3D SCANNING LASER HARDENING

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Abstract

The laser scanning method uses a small laser spot in combination with a laser scanning head. The method is based on a very fast laser beam sweeping executed by the scanning head perpendicularly to the main laser treatment trajectory. The fast sweeping beam acts like a continuous wide laser spot. The method can be advantageously used on parts, which cannot be processed by a “wide-spot” standard laser hardening method. Experiments with a solid state disc laser of maximum power of 5.3 kW and laser scanning head allowing spot displacement speed up to 21.5 m/s are presented. Capabilities of the method are demonstrated on laser hardening of a small hole inner surface, which cannot be processed by a standard laser hardening method. The aim of this work is to demonstrate advantages of 3D scanning method for processing of the complex, hardly reachable parts.

Keywords: Laser hardening, laser quenching, 3D laser scanning, laser scanning, surface treatment

1. INTRODUCTION

Laser hardening has proved to be a very competitive method of material heat treatment [2,3,4]. It differs significantly from the conventional methods of heat treatment. The important feature of the laser hardening is the absence of a cooling medium. Laser radiation acts as a heat source and it heats up rapidly the surface of a part under the laser spot during a short time of the laser-surface interaction [1]. Consequently, the heat absorbed in the surface layer is conduced immediately into a material bulk. The part can be hardened by the laser radiation only in a surface layer, approximately to one tenth of material thickness. The hardened surface can reach a very high hardness due to very rapid heat dissipation. The maximum achievable depth of hardened layer is about 2 mm without melting of the surface (in dependence on the treated material properties, geometry of the part and laser beam parameters) [5,8].

Laser hardening with scanner is a new method of laser processing, which is especially useful for processing of small parts or hardly reachable places [6]. Using laser beam scanning method makes possible to achieve a very precise and fast processing of 3D parts, it helps to achieve a minimal heat affected zones and it minimizes distortions. Gaussian spot profile with smaller size from hundreds of micrometers, to several millimeters in focus is used in contrast with a standard laser hardening [7]. It allows higher control over the process. Hardened area is heated rapidly by quick scanning of the laser beam. Even very complex regions of limited size can be processed as a whole piece. It is necessary to choose the right amplitude, oscillation frequency and traverse speed. Burns occur at the edges of the processed area (oscillation amplitude peaks) due to the limited dynamic of the scanning optics. The burns can be eliminated by switching off the laser on the edges.

The scanner is able to deflect a laser beam with speed above 20 m/s, **Fig. 1a**. High traversing speed is assured by rotating mirrors, with a very low mass and inertia. Only a slight rotational movement of mirrors is converted to very quick linear movement of laser beam on a treated surface, **Fig. 1b**. Difficult to reach areas can be treated thanks to a large working distance. These systems are used mainly in the automotive industry currently. Processes like remote laser cutting, welding or marking are executed by the scanners, which are often fixed to a wrist of an industrial robot for these applications.

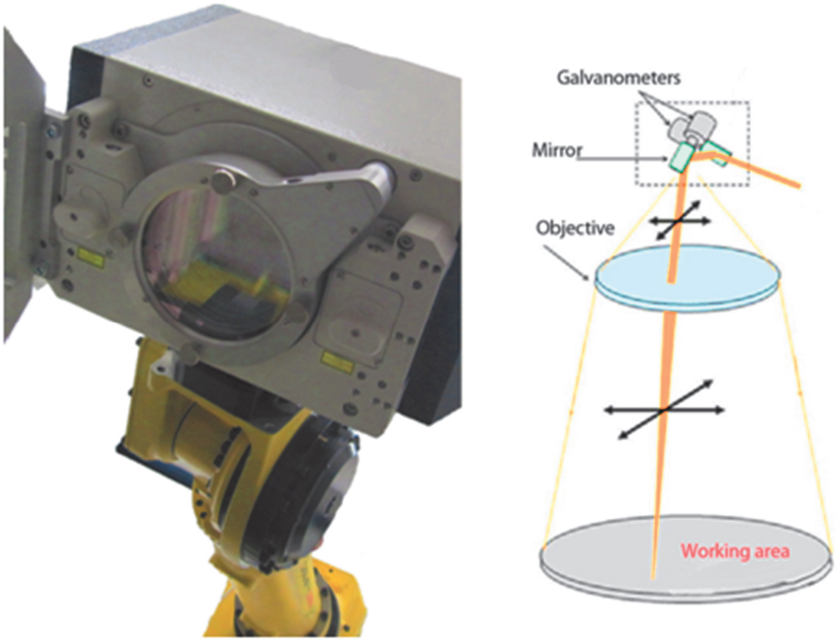

Fig. 1 (a) Scanner mounted on the arm of industrial robot for remote processes; (b) Basic schema of a scanner system

The scanning method is convenient especially for processing of complex parts. The scanner allows changing a width of the processed area easily during the process. Scanning software allows very precise control of energy distribution in the processing area and thus very complex treating patterns can be produced. Processing time is significantly shorter for scanning method. Processing time affects the depth of the hardened layer. Spot size can be modified using a varioscan (z-axis movement).

The process of laser hardening can be easily controlled according to a surface temperature. This value in conjunction with a time period of maintaining the temperature is the main quality quantifier. The surface temperature can be controlled or maintained very precisely thanks to possibility of repeated scanning in a short period of time.

2. EXPERIMENTAL PROCEDURE

2.1 Scanning laser hardening system

Laser system for surface treatment consists of Trumpf disk laser Trudisk 8002 and 3D-scan system ScanLab intelliWELD 30 FC V (scan head - **Fig. 1a**). The laser emits a beam of wavelength 1030 nm. Spot size 800 um was used for first application tests. The maximum laser power is 5.3 kW. Working distance of the scanning optics is 544 mm and the focal length is 460 mm. The scan head is able to process an elliptical image field of dimensions 385 x 270 mm, the maximum laser beam deflection speed is 21.5 m/s. The scan system collimation in z-axis is allowed in range of ± 70 mm. The scanning procedure is controlled by RobotSync Unit or by SAMLight software. Positioning of the scanning head is realized by industrial robot Fanuc M-710iC.

2.2 Experimental procedure

Firstly the processing procedure was based on a low speed laser beam movement in x-axis (laser hardening progress axis) and high speed oscillations in y-axis (perpendicularly to the direction of the laser hardening progress). The amplitude from 1 to 8 mm and the oscillating frequency from 300 to 1000 Hz were the most suitable parameters for the first testing. These procedures brought very similar results to those achieved by conventional “wide beam” laser hardening [9]. The tests were performed using RobotSyncUnit software. Although burrs occurred on the edges of the processed area and the software disallowed any suitable setup variations. It was necessary to find another way to control the scan head.

The scan head was coupled with scanning control software SAMLight. This software allows adjustment of the shape of the processed area and selection of a hatch pattern type. Two different procedures were used [9]. The first one procedure was based on scanning the beam in the rectangular area with dimensions of 20 x 10 mm, **Fig. 2 (a)**. The second procedure was based on scanning the circle (with chosen diameter 10 mm) contour and moving over the selected trajectory with a set speed, **Fig. 2 (b)**. The shape of circle was chosen because the scanning head is able to guide laser beam without speed fluctuation over the whole circle trajectory. The hardening tests were performed on plain samples with dimensions of 100 x 50 x 25 mm from steel ČSN 12050.

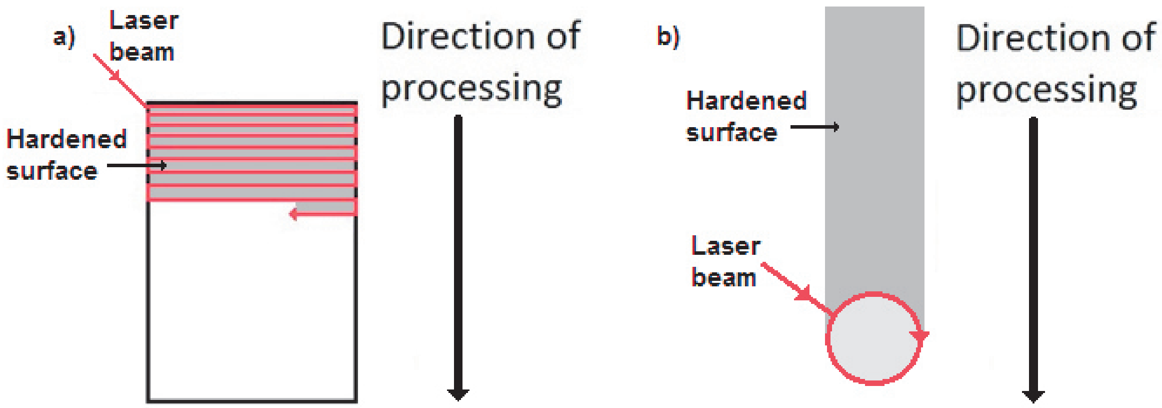

Fig. 2 Scheme of scanning procedures - the first one (a) and the second one (b)

The performed tests were used to find suitable parameters, which allowed achieving a similar hardening depth as a standard “wide-spot” laser hardening. The all previous tests were performed on a plain surface of the sample. The next step was to implement laser hardening procedure on a characteristic 3D part. The procedure was tested on a small hole inner surface hardening, because it is not possible to process similar shapes by standard laser hardening system. The hole diameter was 10 mm. The hole cannot be processed at once, because the scanner cannot reach the whole inner surface of the hole. Therefore, the inner surface had to be divided into two parts, which are processed separately. Model of cylinder jacket was created in a 3D software. The model was exported to the scanning software SAM Light. Scanning of the demanded area has been achieved by appropriate positioning of the scan head, the area was processed according the first one procedure.

3. RESULTS AND DISCUSSION

Following results have been obtained by implementing of the two scanning methods. The first method is based on hatching of a rectangular contour. Measured surface hardness of the hatched area is satisfying and its distribution is very homogenous, **Table 2**. The Second scanning method uses moving of the laser circle pattern over the treated surface. However, this procedure did not bring satisfying results, **Table 1**. The surface hardness was lower and it was not distributed so uniformly. Significantly lower hardness was measured on the edges of the hardened area. From this reason, the first scanning method was preferred in further tests.

As one can see in **Table 2** excellent surface hardness values have been achieved by scanning laser hardening method. Regarding the surface treatment, it is necessary to monitor another important parameter - depth of hardened layer. Depth of hardened layer about 1 mm was achieved by scanning laser hardening method. For standard laser hardening method a hardened layer of depth about 0.5 mm was produced as described in previous research [9]. From this comparison follows that the results of the scanning laser hardening method are fully satisfactory from the point of view of hardening depth. The relations between the depth of the hardened layer and process speed upon constant specific energy are showed on **Fig. 4**.

Table 1 Scanning laser hardening - scanning the circle pattern, Dimension A is parallel to direction of processing

Test no.	Power [W]	Dimension A [mm]	Dimension B [mm]	Process time [s]	Specific energy [J/mm^2]	Surface hardness [HV5]
1	1000	20	10	10.05	50.6	494±44
2	1000	20	10	2.06	10.37	502±10
3	1000	20	10	3.39	17.06	644±17
4	1000	20	10	5.04	25.37	507±27
5	500	20	10	5.04	13.36	328±4
6	500	20	10	10.5	26.63	303±6

Table 2 Scanning laser hardening - hatching of square pattern, Dimension A is parallel to direction of processing

Test no.	Power [W]	Dimension A [mm]	Dimension B [mm]	Process time [s]	Specific energy [J/mm^2]	Surface hardness [HV5]
1	1000	10	20	11.58	57.9	564±14
2	1000	10	20	14.24	71.2	644±13
3	1000	10	20	12.71	63.55	599±18
4	1500	10	20	8.5	63.75	584±11
5	1000	10	20	14.6	73	497±15
6	1000	10	20	14.2	71	533±19
7	1000	10	20	17.73	88.65	533±18

It is evident from **Fig. 4** that the optimal process speed can be found for given specific energy, which the highest depth of hardening can be achieved for. When the speed is too high, the surface layer cannot be heated up to sufficient depth. On the contrary, too low process speed causes heating up of the whole peace, so proper quenching cannot take place.

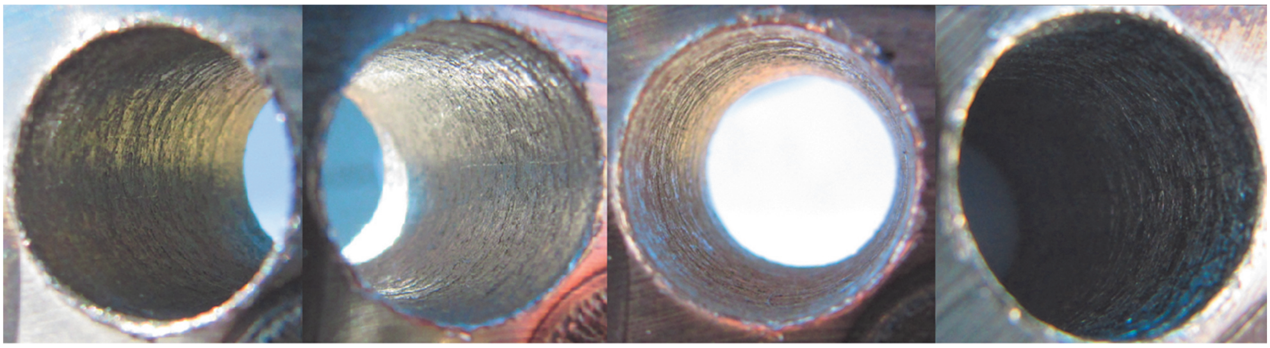

Fig. 3 The 3D part selected for scanning laser hardening parameters.

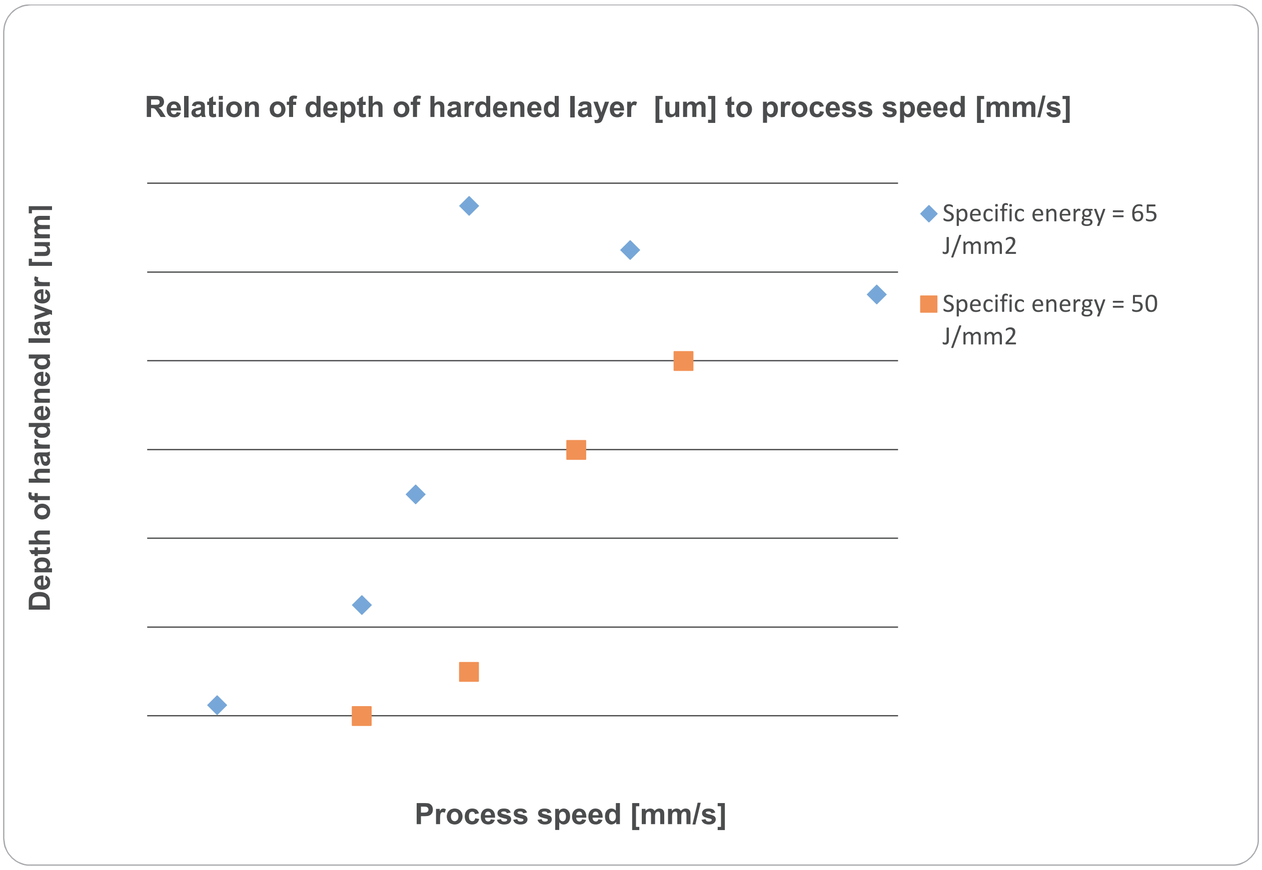

Fig. 4 The Relation of the depth of the hardened layer to process speed upon constant specific energy

The values represented by blue diamonds were measured for lower specific energy than those symbolized by red squares. **Fig. 3** shows the 3D part chosen for demonstration capabilities of the scanning method. The inner surface of the hole was scanned by laser beam.

SUMMARY

The capabilities of 3D scanning system were first proved in 2D applications. Perfect results were achieved for hardening of plain surface. Successful processing of 3D part depends on software setup and possibilities of scanning head. The 3D model of the processed part must be created and hatched in proper way. Than it is important to position the scan head properly, so it will be possible to scan the required area with preciously controlled speed. Deflective (Guiding) speed of scanning head is seriously limited in z-axis. So it is important to have in mind this finding.

The main goal of the work was to verify abilities of scanning laser hardening on the characteristic 3D part. Application tests on the 3D part were accomplished and its metallography analysis is in progress currently. Surface hardness couldn't be found because of hardly reachable measuring area.

Laser scanning hardening is very interesting technology, which has a high potential to be used in complex 3D parts processing. Other possibilities of the method will be researched in future study.

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