APEM journal

Advances in Production Engineering & Management
Volume 10 | Number 3 | September 2015 | pp 115–124
http://dx.doi.org/10.14743/apem2015.3.196

ISSN 1854-6250
Journal home: apem-journal.org
Original scientific paper

Characterizations of 304 stainless steel laser cladded with titanium carbide particles

Mahmoud, E.R.I.[a,*]

[a]Welding and NDT Laboratory, Manufacturing Technology Department, Central Metallurgical Research and Development Institute (CMRDI), Cairo, Egypt

A B S T R A C T

The aim of this paper was to increase the wear resistance of the 304 stainless steel alloy without significant losses of its corrosion resistance. The YAG fiber laser was used to clad it with TiC powder at a fixed processing power of 2800 W and travelling speeds of 4 mm/s, 8 mm/s, and 12 mm/s. The TiC powder with a particle sizes of 3-10 µm were preplaced on a cleaned surface to form a layer of two different thicknesses: 1 mm and 2 mm. The shielding gas that used during and after laser cladding was argon with a flow rate of 15 l/min. Some of the TiC particles were melted and re-solidified as dendrites during the cladding processing. The amount of the dendritic TiC structure was increased by increasing of the travelling speed, and the cohesion of the cladding layer with the substrate was improved for the same reason. At lower travelling speed, cracks were appeared at both the interface and the heat affected zone. The TiC particles were clustered within the top portion of the cladding layer when the preplaced powder was 2 mm. The surface hardness and wear resistance were remarkably improved under all processing conditions, especially at higher travelling speeds. Moreover, the sample treated at a travelling speed of 12 mm/s showed better corrosion resistance than the stainless steel substrate.

A R T I C L E I N F O

Keywords:
Laser cladding
304 stainless steel alloy
TiC particles
Microhardness
Wear and corrosion resistance

**Corresponding author:*
emahoud@kku.edu.sa
(Mahmoud, E.R.I.)

Article history:
Received 30 December 2014
Revised 19 August 2015
Accepted 24 August 2015

APEM journal

Advances in Production Engineering & Management
Letnik 10 | Številka 3 | September 2015 | Strani 115–124
http://dx.doi.org/10.14743/apem2015.3.196

ISSN 1854-6250
Spletna stran: apem-journal.org
Izvirni znanstveni članek

Karakterizacija nerjavnega jekla 304, prevlečenega z nanosom iz titanovih karbidnih delcev

Mahmoud, E.R.I.[a,*]

[a]Welding and NDT Laboratory, Manufacturing Technology Department, Central Metallurgical Research and Development Institute (CMRDI), Cairo, Egypt

P O V Z E T E K

Namen tega članka je bil povečati odpornost na obrabo nerjavnega jekla 304, pri tem pa se odpornost na korozijo ne sme bistveno zmanjšati. Za nanašanje praškastega materiala TiC je bil uporabljen vlakenski laser YAG pri konstantni moči 2800 W in podajalnih hitrostih 4 mm/s, 8 mm/s in 12 mm/s. Praškasti material TiC z velikostmi delcev 3-10 µm je bil nanešen na očiščeno površino na način, da so ustvarili dve plasti različnih debelin: 1 mm in 2 mm. Zaščitni plin, ki je bil uporabljen med nanašanjem in po njem, je bil argon s pretokom 15 l/min. Nekateri delci TiC so se med postopkom nanašanja stalili in se nato spet strdili kot dendriti. Količina dendritske strukture TiC se je povečala s povečano podajalno hitrostjo, zaradi enakega razloga pa tudi kohezija nanešene plasti z osnovnim materialom. Pri nizkih podajalnih hitrostih so se pojavile razpoke na stiku in v toplotno vplivni coni. Pri vseh preučevanih obdelovalnih pogojih sta se površinska trdota in odpornost na obrabo izjemno povečali, še posebej pa pri višjih podajalnih hitrostih. Še več, vzorec, ki je bil narejen s podajalno hitrostjo 12 mm/s, je izkazoval višjo korozijsko obstojnost kot bazično nerjavno jeklo.

P O D A T K I O Č L A N K U

Ključne besede:
Lasersko nanašanje
304 nerjavno jeklo
TiC delci
Mikrotrdoda
Obstojnost na obrabo in korozijo

**Kontaktna oseba:*
emahoud@kku.edu.sa
(Mahmoud, E.R.I.)

Zgodovina članka:
Prejet 30. decembra 2014
Popravljen 19. avgusta 2015
Sprejet 24. avgusta 2015

References

[1] Xu, P., Lin, C.X., Zhou, C.Y., Yi, X.P. (2013). Wear and corrosion resistance of laser cladding AISI 304 stainless steel/Al_2O_3 composite coatings, *Surface and Coatings Technology*, Vol. 238, 9-14, doi: 10.1016/j.surfcoat.2013.10.028.

[2] Ul-Hamid, A., Tawancy, H.M., Abbas, N.M. (2012). Failure of weld joints between carbon steel pipe and 304 stainless steel elbows, *Engineering Failure Analysis*, Vol. 12, No. 2, 181-191, doi: 10.1016/j.engfailanal.2004.07.003.

[3] Fissolo, A., Stelmaszyk, J.M., Gourdin, C., Bouin, P., Pérez, G. (2010). Thermal fatigue loading for a type 304-L stainless steel used for pressure water reactor: Investigations on the effect of a nearly perfect biaxial loading, and on the cumulative fatigue life, *Procedia Engineering*, Vol. 2, No. 1, 1595-604, doi: 10.1016/j.proeng.2010.03.172.

[4] Chiu, K.Y., Cheng, F.T., Man, H.C. (2005). Laser cladding of austenitic stainless steel using NiTi strips for resisting cavitation erosion, *Materials Science and Engineering: A*, Vol. 402, No. 1-2, 126-134, doi: 10.1016/j.msea.2005.04.013.

[5] Majumdar, J.D., Chandra, B.R., Manna, I. (2007). Laser composite surfacing of AISI 304 stainless steel with titanium boride for improved wear resistance, *Tribology International*, Vol. 40, No. 1, 146-152, doi: 10.1016/j.triboint.2006.04.006.

[6] Li, S.C. (2000). Cavitation damage in turbines, In: Li, S.C. (ed.), *Cavitation of Hydraulic Machinery*, Imperial College Press, 277-294.

[7] Yang, Y.L., Guo, N., Li, J.F. (2013). Synthesizing, microstructure and microhardness distribution of Ti–Si–C–N/TiCN composite coating on Ti–6Al–4V by laser cladding, *Surface and Coatings Technology*, Vol. 219, 1-7, doi: 10.1016/j.surfcoat.2012.12.038.

[8] Qiu, X.W., Zhang, Y.P., He, L., Liu, C.G. (2013). Microstructure and corrosion resistance of AlCrFeCuCo high entropy alloy, *Journal of Alloys and Compounds*, Vol. 549, 195-199, doi: 10.1016/j.jallcom.2012.09.091.

[9] Guo, C., Zhou, J.S., Chen, J.M., Zhao, J.R., Yu, Y.J., Zhou, H.D. (2010). Improvement of the oxidation and wear resistance of pure Ti by laser cladding at elevated temperature, *Surface and Coatings Technology*, Vol. 205, No. 7, 2142-2151, doi: 10.1016/j.surfcoat.2010.08.125.

[10] Thawari, G., Sundarararjan, G., Joshi, S.V. (2003). Laser surface alloying of medium carbon steel with $SiC_{(P)}$, *Thin Solid Films*, Vol. 423, No. 1, 41-53, doi: 10.1016/S0040-6090(02)00974-4.

[11] Liang, G.Y., Wong, T.T., MacAlpine, J.M.K., Su. J.Y. (2000). Study of wear resistance of plasma-sprayed and laser-remelted coatings on aluminium alloy, *Surface and Coatings Technology*, Vol. 127, No. 2-3, 232-237, doi: 10.1016/s0257-8972(00)00551-x.

[12] Sun, R.L., Yang, D.Z., Guo, L.X., Dong, S.L. (2001). Laser cladding of Ti–6Al–4V alloy with TiC and TiC+NiCrBSi powders, *Surface and Coatings Technology*, Vol. 135, No. 2-3, 307-312, doi: 10.1016/S0257-8972(00)01082-3.

[13] Sun, R.L., Mao, J.F., Yang, D.Z. (2002). Microscopic morphology and distribution of TiC phase in laser clad NiCrBSiC–TiC layer on titanium alloy substrate, *Surface and Coatings Technology*, Vol. 155, No. 2-3, 203-207, doi: 10.1016/S0257-8972(02)00006-3.

[14] Mateos, J., Cuetos, J.M., Fernández, E., Vijande, R. (2000). Tribological behaviour of plasma-sprayed WC coatings with and without laser remelting, *Wear*, Vol. 239, No. 2, 274-281, doi: 10.1016/S0043-1648(00)00325-2.

[15] Cheng, F.T., Kwok, C.T., Man, H.C. (2001). Laser surfacing of S31603 stainless steel with engineering ceramics for cavitation erosion resistance, *Surface and Coatings Technology*, Vol. 139, No. 1, 14-24, doi: 10.1016/S0257-8972(00)01103-8.

[16] Mahmoud, E.R.I., El-Labban, H.F. (2014). Laser surface cladding of high C-Cr bearing tool steel with TiC powders, *The IUP Journal of Mechanical Engineering*, Vol. 7, No. 4, 67-79.

[17] Liu, Y.F., Mu, J.S., Xu, X.Y., Yang, S.Z. (2007). Microstructure and dry-sliding wear properties of TiC-reinforced composite coating prepared by plasma-transferred arc weld-surfacing process, *Materials Science and Engineering: A*, Vol. 458, No. 1-2, 366-370, doi: 10.1016/j.msea.2006.12.086.

[18] Dong, Y.J., Wang, H.M. (2009). Microstructure and dry sliding wear resistance of laser clad TiC reinforced Ti–Ni–Si intermetallic composite coating, *Surface and Coatings Technology*, Vol. 204, No. 5, 731-735, doi: 10.1016/j.surfcoat.2009.09.024.

[19] Deng, J.X., Liu, L., Yang, X.F., Liu, J.H., Sun, J.L., Zhao, J.L. (2007). Self-lubrication of Al_2O_3/TiC/CaF_2 ceramic composites in sliding wear tests and in machining processes, *Materials & Design*, Vol. 28, No. 3, 757-764, doi: 10.1016/j.matdes. 2005.12.003.

[20] Moya, J.S., Lopez-Esteban, S., Pecharromán, C. (2007). The challenge of ceramic/metal microcomposites and nanocomposites, *Progress in Materials Science*, Vol. 52, No. 7, 1017-1090, doi: 10.1016/j.pmatsci.2006.09.003.

[21] Lo, K.H., Cheng, F.T., Man, H.C. (2003). Cavitation erosion mechanism of S31600 stainless steel laser surface-modified with unclad WC, *Materials Science and Engineering: A*, Vol. 357, No. 1-2, 168-180, doi: 10.1016/S0921-5093(03)00216-8.

[22] Laroudie, F., Tassin, C., Pons, M. (1995). Hardening of 316L stainless steel by laser surface alloying, *Journal of Materials Science*, Vol. 30, No. 14, 3652-3657, doi: 10.1007/BF00351880.

[23] Guan, K., Wang, Z., Gao, M., Li, X., Zeng, X. (2013). Effects of processing parameters on tensile properties of selective laser melted 304 stainless steel, *Materials & Design*, Vol. 50, 581-586, doi: 10.1016/j.matdes. 2013.03.056.

[24] Viswanathan, A., Sastikumar, D., Rajarajan, P., Kumar, H., Nath, A.K. (2007). Laser irradiation of AISI 316L stainless steel coated with Si_3N_4 and Ti, *Optics & Laser Technology*, Vol. 39, No. 8, 1504-1513, doi: 10.1016/j.optlastec.2007.01.004.

[25] Zhang, D., Zhang, X. (2005). Laser cladding of stainless steel with Ni-Cr_3C_2 and Ni-WC for improving erosive-corrosive wear performance, *Surface and Coatings Technology*, Vol. 190, No. 2-3, 212-217, doi: 10.1016/j.surfcoat. 2004.03.018.

[26] Majumdar, J.D., Manna, I. (1999). Laser surface alloying of AISI304-stainless steel with molybdenum for improvement in pitting and erosion-corrosion resistance, *Materials Science and Engineering: A*, Vol. 267, No. 1, 50-59, doi: 10.1016/S0921-5093(99)00053-2.

[27] El-Labban, H.F., Mahmoud, E.R.I., Al-Wadai, H. (2014). Laser cladding of Ti-6Al-4V alloy with vanadium carbide particles, *Advances in Production Engineering & Management*, Vol. 9, No. 4, 159-167, doi: 10.14743/apem 2014.4.184.