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STEEL SURFACE LASER MELTING PARAMETERS OPTIMIZATION

OPTIMALIZACE PARAMETRŮ LASEROVÉHO PŘETAVOVÁNÍ POVRCHU

Abstract

Laser beam with power density 10^2 W.mm^{-2} causes metal surface melting without material vaporization. Temperature gradient between melted spot centre and solid state boundary is formed, surface structure is changed. Cooling rate affects melted zone microstructure. In result, surface quality, porosity, homogenization, mechanical and chemical resistivity are improved. Laser melting parameters optimization of steel samples was made by means of pulsed solid state laser with average power 100 W. Energy, pulse length, feed speed and laser beam diameter were subsequently changed. Melted traces on steel surface were analyzed to discover microstructure and dimensions of affected zones. Result dependence on process parameters was evaluated and optimal parameters were chosen.

Abstrakt

Laserový svazek s hustotou výkonu řádově 10^2 W.mm^{-2} způsobuje natavení povrchu kovů bez odpaření materiálu. Vzniká teplotní gradient mezi středem natavené stopy a rozhraní s pevnou fází, mění se struktura povrchu. Rychlost ochlazování ovlivňuje mikrostrukturu natavené oblasti. Výsledkem je zlepšení kvality povrchu, např. nízká porosita, homogenizace, zvýšení mechanické a chemické odolnosti. Na laserovém systému jsme provedli optimalizaci parametrů natavení povrchu vzorků z oceli ČSN 11 373 pomocí pulsního Nd:YAG laseru s průměrným výkonem 100 W. Proměnnými byly postupně energie a délka pulsu, rychlost posuvu a průměr stopy svazku. Natavené stopy byly podrobeny analýze pro zjištění mikrostruktury a rozměrů ovlivněných oblastí. Byla zjišťována závislost těchto výsledků na použitých parametrech procesu a vybrány jejich optimální hodnoty pro daný materiál.

1 INTRODUCTION

Laser melting is one of the surface treatment applications, when absorbed radiation causes microstructure changes in thin surface layer to improve their properties [1].The melted region exhibits low porosity and few imperfections, and has a sound metallurgical bond with the substrate. The energy input is low, causing little distortion to a component, which reduces or eliminates the need for post-melting finishing operation [2]. Aim of our experiments was to find optimal parameters

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for melting on pulsed Nd:YAG laser with average power 100 W. For the first estimation of parameters we used available material steel ČSN 11373, EN 10025, S235JRG2 with chemical composition (table 1):

Tab. 1 Chemical composition of steel ČSN 11373 (EN 10025)

C	Mn	P	S	N	Cu	Al	Cr	Mo	Ni	Cr+Mo +Ni
max 0,17	max 1,40	max 0,035	max 0,035	max 0,012	max 0,55	max 0,020	max 0,30	max 0,08	max 0,30	max 0,48

The main variable is surface power density Q_e , recommended between $10^2 – 10^4$ W.cm^{-2} . In case of pulsed lasers, quotient of energy and pulse length determines peak power, that influes penetration to the material [3]. The same peak power, charging in diffrent values of energy an pulse length, causes different penetration to material. Feed speed of sample is the external parameter that affects interaction time and laser spot overlap at constant pulse frequency, used values varied from 46 to 78 %. These four variables – pulse energy, pulse length, laser beam diameter and feed speed were tested on steel samples by constant frequency 7 Hz. Spot dimensions were analyzed by available modern devices – contact profilometer TALYSURF and laser confocal microscope LEXT. Spot microstructure in cross section will be analyzed to discover changes in material phases and hardness.

2 EXPERIMENT

2.1 Surface melting dependence on energy

Sample with dimension 50 x 50 mm was positioned on the XYZ table with speed 3,6 mm /s. Five traces were melted with constant beam diameter 1,2 mm and pulse length 10 ms, energy varied from 5,4 J to 9,3 J (table 2), peak power from 0,54 kW to 0,93 kW.

Tab. 2 Energy variable values

trace no.	1	2	3	4	5
energy (J)	5,4	6	7,2	8,25	9,3
density Q_e (J/cm^2)	276	306	367	421	474
peak power (kW)	0,54	0,6	0,72	0,825	0,93

Cross diameter (from 1,12 to 1,37 mm) and high of melted trace (8 – 15 μm) increase with energy as was expected and that is illustrated by surface analyze trace no.5. Efficiency laser spot area decrease with energy, trace no.1 has inconvenient profile with hollows along trace boundary (fig.1).

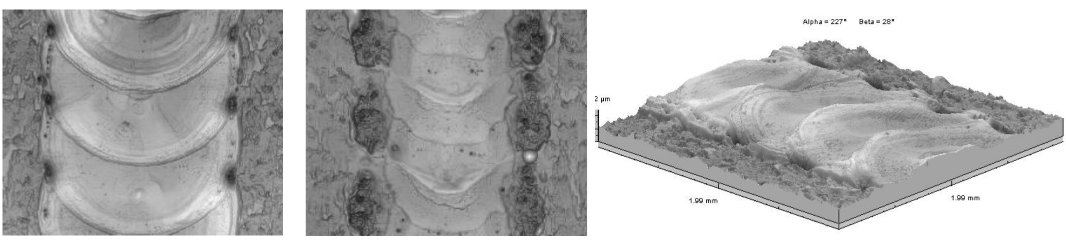

Fig. 1 2D and 3D photo simulation of the trace no.5 and no.1, energy dependence.

2.2 Surface melting dependence on beam diameter

With constant energy E = 10,52 J, feed speed v = 3,6 mm/s and pulse length t = 10 ms laser beam diameter was variable. It is power of the focus plane distance from material, depending on beam divergence. Diameter varied from 1,11 mm to 1,43 mm (table 3), with lower energy density decreases trace high from 20 μm to 6,35 μm.

Tab. 3 Beam diameter variable values

trace no.	1	2	3	4	5
diameter (mm)	1,11	1,18	1,27	1,34	1,43
density Q_e (J/cm^2)	699	610	534	471	418

2.3 Surface melting dependence on pulse length

With constant feed speed v = 5,6 mm/s, beam diameter D = 1,27 mm and peak power 1,1 kW six traces with increasing pulse length and energy were applied (table 4). Observations were made by laser confocal microscope LEXT with magnification 240 x, radial cracks in single spot of trace no.6 are seen in fig.2.We can compare possibilities of contact and non-contact optical scanning [4].

Fig. 2 Detail of laser spot in trace no.5.

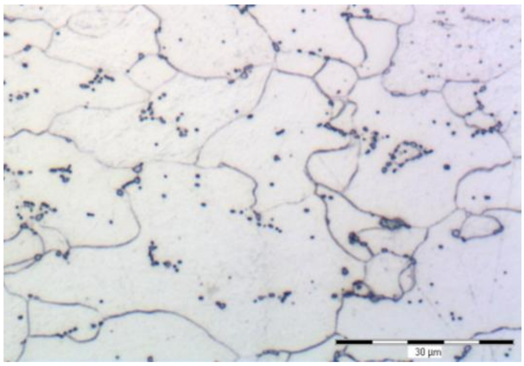

Fig. 3 Microstructure of basic material.

Tab. 4 Pulse length variable values

trace no.	1	2	3	4	5	6
pulse length (ms)	5	6	7	8	9	10
energy (J)	5,5	6,5	7,38	8,3	9,6	10,6
density Q_e (J/cm^2)	279	330	374	421	487	538

2.4 Surface melting dependence on feed speed

Despite of all laser parameters are constant, energy E = 10,8 J, f = 7 Hz, t = 10 ms, increasing feed rate decreases pulse overlap and interaction time of laser beam and material (table 5). The highest overlap 78 % creates smooth melted trace with minimal sum of high and depth.

Tab. 5 Feed speed variable results

v (mm/s)	2,4	3,6	4,8	6
pulse overlap	78 %	67 %	57 %	46 %
high + depth (μm)	20	24,5	26	35,4

3 CONCLUSIONS

Four processing parameters influence on dimensions and microstructure of melted zone in carbon steel ČSN 11 373 was tested in experiment with pulsed Nd:YAG laser. The main variables are: peak power above 1 kW in 10 ms long pulse and power density above 5.10^2 J/cm^2 with sufficient overlap of laser spots 1,2 mm in diameter ensure smooth and high melted trace. Surface measuring were made by profilometer TALYSURF and laser confocal microscope LEXT. Microstructures analyze in cross section detected dimensions of heat affected zones and phase changes in basic material (fig.3, 4). Melted zones were measured in microscope with magnification 75 x (table 6).

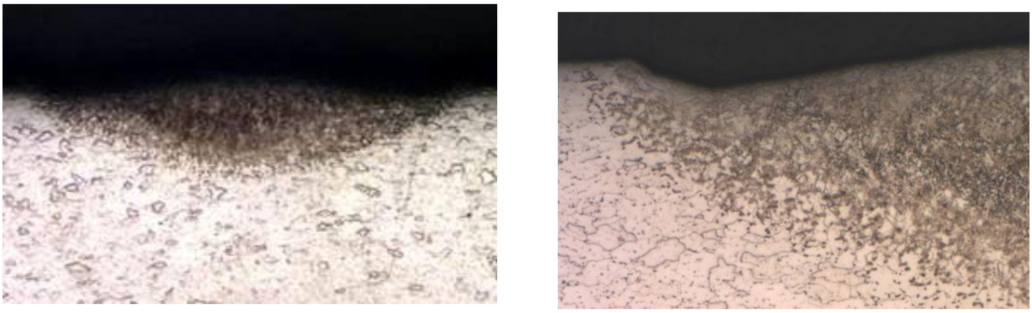

Fig. 4 Cross section of trace melted with energy E = 12,7 J, magnification 30 x and 100 x

Tab. 6 Dimensions of melted zones in cross section dependent of energy

E (J)	7,8	9,4	10,6	12,7
zone width (mm)	1,22	1,3	1,36	1,39
zone depth (mm)	0,242	0,304	0,322	0,374

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REFERENCES

[1] STEEN, W. M. *Laser Material Processing.* 2nd ed. London : Springer, 1998. 236 pp. ISBN 3540761748.

[2] ION, J.C. *Laser processing of engineering material.* 1st ed. Oxford: Elsevier, 2005. 264 – 265 pp. ISBN 0 7506 6079 1

[3] IFFLANDER, R. *Solid-State lasers for Material processing.* 2nd ed. London : Springer, 2001. 233-236 pp. ISBN 3540669809.

[4] CHMELÍČKOVÁ, H.& LAPŠANSKÁ, H. & HIKLOVÁ, H. & HAVELKOVÁ, M. Srovnání kontaktního a optického měření povrchu laserem natavených vrstev. *Jemná mechanika a optika.* 2007, LII. Nr.11 – 12, pp. 307-310. ISSN 0447-6441.

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