surface layer. Measurements of microhardness were carried out across the depth of the surface layer according to Fig. 2.

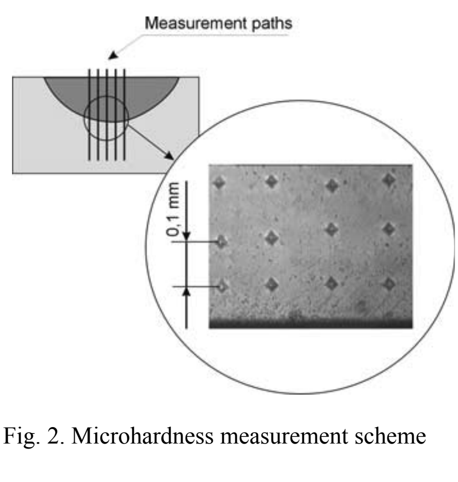

Fig. 2. Microhardness measurement scheme

The greatest microhardness of the structure in the remelted layers of C15 and C45 steels was achieved in samples remelted using an electric arc with intensity of 100A and it was equal to 680 HV0,065 for C15 steel and 800 HV0,065 for C45 steel. For the C90U steel the maximum microhardness of 880 HV0,065 was achieved after the treatment with an electric arc with intensity of 50A. Increasing the intensity of the electric arc to 200A and 300A resulted in lower values of microhardness (Fig. 3) and increased thickness of the strengthened layer of the material (Fig.5a,c,e). Increasing the speed of the electric arc movement in relation to studied sample caused an increase in microhardness of the structure (Fig. 4). This increase in microhardness can be explained by the faster cooling. With increased speed of the electric arc movement we observed decreased thickness of the strengthened material (Fig. 5b,d,f).

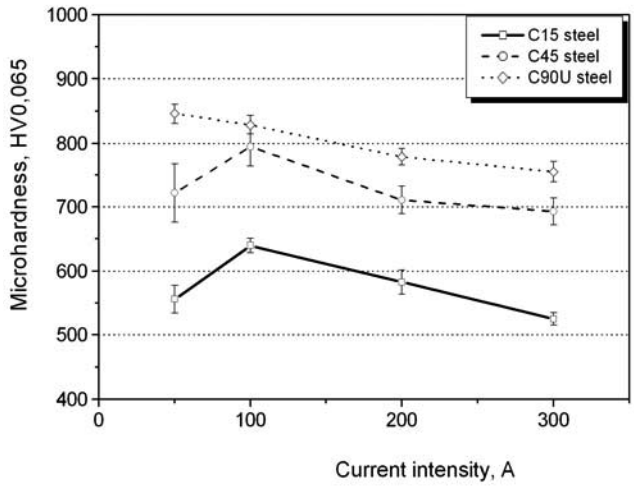

Fig3. Average microhardness of the remelted zone in studied samples as a function of intensity of the electric arc

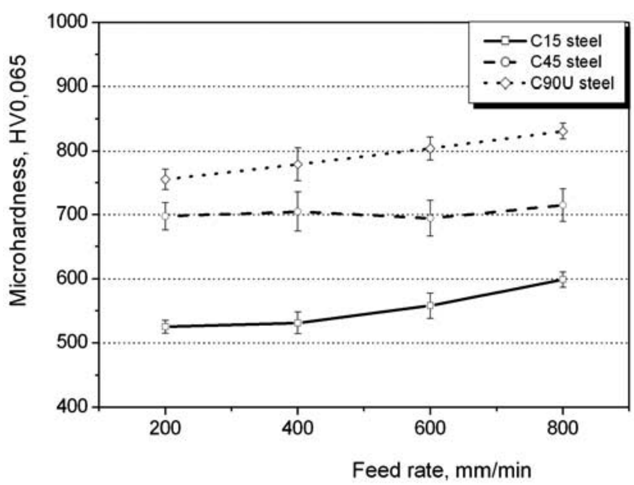

Fig. 4. Average microhardness of the remelted zone in studied samples as a function of the feed rate of the electric arc

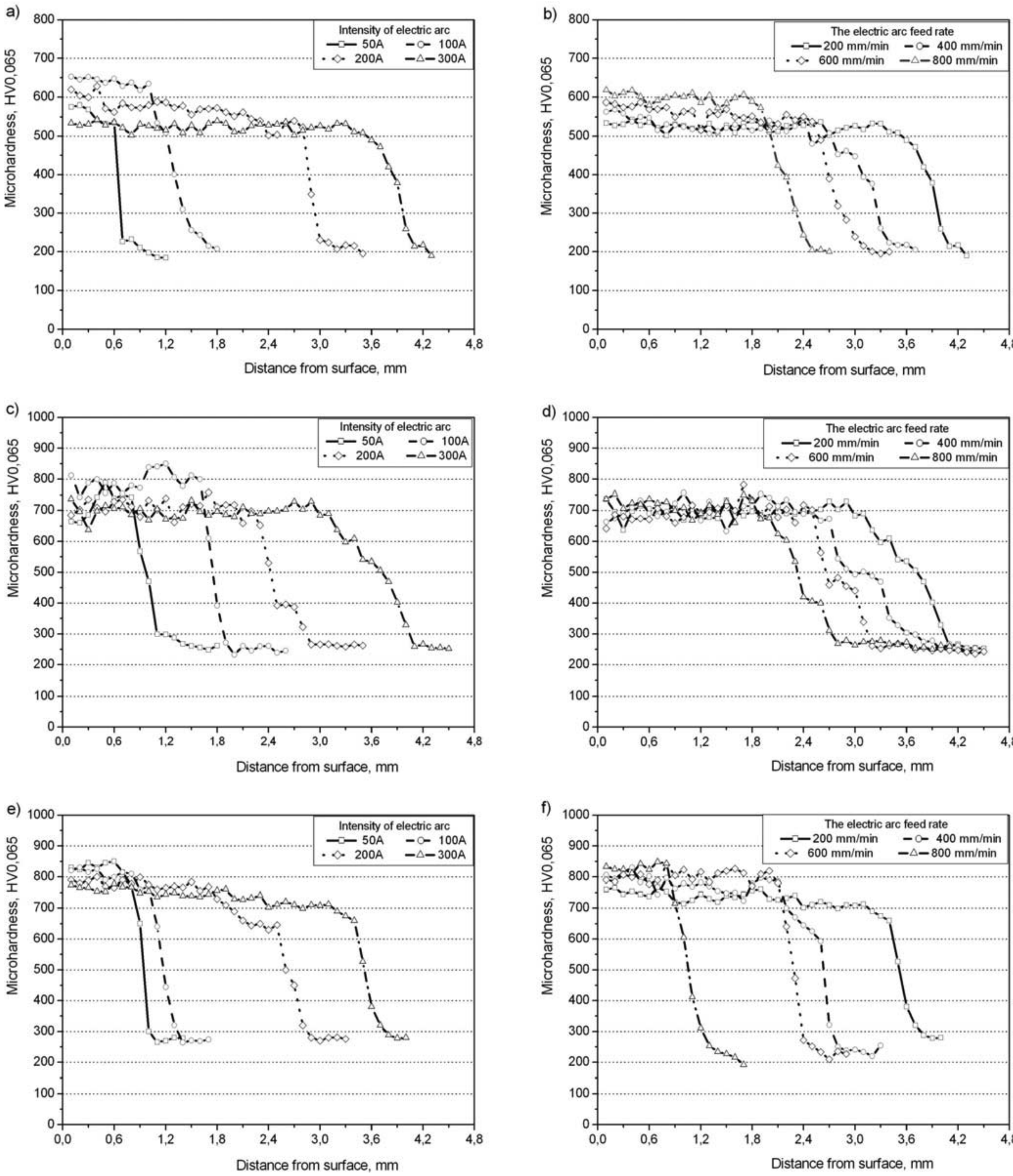

Fig.5. Layout of microhardness areas after the GTAW treatment: a,b) C15 steel, c,d) C45 steel, e.f) C90U steel, a,c,e) at various values of the intensity of electric current arc, b,d,f) at various speeds of the electric arc movement

Remelting of the surface layer in studied samples had a significant impact on decreasing their wear as a result of dry-friction. Frictional coefficient of the tested samples as compared to HS 6-5-2 heat-treated steel was 0,5-0,6 for C45 steel and 0,7 - 0,8 for C15 and C90U steels. There was no observable relationship between the value of frictional coefficient and the intensity of the wear. The smallest intensity of tribological wear was observed in samples remelted with an electric arc of 100A intensity. However, a relationship between tribological wear in studied samples and microhardness of their structure could be observed. The results of analyses of tribological wear are presented in Fig 6.

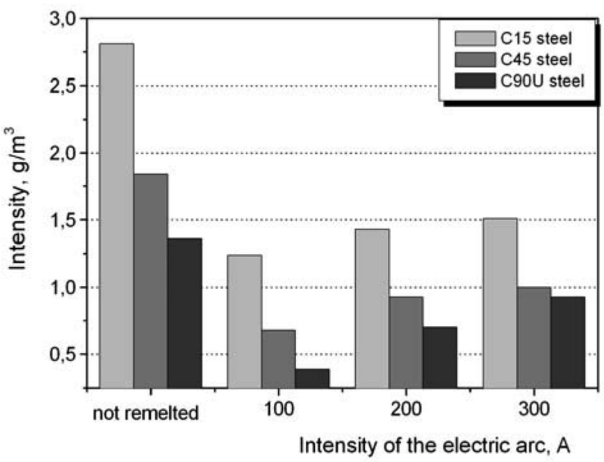

Fig. 6. Intensity of tribological wear as a function of intensity of the electric current arc

The main cause of the destruction of the surface layer under the dry-friction conditions was frictional wear. The evidence of that was a number of scratches appearing on the treated surfaces as a result of scratching with loose particles of sample and anti-sample (Fig 7).

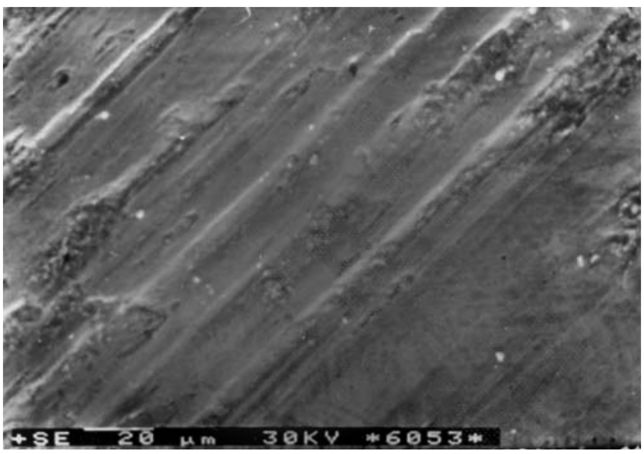

Fig. 7. The surface of the C45 steel after the tribological tests with traces of the frictional wear

4.Conclusions

As a result of remelting of the surface layer and the subsequent tempering during the cooling cycle, the hardness of the studied steel increased significantly. During the treatment with varying values of current intensity of the electric arc it was observed that the greatest increase in structure's hardness of C15 and C45 steels occurred after a treatment with electric current intensity of 100A. For the C90U steel the maximum microhardness was achieved after a treatment with electric arc with intensity of 50A. Increasing the speed of the electric arc movement in relation to studied sample caused an increase in microhardness of the structure.

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