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Influence of TiN nanoparticles on the microstructure and hardness of arc overlaid welding layers

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Abstract

Electrodes for manual arc overlay welding with coating containing nanomodifier TiN in concentrations between 0.2% and 1.5% were developed and manufactured. Samples of welded overlay layers with electrodes were both examined by electron microscopy and X-ray microanalysis. Some samples were subjected to heat treatment consisting of annealing and subsequent hardening in water and oil. The Vickers hardness $HV_{15/15}$ *of the samples in the prepared state, and both after annealing and hardening were measured. It was found that growth of the hardness of nanomodified layers were up to 180 percent compared to the reference sample.*

Keywords: arc overlay welding, nanomodifiers, nanosized TiN, nanopowders, heat treatment, Vickers hardness

1. Introduction

Intensive work has been completed in the last few decades, in the field of nanomaterials and their application in all areas of human life. The introduction of nanoceramic powders into metals and alloys leads to an improvement of their structure and increases their performance [1−7]. It has been found that modified with TiN + Cr nanoparticles arc welded overlaid layers based on electrode E300 show high hardness and wear resistance [8].

The application of SiC nanoparticles in the electrodes for manual arc welding results in increasing the welded layer hardness which is maintained and is even further increased after subsequent annealing and quenching [9].

This paper presents some results obtained in the study of welded layers produced by means of manual arc overlay welding with electrodes in which coating TiN was introduced in the form of nanosized powder particles.

2. Experimental

Electrodes for manual arc welding are produced based on electrodes grade E300, the coating of which is modified with TiN nanopowder with an average particle size of about 50 nm. Details on the manufacturing process and the technological parameters are given in a previous article [10]. Steel plates 235JR are weld overlaid to test the electrodes. They are cut out using a water cutting machine for specimens. The TiN content is as follows:

1. Sample 1, welded overlaid with electrode E 300 with no addition of nanoparticles in the coating.
2. Sample 2, welded overlaid with electrode E 300 with 0.1% nanosized particles TiN.
3. Sample 3, welded overlaid with electrode E 300 with 0.2 % nanosized particles TiN.
4. Sample 4, welded overlaid with electrode E 300 with 0.4 % nanosized particles TiN.
5. Sample 5, welded overlaid with electrode E 300 with 0.8 % nanosized particles TiN.
6. Sample 6, welded overlaid with electrode E 300 with 1.5 % nanosized particles TiN.

The surface of the samples was flattened by grinding. A metallographic study of selected samples was carried out. Preparation of the samples was completed according to the following procedure:

1. Grinding with SiC sandpapers (220, 400, 800, 1200, 2000).
2. Polishing mechanically with a diamond paste.
3. Revealing the microstructure with 2% Nital ~6−8 s.
4. Observation in a light field of view with a Zeiss microscope.
5. Revealing the microstructure with 4% Nital.
6. Observation with a PolyvarMet microscope.
7. Observation with a Quanta 450 FEG Scanning Electron Microscopy (SEM).

Quantitative metallographic analysis was performed with an Olympus MicroImage quantitative analysis system. The average grain size diameter was determined.

2.1. Energy Dispersive Spectroscopy (EDS)

Energy dispersive X-ray analysis (EDX) was carried out with on TEAM system with Si – drift detector with ultrathin polymer window (20 cm^2) at working distance of 10 mm, take off angle of 35°, accelerated voltage of 15 kV and beam current of 2.3 nA. Elements lighter than Al were identified semi-quantitatively with an accuracy of ~0.1 wt. %.

2.2. Hardness measurement

Hardness $HV_{15/15}$ was measured. The value of the ratio of the average hardness of the corresponding sample to the average hardness of the base sample is used as the assessment criterion.

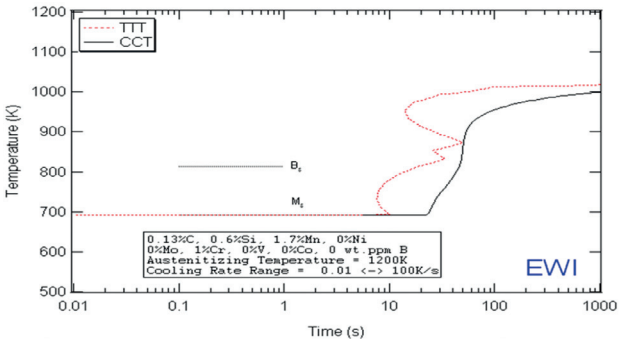


Fig. 1. Phase diagram for overlay welded metal with reference electrode type E300

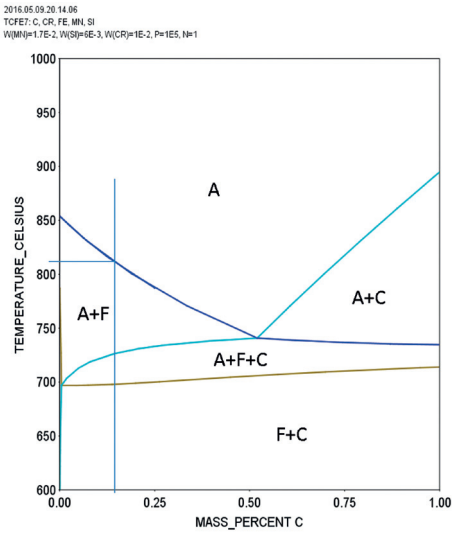


Fig. 2. C-curves for overlay welded metal with reference electrode type E300

2.3. Heat treatment

A prerequisite for carrying out a study on the effect of thermal treatment on the hardness of the nanomodified welded overlaid layers are the results obtained with welded layers containing nanoparticles SiC [7]. In determining the heat treatment mode, the chemical composition of the weld metal, the state diagram (Fig. 1) and the “C” curves (Fig. 2) are taken into account. The heating temperature for annealing and quenching is 870ºC.

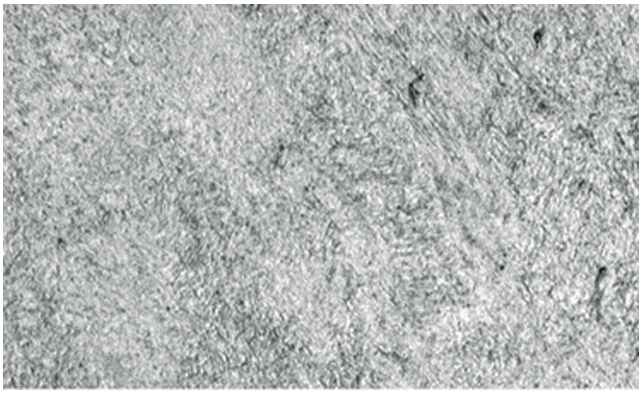
3. Results

In Figures 3 and 4 respectively are shown the structures of the base sample 1 and the nanomodified sample 4 observed with a visible light microscope (Figs. 3a, 4a) and the SEM (Figs. 3b, 4b) in post-welding state. Both martensitic patterns are observed in both samples. Within the pattern of sample 4, typical point-like entities are visible.

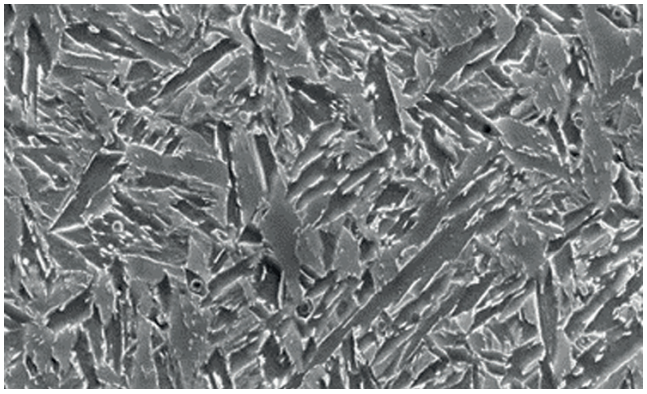
The results of the quantitative analysis of the image reveal the following values for the average grain diameter: sample 1 – 1193 μm (Fig. 5), sample 4 – 53 μm (Fig. 6). Consequently the addition of nanoparticles led to significant grain size reduction. In particular, the addition of 0.4% TiN resulted in a grain size decrease of 22 times.

Figure 7 shows a SEM image of a nanomodified layer welded with an electrode in which the nanopowder TiN was activated with a Cr powder one-to-one ratio and the areas in which an EDS analysis was performed.

Figure 8 shows energy dispersive X-ray analysis results. The presence of Ti in the examined sphere shaped

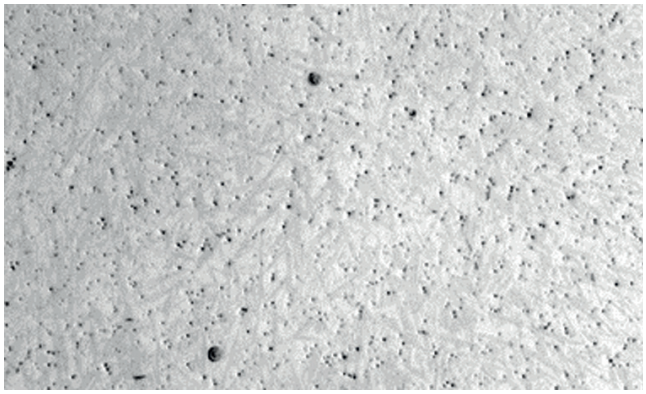


a)

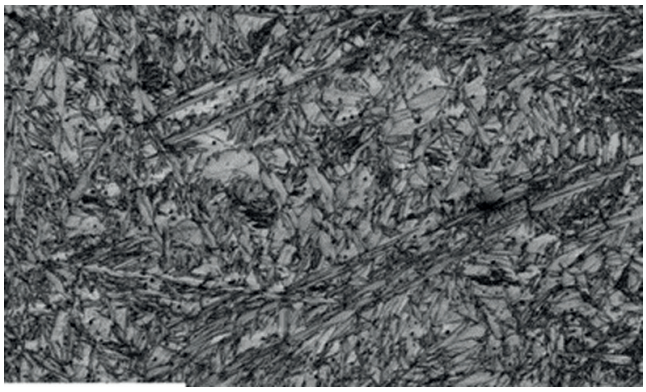


b)

Fig. 3. Sample 1: a) microscope image, b) SEM image



a)



b)

Fig. 4. Sample 4: a) microscope image, b) SEM image

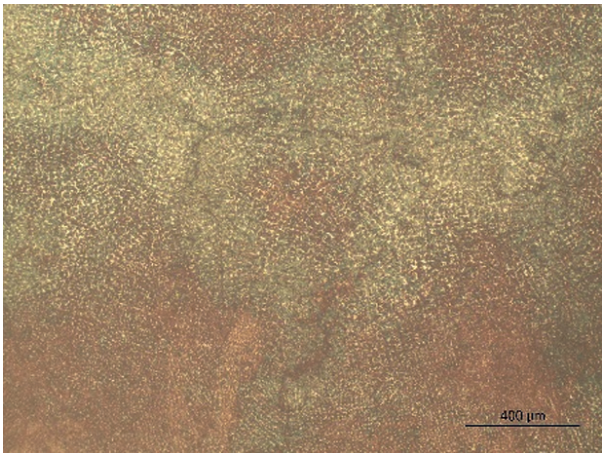


Fig. 5. Sample 1

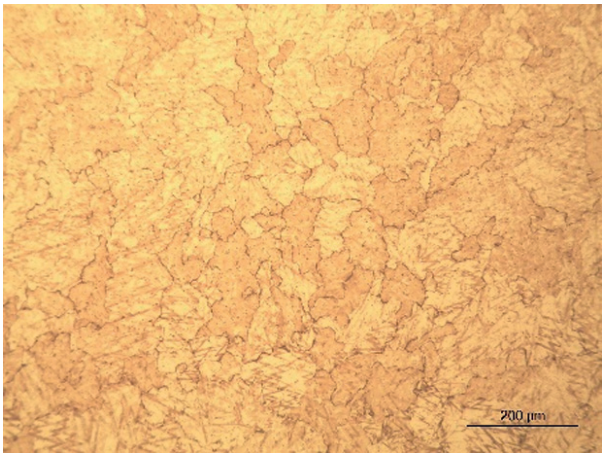


Fig. 6. Sample 4

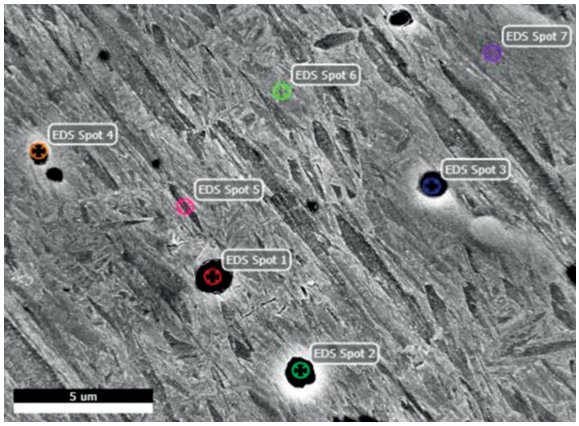
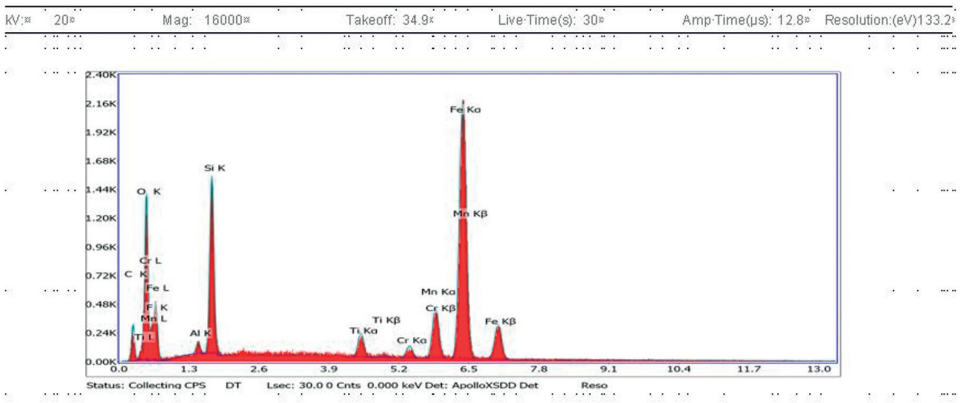


Fig. 7. SEM image of layer modified with TiN + Cr

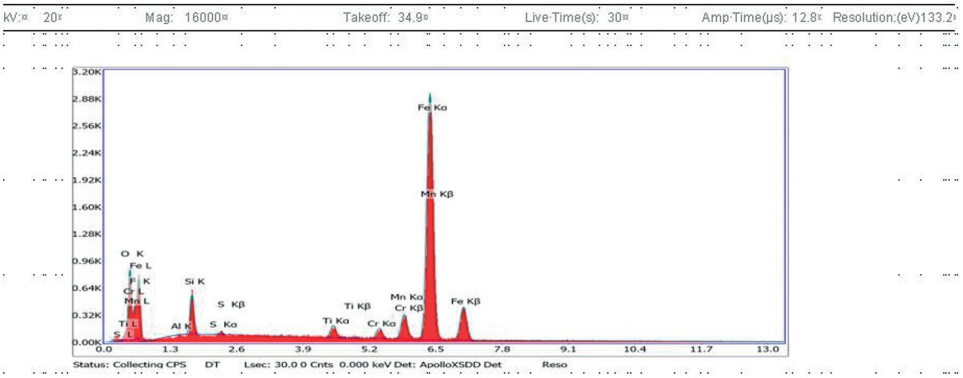
formations (spot 1, 2, 4), which are contained only in the nanomodifier, were recorded.

The change of hardness calculated as a ratio of the nanomodified sample hardness and one of the base samples is presented in Figure 9. A well-formed maximum at 0.2% nanoparticles TiN content was detected.

The effect of the treatment on hardness is presented on Figure 10.



a)



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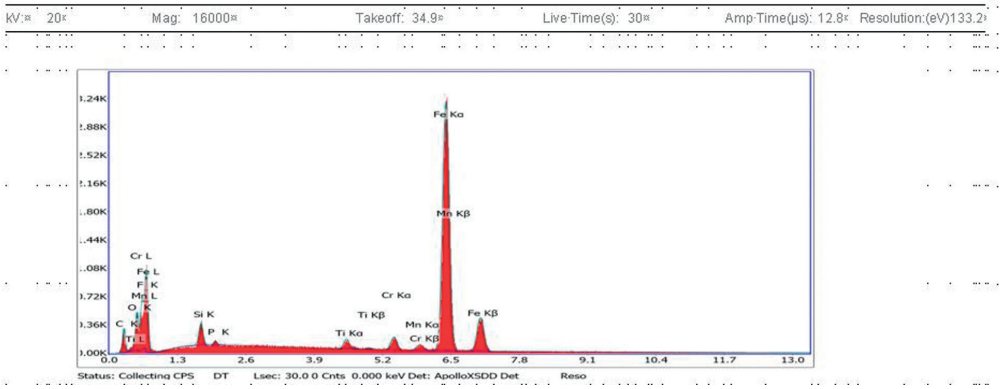
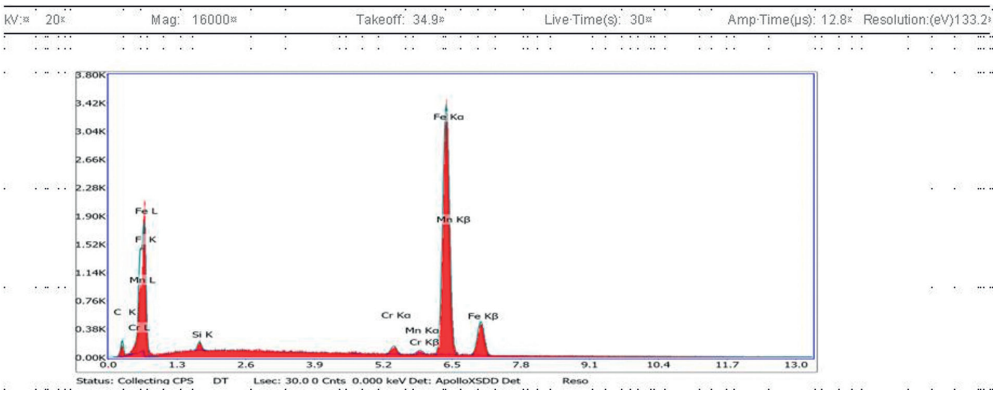


c)



d)

Fig. 8. a) Spot 1, b) spot 2, c) spot 4, d) spot 6

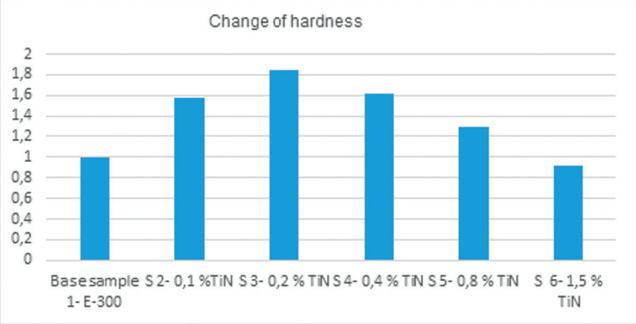


Fig. 9. The change of hardness dependence on the TiN content

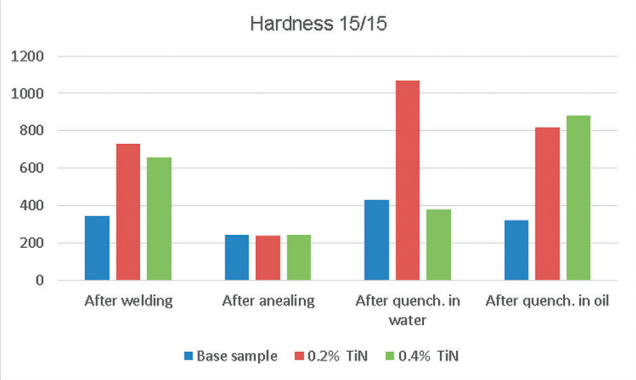


Fig. 10. Hardness after heat treatment

4. Conclusions

The modification of the welded overlaid layers by the introduction of TiN nanopowders in the coating of an E300 electrode leads to a substantial change of the structure. The addition of 0.4% TiN resulted in the grain size decreasing 22 times, compared to those of the base sample.

The maximum hardness of the welded overlaid layer was achieved at a TiN nanoparticles concentration of 0.2%. The additional increase in TiN concentration results in a decrease in hardness.

The annealing of nanomodified with TiN welded layers decreases its hardness, which makes it possible to process them with conventional metal cutting tools.

Performed heating, related with annealing and subsequent quenching, does not reduce the effect of nanomodification. Achieved hardness levels after welding overlay were maintained and even rose after hardening.

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