The Effect of laser melting on the gray cast iron surface roughness

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Abstract

Some of surface engineering processes used to manipulate the surface properties associated with undesirable features. In this work investigation of the effect of processing variables on the average surface roughness (Ra) of gray cast iron melted by CW diode-fiber Yb:YAG laser. Power intensity (I), time of interaction (t), and gas flow rate (g) were used as variables. It is found that for power intensities that maintain melting, decreasing time of interaction or increasing shrouding gas flow rate or increasing both of them led to increased average surface roughness.

Introduction

The surface condition of a component is usually the most important engineering factor affecting its performance. Almost inevitably the outer surface of a workpiece is subjected to wear, fatigue and corrosion while it is in service [1]. Average roughness (Ra) is important feature of the surface. It contributes slide wear, friction, corrosion, oxidation, fatigue, physical properties (optical, electrical, and thermal properties) and esthetic [2].

Laser as a source of high concentrated heating energy was used successfully in surface treating of ferrous material products [3- 6]. Laser heating or melting induces phase transformation and structural changes, also low distortion with minimal disruption. Heating rates in laser melting are orders of magnitude higher than conventional methods. So temperature gradients are developed radially between the pool center and the cooled substrate in the order of 10^2–10^4 K mm^{-1}. Consequently rapid cooling rate will lead to structural changes as grains refining, solubility increasing and stabilizing of metastable phases [7]. These changes affect the surface roughness either negatively or positively that is depending on the processing set of parameters. Laser processing variables comprise that related to laser source (power intensity, operation mode and wavelength) and to the material (physical properties, surface absorptivity and geometry) in addition to laser scanning speed and shrouding gas flow rate. [8]. To avoid post processing and get preferred surface roughness the relation between laser parameters and surface roughness is to be investigated for a given material. Many researchers study the effect of laser cutting and heat treating parameters on surface roughness [9-13].

According to DIN, EN, ISO 4287, ASME B46.1 average surface roughness (Ra) represents the arithmetic average of the absolutes of the roughness profile ordinate.

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Methods and Materials

Gray cast iron was used with chemical composition as listed in **Table 1**. Samples of 80mm long, 40mm width and 5mm thickness were cut from automobile brake flange. The surface average roughness of as received samples is 1.23µm and its microhardness is 200Hv.

Table 1. Chemical composition of as received gray cast iron.

Fe	C	Si	Mn	P	S	Cr
Base	3.79	1.88	0.677	0.0441	0.107	0.124
Al	Co	Cu	V	Mo	Ni	
0.007	0.0031	0.184	0.0045	0.0118	0.0517	

Experimental Methods

A solid state continuous wave Yb: YAG fiber laser with 600W maximum power and λ =1080nm was used for surface melting of the specimens. Gaussian mode was used with different focus distance to get different beam radius and then different power intensities; four traverse speeds were applied to get different times of interaction. Argon flow rate ranged between 0 and 20 standard litter per minute (SLPM) was delivered during processing as shrouding gas. Table 2 shows processing parameters. Where (I) is power intensity, (g) is shrouding gas flow rate, and (t) is time of interaction. Each specimen was processed with three tracks with the same parameters to get the average response of them.

Table 2 Process parameters values.

Sample No.	I (W/mm2)	g (SLPM)	t (s)
L1	44.45	0	0.66
L2	62	10	1.32
L3	81.15	20	0.76
L4	84	5	0.96
L5	117	20	0.48
L6	134	10	0.096
L7	187	0	0.19
L8	215	20	0.15

One specimen was covered by laser tracks with 20% overlapped to suite Spectrometry and XRD testing requirements. And to investigate the effect of laser processing on the elementary composition and on contained phases.

Laser processing followed by sectioning the specimens transversely into many samples. Metallography analysis was done using optical microscope type MTM-IA, and electron microscope type VEGA3LM. Phase analysis was carried on for sample with overlapped tracks by X-Ray Diffractometer type SHIMADZU XRD-600, and composition analysis was done by spectrometer type FOUNDRY –MASTER. Average surface roughness (Ra) was measured at temperature 30°C by portable surface roughness gage "pocket Surf® III". Selection of Ra parameters switch, 5mm traverse length and 0.8 cut offs were done.

Result and Discussion

Elementary analysis

The result of the spectrometry analysis of the sample in **Fig. 1** (with 20% overlapped laser tracks) is listed in **Table 3.** It indicates that the gray cast iron which used is hypereutectic according to its content of carbon and silicon [14]. And after laser processing the composition didn't affected, the little difference in composition is due to the segregation phenomena associated with gray cast iron. Also it indicates that the laser parameters which used in this research didn't cause evaporation of any of the constituent elements.

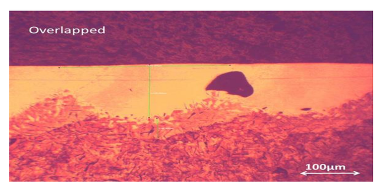


Fig. 1. Micrograph of processed sample with 20% overlapped laser tracks.

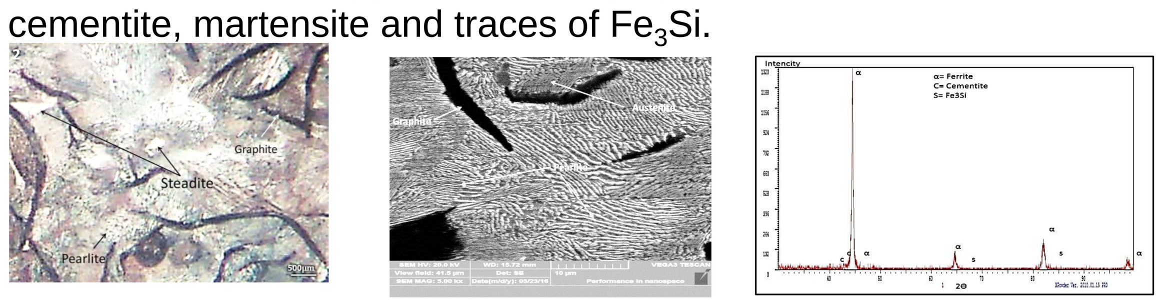
Table 3 : Chemical composition of laser processed gray cast iron.

Fe	C	Si	Mn	P	S	Cr
Base	4.02	1.91	0.667	0.034	>0.28	0.154
Mo	Ni	Al	Co	Cu	V	
0.005	0.047	0.007	0.008	0.154	0.008	

Microstructure and XRD analysis

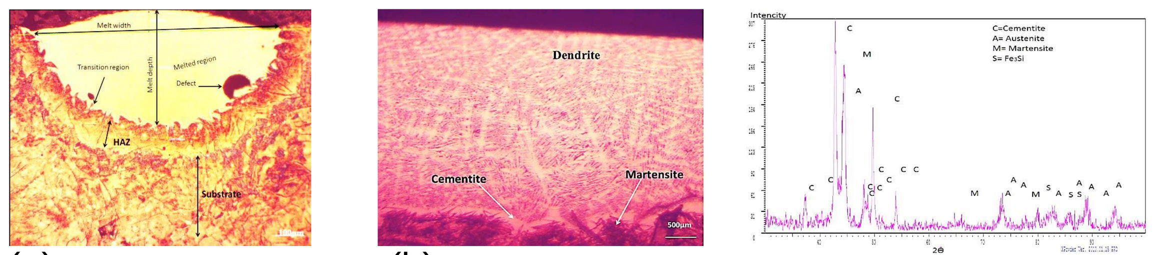
An optical microscope shows typical microstructure of as received gray cast iron which declared in **Fig.** 2(a) and SEM analyses in **Fig. 2(b**). It reveals that the microstructure contains flake graphite in matrix of pearlite/ferrite in addition to spaces of steadite. Flake graphite distributed regularly and oriented randomly as type A in the classification of ASTM 148A [13], and its volume fraction is within the range of 8-12%. **Fig. 2(c)** Represents XRD analyses which insist the presence of ferrite phase as well as cementite in addition to graphite and peaks with low intensity related to steadite.

While the micrograph of laser melted sample in **Fig. 3** reveals that the processed surface consists of four zones: the melted zone with completely disappearance of graphite and existence of, transition zone containing martensite and refined graphite surrounded by cementite, as indicated in Figure 4 (b) of SEM micrograph, heat affected zone with partially dissolved graphite which compensated by appearance of cementite, and the fourth zone is unaffected substrate. XRD analyses of laser processed sample in Figure 5 declared occurrence of phase transformation, disappearance of graphite and existence of retained austenite, cementite, martensite and traces of Fe_3Si.



(a) (b) (c)

Fig. 2.: Microstructure of as received gray cast iron. (a) Optical micrograph, (b) ESM micrograph. (c) : XRD analysis of as received gray cast iron



(a) (b) (c)

Fig. 3 : Microstructure of gray cast iron after laser melting. (a): Optical micrograph, (b): SEM micrograph.

Surface roughness

Surface roughness measurements and microhardness of the samples are listed in Table 4.

Table 4: Processing parameters via average surface roughness of laser melted gray cast iron specimens.

Sample No.	I (W/mm2)	t (s)	g (SLPM)	Ra (µm)	Hv kg/m²
1	44.45	0.66	0	1.63	280
2	62	1.32	10	1.24	811
3	81.15	0.76	20	3.13	652
4	84	0.96	5	1.2	626
5	117	0.48	20	1.83	601
6	134	0.096	10	4.99	694
7	187	0.19	0	4.45	792
8	215	0.15	20	4.46	859

The result indicates that phase changes were happened. And it is due to the rapid solidification and bulk quenching. And the new structure induces properties changes as microhardness and surface properties in different degrees which visualized in **Table 4**. It is clear that the processing variables affect mentioned features

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Conclusions

For laser irradiance that maintains melting gray cast iron it is found that:

-- Reducing time of interaction led to increasing Ra.
-- Increasing shrouding gas flow rate increases Ra.
-- The combination of reducing time of interaction and increasing shrouding gas flow rate increases Ra.

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References

R. Groningen, "Laser treatment of alloys: processing, microstructure and structural properties", MSC PhD thesis series 2007-01, Netherland Institute for Metals Researches.
2- ASM, International, "Introduction to surface engineering for corrosion and wear resistance", Ch. 1, (2001).
3-S. Razi, M. Mollabashi, K. madanipour. "Nanosecond laser surface pattering of bio grade 316L stainless steel for controlling its wettability characteristics", IJOP, Vol.9, No. 1(2015).
4- J. Dossett and G.E. Totten. "Introduction to surface hardening of Steels", ASM Handbook, Vol. 4A, Steel heat treating fundamentals and processes, (2013).
5-M. Denys, K. Martin, H. Sarka, K. Robin, "Application of shifted laser surface texturing", Metal, Jun 3rd – 5th, (2015).
6=S.S. Bhavikatti, S.S. Pardeshi, P.K. Mishra, "Investigation for hardening of cast iron using low-power fiber laser", International J. of Engineering & Innovative Technology (IJEIT), 2(2012).
7-J.C. Ion, "Laser processing of engineering materials", (2005).
8-R.H. Khanjar, " Analysis of gray cast iron microstructure and hardening by using Yb:YAG Laser", PhD Thesis series 2016-10,University of technology-Baghdad.
9- D.A. Nikam, M.T. Shete,"Optimization of surface roughness in laser cutting of mild steels", A Review, Inernational conference on electrical, electronics, and optimization techniques (2016). PP 67-71.
10-E.G. Lopez, A.G.M. Telez, J.R. I. Medina, H.R. Siler and C.A. Rodriguez, "Experimental study of back wall dross and surface roughness in fiber laser microcutting of 316L miniature tubes", MDPI Micromachines (2018).
11-R.M. Mahmood & E.T. Akinlabi, "Effect of laser power on surface finish during laser metal deposition process", WCECS, Vol.11 (2014).
12- V. Senthilkumar, G. Jayaprakash, M. Thilak, , "Parametric analysis of laser cutting of mild steel material", JCPS, Vol.10, Issue1 (2017).
13V. Senthilkumar, G. Jayaprakash, "State of art of laser cutting process", International Journal for modern trends in science & technology, Vol.3, Issue 4, (2017).
14- R. Elliot BSc, PhD, "Cast iron technology", (1975).

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