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Industrial Paper

Coaxial Laser Hardening of Bore Holes

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Abstract

An inductive hardening process of bore holes with small dimensions is critical to handle. Problems are distortion, melting of edges and a fast wear of the inductor. Laser hardening leads to a more stable and controllable process. However, a good accessibility of the beam to the surface is necessary. It's a challenge at classic laser hardening of bore holes. A new idea is the use of a tiny angle between the laser beam and the inner faces. The angle results out of the divergence of the laser. It leads to a high absorption of the P-polarized radiation. The new system technology will be shown in this paper. Furthermore, hardening results will be presented and discussed.

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1. Introduction

The surface hardening process of bore holes and inner surfaces of work pieces with small dimensions is critical to handle. Typically, inductive hardening is state of the art for such applications, which can be found at e.g. fuel pumps, camshafts or valves. Problems are distortion as well as a melting of edges. Another critical fact is a fast wear of the inductor, especially if the holes have small dimensions.

A new idea for surface hardening of small bore holes and inner surfaces is needed. It's known that temperature-controlled laser hardening leads to a very stable and controllable process [1, 3]. Melting of edges or distortion are normally no problem. However, a good accessibility of the laser beam to the surface is necessary. For bore holes that's critical [2]. Known laser technologies are using mirrors, like discussed in [2].

The idea presented in this paper is the use of a tiny angle between the laser beam and the inner face of the work piece without mirrors. The tiny angle results out of the divergence of the laser beam and beam forming by two axicon. It leads to a high absorption of the P-polarized laser radiation at the work piece faces. In particular, angles between 15° and 25° reach best results. For applications with hole diameter between of 5 and 15 mm a new optical system was developed. Properties are:

- Creation of different circular laser beam diameters (donut); adjustable to the bore hole size
- Movable collimation (beam moving) to realize hardening of long hole lengths
- Temperature-measurement by the use of an pyrometer for a controllable heat demand

The idea of the new and patent pending system technology will be shown in this paper. Furthermore, hardening results will be presented and discussed by the use of hardness measurements and micro sections. A potential for further applications will be given.

2. System technology for coaxial laser hardening of bore holes

The system design of the coaxial hardening device is basically the design of a standard laser processing optic with a collimation and focusing lens added by two axicon lenses to form a ring shaped beam profile in process

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area. In [2] a similar technology can be seen. To ensure that the beam can move in axial direction through the workpiece the focusing lens is also movable in axial direction.

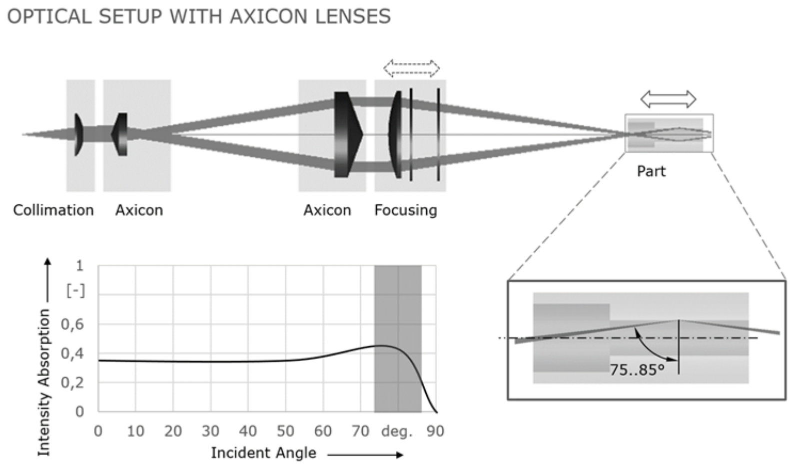

Fig. 1. Experimental Setup for coaxial laser hardening of bore holes

Due to the optical design the incident angle of the laser beam on the workpiece is always between 75 and 85 degrees. As shown in figure 1, this incident angle leads to a high absorption rate. The fact that nearly 100% of the laser emission hits the workpiece surface ensures a highly efficient process, which needs a minimum on heat input and therefore produces a minimum of distortion on the workpiece. The design is suitable for various borehole diameters from 3 to 10 mm, borehole depths from 5 to 40 mm and is even applicable for blind holes.

3. Process technology for coaxial laser hardening of bore holes

3.1. Experimental setup

For experimental validation of the coaxial laser hardening a simple optic of the series “Scansonic BO” was used and modified by two axicon which are located between the collimation and focusing lens. It results into the formation of a donut spot by using a disc laser with λ = 1.030 nm and a fiber of d = 0.6 mm. The angle of the flanking beams to the hole is ~ 20°. The used material for the hardening tests is a C45 carbon steel cylinder with a length of l = 30.0 mm and a diameter of d_{out} = 35.0 mm. The diameter of the bore hole is d_{in} = 8.0 mm. The samples have through and blind holes. Figure 2 shows the main information. Hardness results were measured by the use of a Vickers Hardness Test. Other sample geometries and process parameter were investigated for different customers. These results will not be discussed.

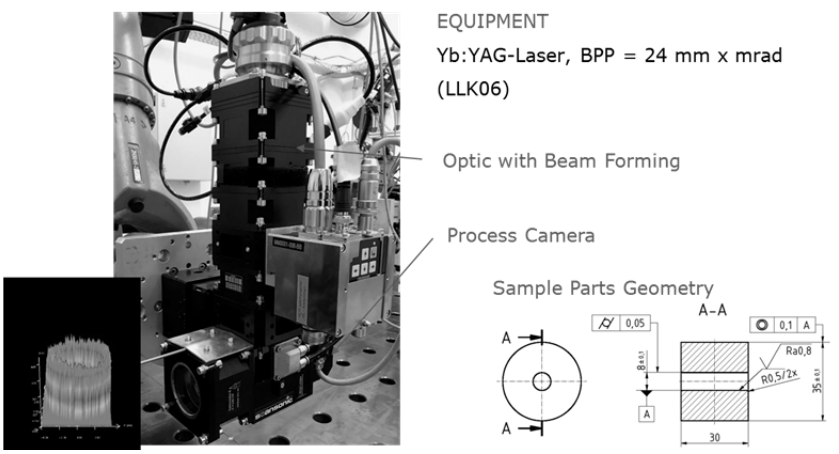

Fig. 2. Experimental Setup for coaxial laser hardening of bore holes

3.2. Results and discussion

At constant parameter for laser power and velocity still good results are possible. At the sample hole a maximum hardness of HV1 > 700 and a hardness depth of > 1mm was reached. But, along the hole depth the hardness values are fluctuating. At the beginning of the heat treatment the material needs a higher laser interaction time or a lower velocity. Figure 3 demonstrate the results by hardness measurements. The upper diagram demonstrates the radial hardness in a distance of 2mm from the sample edge. The lower diagram shows the axial hardness in a 1 mm distance to the bore hole. Possible reasons for the fluctuations could be a misalignment of the laser axis to the sample axis or different surface properties as well as a different heat conduction based on the sample geometry.

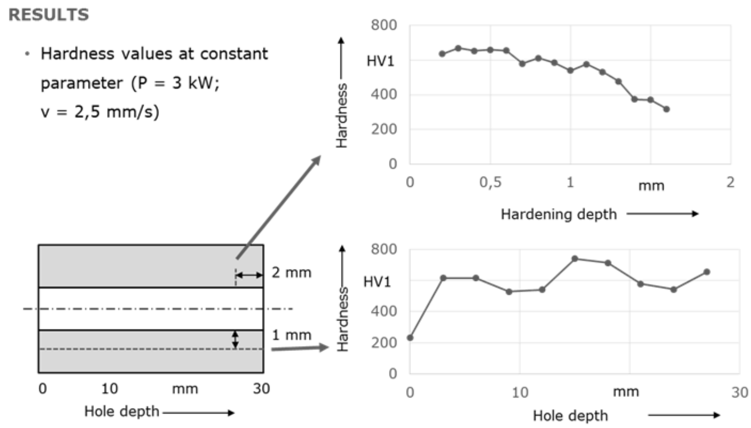

Fig. 3. Hardness values inside of a hole at constant parameter for laser power and velocity

Based on these results the hardening process was stepped into several areas which need several process parameter. Results of a thermal simulation were used. With this strategy it is possible to realize more stable hardness values along the bore hole axis. In figure 4 the hardened area of two samples can be seen.

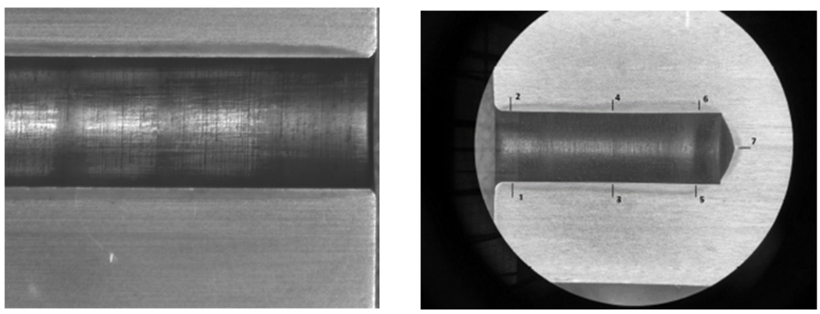

Fig. 4. Micro sections of laser hardened holes

However, a completely controlled laser hardening process will lead to a further stability. In next development steps a pyrometer and a PID controller will be implemented. At a constant velocity the laser power will be adjusted automatically to reach a constant heat input and constant hardness values along the bore hole depth.

4. Potential applications

The technology has a high potential for hardening of small holes with an aspect ratio between diameter and length of ~ 5. Typical applications are valves, holes in camshafts, crankshafts or fuel pumps. At all parts only a low distortion is allowed and the use of conventional hardening technologies are limited.

References

[1] Becker, S.; Kranhold, A.: Laserstrahl-Remotehärten. In: Der Wärmebehandlungsmarkt 1/2015. 22. Jahrgang, Print 01, Page 5-8.

[2] Bloehs, W.: Laserstrahlhärten mit angepaßten Strahlformungssystemen. Dissertation IFSW, Teubner, Stuttgart, 1997

[3] Elsner, C.: Laserhärten von Powertrain-Komponenten, In: Proceedings of EALA2013, Bad Nauheim, 2013