P. Tashev[1a], H. Kondov[1b], E. Tasheva[2c]

Improvement of the properties of layers obtained by surfacing using TiN and SiC nanoparticles

Poboljšanje svojstava slojeva dobijenih navarivanjem pomoću nanočestica TiN i SiC

Originalni naučni rad / Original scientific paper

Rad je u izvornom obliku objavljen u Zborniku sa 4. IIW Kongresa zavarivanja Jugoistočne Evrope „Safe Welded Construction by High Quality Welding" održanog u Beogradu 10-13. Oktobra 2018

Rad primljen / Paper received:
Oktobar 2019.

Adresa autora / Author's address:
1 Institute of Metal Science, Equipment and Technologies with Hydroaerodynamics Centre "Acad. A. Balevski" – Bulgarian Academy of Sciences, 67 Shipchenski prohod, 1574 Sofia, Bulgaria
2 158, Todor Kableshkov Higher School of Transport, Geo Milev Str., 1574 Sofia, Bulgaria
E-mail: a ptashev@ims.bas.bg , b hriko61@gmail.com , c elitasheva@abv.bg

Ključne reči: Navarivanje nanočestice, obložene elektrode, tvrdoća, otpornost na habanje

Key words: Surfacing, nanoparticles, coated electrodes, hardness, wear resistance

Abstract
In the paper, investigation results are presented, the objective was to improve the mechanical characteristics (hardness and wear resistance) of layers produced by surfacing using TiN and SiC nanoparticles in coated electrodes (SMAW process). The two parameters were controlled by varying the introduced nanoparticles. Metallographic investigation of selected samples have been carried out and the microstructure changes have been established.

Introduction
The development of technics and technologies outlines new horizons for improvement of the welding technology and the materials used are refined. There is a tendency to increase the performance of overlay metal by using innovative coated electrodes for process 111 with introduced nanoparticles [1 - 4]. Studies on the effect of nanoparticles of various refractory compounds introduced in the coating of the welding electrodes show good tendencies in terms of increase in hardness and wear resistance [5, 6].

Experiments
Developed is a series of electrodes for SMAW based on electrodes grade E300, which contain TiN and SiC nano particles with dimensions about 50 nm in concentrations 0.1, 0.2, and 0.8 weight percent. For better absorption of the nano particles, "activation" in planetary mill with iron powder is carried out in advance. The particles are introduced during the preparation of the mixture for coating on the step of wet homogenization. The coating is pressed and dried according to the traditional manufacture recipe Fig. 1 [7].

Rezime
U radu su predstavljeni rezultati ispitivanja, čiji je cilj bio da se poboljšaju mehaničke karakteristike (tvrdoća i otpornost na habanje) slojeva dobijenih navarivanjem pomoću TiN i SiC nanočestica u obloženim elektrodama (SMAW-REL postupak). Dva parametra su kontrolisana variranjem uvedenih nanočestica. Obavljeno je metalografsko istraživanje odabranih uzoraka i utvrđene su promene mikrostrukture

Uvod
Razvoj tehnike i tehnologija ocrtava nove horizonte za poboljšanje tehnologije zavarivanja i korišćenih materijala. Postoji tendencija povećanja performansi metala koji se nanosi orišćenjem inovativnih obloženih elektroda za postupak 111 sa uvedenim nanočesticama [1 - 4]. Studije o uticaju nanočestica različitih vatrostalnih jedinjenja uvedenih u obloge elektroda pokazuju dobre tendencije u pogledu povećanja tvrdoće i otpornosti na habanje [5, 6].

Eksperimenti
Razvijen je niz elektroda za SMAW zasnovanih na elektrodama klase E300, koje sadrže nanočestice TiN i SiC dimenzija oko 50 nm u koncentracijama 0,1, 0,2 i 0,8 masenih procenata. Za bolju apsorpciju nanočestica, „aktiviranje" u planetarnom mlinu železnim prahom vrši se unapred. Čestice se unose tokom pripreme smeše za oblaganje na koraku vlažne homogenizacije. Obloga se presuje suši u skladu s tradicionalnom proizvodnom recepturom Sl. 1 [7].

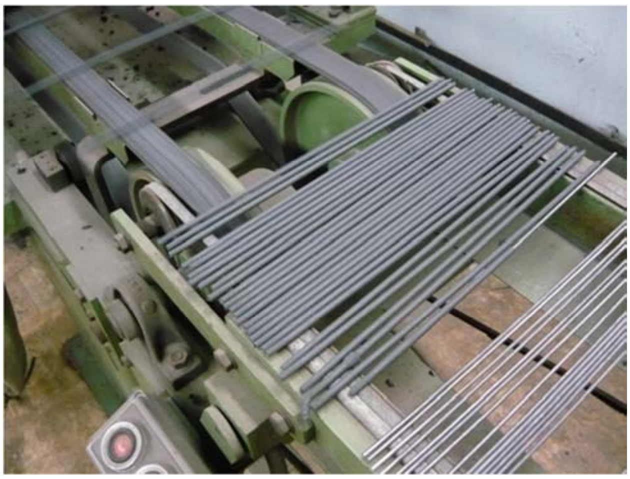


Figure 1. *Manufacture line for pressing of the coating*
Slika 1. *Proizvodna linija za presovanje oblog*

Test plates made of steel grade 235JR are prepared and three layers are overlay welded on each plate using electrodes with different coatings. The uneven surface layers are grinded. Test samples for the intended tests are cut out using water jet machine (Fig 2).

Pripremljene su ispitne ploče od čelika klase 235JR i tri sloja su navarena na svaku ploču pomoću elektrodama sa različitim oblogama. Neravni površinski slojevi se bruse. Ispitni uzorci za predviđena ispitivanja se izrezuju vodenim mlazom (Sl. 2).

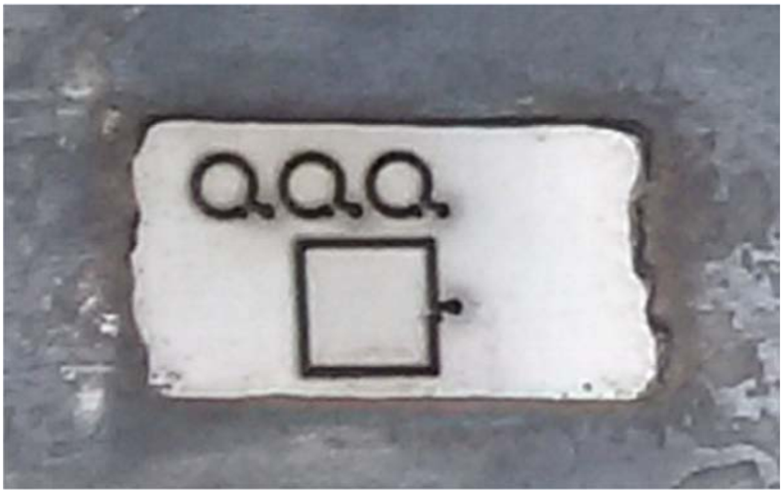


Figure 2 *Sample cutting scheme*
Slika 2. *Šema sečenja uzoraka*

Measurements of hardness HV15/15 and wear resistance of the overlay layer are carried out according to the methodology developed [5].

Results

Based on the experiments carried out it is found that the burning of the electrodes is very good and differs minimally from the reference electrodes E300. Only single cracks and imperfections are observed in the overlay metal at the highest concentrations of nano particles. The gradient of hardness of the overlay layers is represented as a ratio between the hardness of samples modified with nano particles and hardness of the base sample overlay welded using reference electrodes (Fig.3 и Fig.4).

Merenja tvrdoće HV 15/15 i otpornosti na habanje navarenog sloja izvode se prema razvijenoj metodologiji [5].

Rezultati

Na osnovu obavljenih eksperimenata utvrđeno je da je sagorevanje elektroda vrlo dobro i da se minimalno razlikuje od referentnih elektroda E300. U metalu navara uočene su samo pojedinačne prsline i nesavršenosti pri najvećim koncentracijama nanočestica. Gradijent tvrdoće navarenih slojeva predstavljen je odnosom između tvrdoće uzoraka modifikovanih nanočesticama i tvrdoće navara osnovnog uzorka navarenog referentnim elektrodama (Sl.3 i Sl.4).

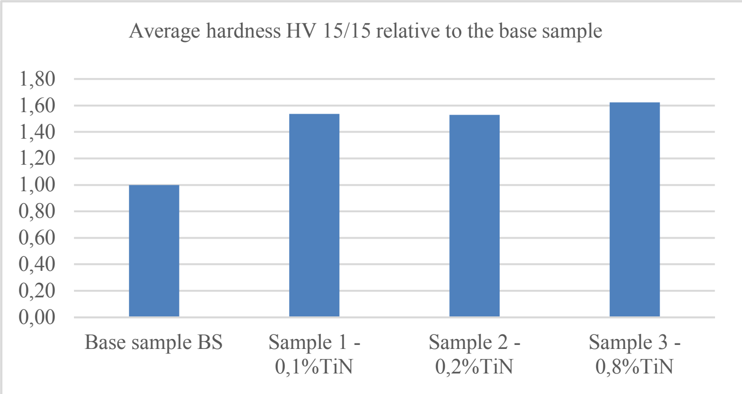


Figure 3. *Hardness gradient HV15/15 in dependence of TiN concentration*
Slika 3. *Gradijent tvrdoće HV15 / 15 u zavisnosti od koncentracije TiN*

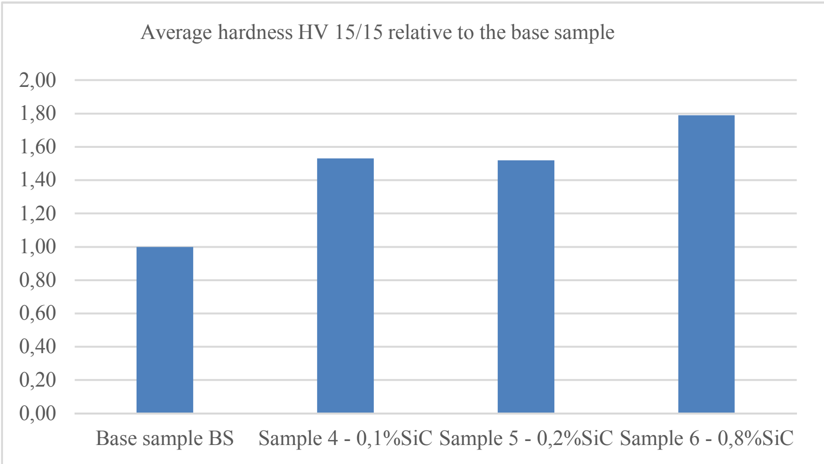


Figure 4. *Hardness gradient HV15/15 in dependence of SiC concentration*
Slika 4. *Gradijent tvrdoće HV15 / 15 u zavisnosti od koncentracije SiC*

The wear resistance gradient is also represented in comparison with the base sample (Fig. 5 and Fig. 6).

Gradijent otpornosti na habanje je takođe predstavljen u poređenju sa osnovnim uzorkom (Sl. 5 i Sl. 6).

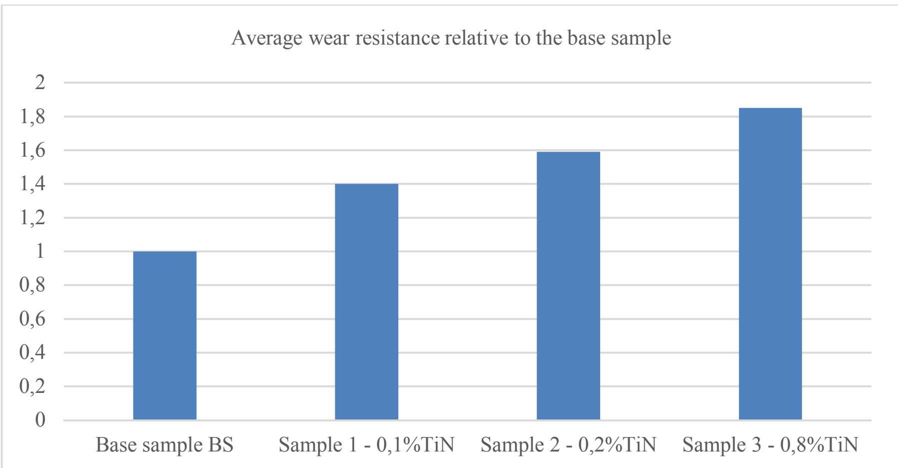


Figure 5. *Wear resistance gradient HV15/15 depending on TiN concentration*
Slika 5. *Gradijent otpornosti na habanje HV15 / 15 u zavisnosti od koncentracije TiN*

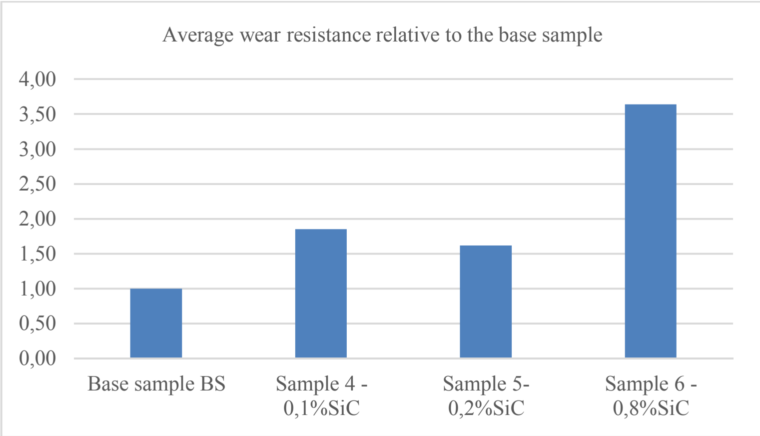


Figure 6. *Wear resistance gradient HV15/15 depending on SiC concentration*

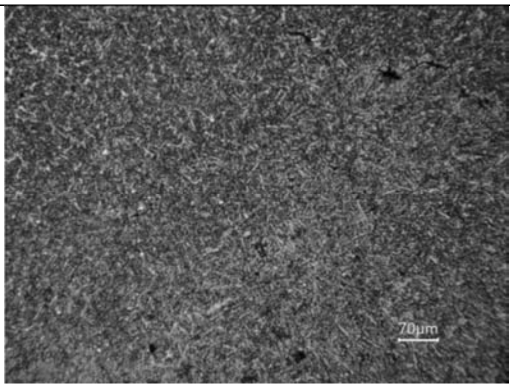
Slika 6. *Gradijent otpornosti na habanje HV15 / 15 u zavisnosti od koncentracije SiC*

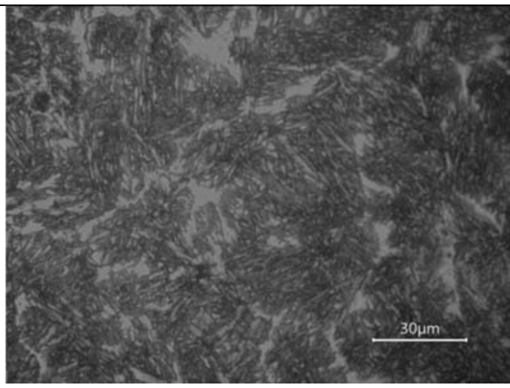
Metallography

The metallographic analysis is carried out on samples showing the best results for hardness and wear resistance. The surface of the samples is analyzed in state after overlay welding. For the purpose the surfaces of all samples are leveled through grinding to the same depth. The structure is developed according to the standard methodology. The metallographic analysis is carried out using microscope JENAVERT made by Carl Zeiss company. The results are shown in Table 1.

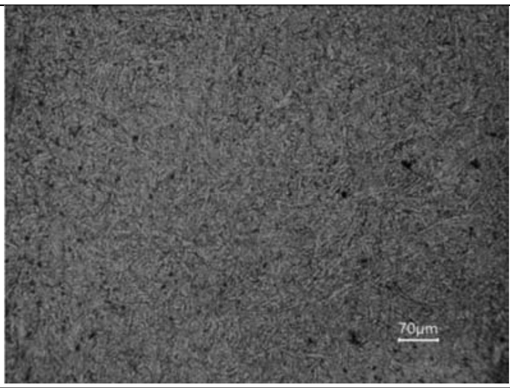
Metalografija

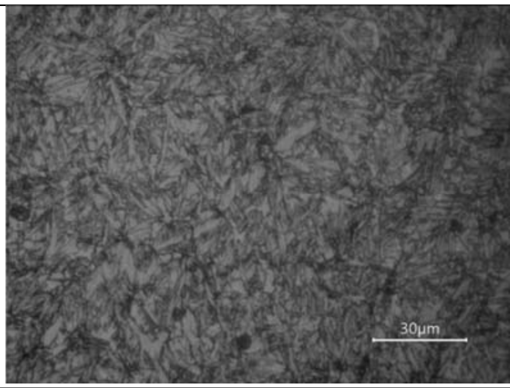
Metalografska analiza se obavlja na uzorcima koji pokazuju najbolje rezultate za tvrdoću i otpornost na habanje. Površina uzoraka se analizira u stanju posle navarivanja. U tu svrhu se površine svih uzoraka izravnavaju brušenjem do iste dubine. Struktura je razvijena prema standardnoj metodologiji. Metalografska analiza se radi pomoću mikroskopa JENAVERT kompanije Carl Zeiss. Rezultati su prikazani u Tabeli 1.





Base sample. The microstructure consists of rounded bainitic-martensitic areas confined by structurally free ferrite.
Osnovni uzorak. Mikrostruktura se sastoji od zaobljenih beinitno-martenzitnih područja omeđenih strukturalno slobodnim feritom





Sample 4. The microstructure is refined and homogenized and consists of fine bainite and structurally free ferrite.
Uzorak 4. Mikrostruktura je rafinisana i homogenizovana a sastoji se od finog beinita i strukturno slobodnog ferita

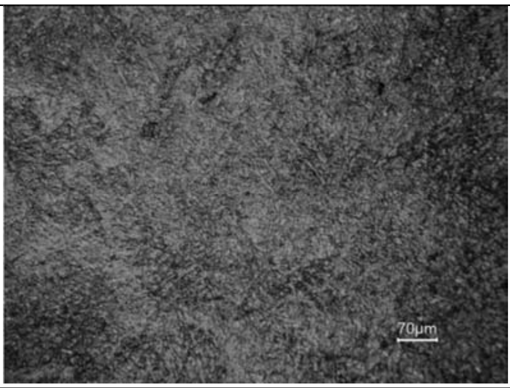
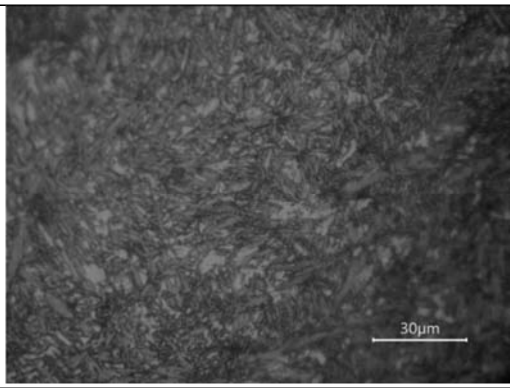
<table>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Sample 6. Grain refinement; the structure is bainitic-martensitic confined by structurally free ferrite.
Uzorak 6. Rafinacija zrna; struktura je beinitno-martenzitna ograničena strukturno slobodnim feritom.</td></tr>
</table>

Table 1. *Results from metallographic analysis*

Tabela 1. *Rezultati metalografske analize*

The microstructure is bainitic with different contents of martensite and ferrite. The presence of larger amount of pores is observed in the samples overlay welded with nano modified electrodes compared to the reference electrode. The pores affect the rate of cooling and crystallization of the overlay welded metal, which is probably the reason for formation of non-homogenized and non-uniform structure. This metallographic analysis cannot reveal obvious dependence between grain size and concentration of modifier. It is necessary to carry out an additional EBSD analysis (Electron BackScattered Diffraction) allowing making quantitative analysis in terms of grain size depending on their number in the area of a particular crystallographic plane. Such analysis is carried out [8] on samples of non-modified metal obtained with TIG welding. Determined is the distribution of the amount of grains depending on the diameter (per unit area) both for modified and non-modified structures (Fig. 6).

Mikrostruktura je beinitna sa različitim sadržajem martenzita i ferita. Prisustvo veće količine pora primećeno je na uzorcima koji su zavareni nano modifikovanim elektrodama u poređenju sa referentnom elektrodom. Pore utiču na brzinu hlađenja i kristalizacije navarenog metala, što je verovatno razlog za formiranje nehomogenizovane i neujednačene strukture. Ova metalografska analiza ne može otkriti očiglednu zavisnost između veličine zrna i koncentracije modifikatora. Potrebno je izvršiti dodatnu EBSD analizu (Electron Back Scattered Difraction-Difrakcija rasutim povratnim elektronima) koja omogućava kvantitativnu analizu u smislu veličine zrna u zavisnosti od njihovog broja u području određene kristalografske ravni. Takva analiza se radi [8] na uzorcima nemodifikovanog metala dobijenim TIG navarivanjem. Određena je raspodela količine zrna u zavisnosti od prečnika (po jedinici površine) kako za modifikovane tako i za ne-modifikovane strukture (Sl. 6).

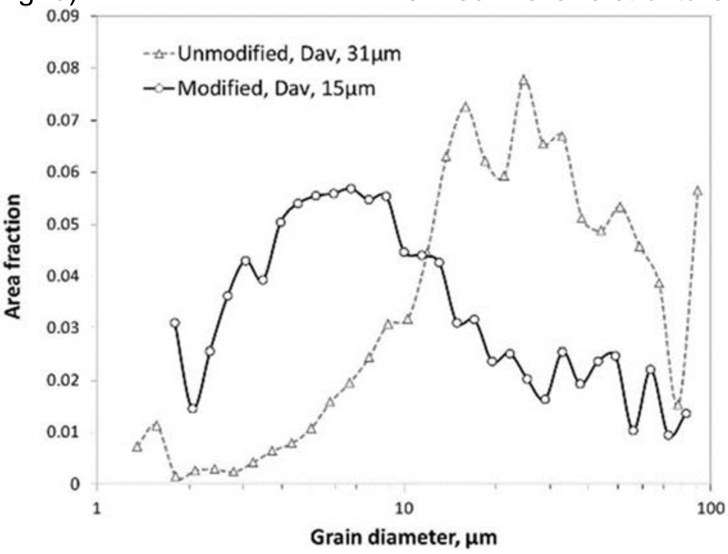


Figure 7. *Distribution of the average grain diameter (per unit area) in crystallographic planes for both modified and non-modified structures [8].*

Slika 7. *Distribucija prosečnog prečnika zrna (po jedinici površine) u kristalografskim ravninama za modifikovane i ne-modifikovane strukture [8].*

Conclusion

The introduction of nano size particles in the coating of electrodes for overlay welding grade E300 results in increase of hardness and wear resistance of the overlay layers manifested most distinctly in Sample 3 и Sample 6.

The metallographic analysis didn't find a distinct dependence between grain size and concentration of the modifier. It is necessary to carry out additional EBSD analisis.

In the future research, work should be done to reduce the formation of pores in the metal.

Zaključak

Uvođenje čestica nano veličine u sloj elektroda za navarivanje klase E300 rezultuje povećanjem tvrdoće i otpornosti na habanje nanetih slojeva, što se najviše manifestuje na uzorcima 3 i 6.

Metalografskom analizom nije pronađena razlika između veličine zrna i koncentracije modifikatora. Neophodno je obaviti dodatnu analizu EBSD-a.

U budućem istraživanju trebalo bi raditi na smanjenju stvaranja pora u metalu.

References

Reference

[1] Fattahi, M., N. Nabhani, M.R. Vaezi, E. Rahimi. Improvement of impact toughness of AWS E6010 weld metal by adding TiO2 nanoparticles to the electrode coating, Materials Science and Engineering A 528 (2011), pp.8031–8039.

[2] Fattahi, M., N. Nabhani, M.Hosseini, N. Arabian, E. Rahimi. Effect of Ti-containing inclusions on the nucleation of acicular ferrite and mechanical properties of multipass weld metals, Micron 45 (2013) pp.107–114.

[3] Antonov A.A., A.A.Artemev, G.N. Sokolov, I.V. Zorin, Y.N. Dubcov. 2015. "Effect of ultra-dispersed particles of TiN on the structure of overlay metal system Fe-Cr-C-Mo-Ni-Ti-B". Records of VolgGTU Ser. Problems of material science, welding and strength in Mechanical Engineering 168 (8). (in Russian)

[4] Sokolov G.N, I.V. Lysak, A.S. Troshkov, I.V. Zorin, S.S. Goremykina, A.V. Samohin, N.V. Alekseev, Y.V. Cvetkov. 2009. "Modifying the structure of the metal overlay welded with nano-dispersed tungsten carbides". Phisics and Chemistry of Material Processing (6): 41–47. (in Russian)

[5] P. Tashev, H. Kondov, E. Tasheva, M. Kandeva, „Study on hardness and wear resistance of layers overlayed using electrodes with nano-modified coating", International Journal of Engineering and Applied Sciences (EAAS); Islamabad, Pakistan, Vol 06. No. 04, 2015; pp 01 – 06, ISSN 2305-8269 [6] C. Vimalraj, P. Kah, B. Mvola and J. Martikainen "Effect of nanomaterial addition using GMAW and GTAW processes" Rev.Adv. Mater. Sci. 44 (2016) 370-382.

[7] P. Tashev, Ch. Kondov, Y. Lukarski, E. Tasheva, „Development of nano-modfied electrodes for manual arc welding, hardness of the overlay welded metal", Engineering Sciences, Year LII, 2015, № 3, scientific journal of BAS, p. 71, ISSN 1312-5702. (in Bulgarian)

[8] Tashev P., R. Lazarova, M. Kandeva, R. Petrov and V. Manolov, "Tungsten Inert Gas Weld Overlay using Nano-sized TiN Powder", JOURNAL OF THE BALKAN TRIBOLOGICAL ASSOCIATION, Vol. 22, No 3, 2238-2254, IF (2016).

[9] Petch N. J., Acta Metall., 34, 1387 (1986)

[10] Anchev V. C., Generalized "Strenght – Grain Size" Relationship, Max Planck Institute fur Metallforschung Stuttgart, Sonderseminar in Werkstoffkunde, 9. August 1994, Stuttgart