ACTIVE THERMOGRAPHY INSPECTION OF WELDING LASERS SCANNING HEAD PROTECTIVE GLASS

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Abstract

Technological lasers are a useful tool for laser welding as well as other material treatment and production processes. Lasers with an optical scanning head are the important group of technological lasers. A protection glass of the scanning heads can be contaminated during technological operations. This results in properties change and degradation of the glass and subsequent production quality reduction. Active thermography is one of the methods, which can be used for the protection glass inspection. The method uses external thermal excitation of the glass and detection of its response by an infrared camera. Experiments performed showed that a pollution of the protection glass can be inspected using flash-pulse thermography. Experimental set-up for the flash-pulse thermographic testing and results of tested samples inspections are presented in the contribution. Possibilities, advantages or disadvantages and possible development of the thermographic inspection of laser scanning heads protection glasses are discussed.

Keywords: Laser beam welding, active thermography, inspection, infrared testing, protective glass

1. INTRODUCTION

Technological lasers are a modern and useful tool for material treatment and production processes. The laser technologies are successfully used for example for welding, cutting, hardening and many other technological operations, which are introduced for example in [1] or [2]. Lasers with scanning heads are the important group of technological lasers. These laser systems use optical scanning heads, which scan a focused laser beam at a high speed over a whole processed area.

Laser scanning heads have a protection glass, which protects inner parts of the head. The laser beam passes through the protection glass, which must therefore have specific properties according to a used laser system. The fundamental requirement is for example a maximum transmissivity for the used laser beam wavelengths range. Quality and properties of the laser scanning heads protection glasses are generally solved from the point of view of their production process. However, development of an industrial application of the laser technologies brought the problem of how to evaluate the protection glasses degradation during their operation.

This problem can mostly occur in laser technologies, where by-products are produced during a laser beam interaction with a treated material. The by-products can be for example fumes, metal vapors or spatter, which cannot be removed by air cross-jet. This effect occurs typically at laser welding [3] for example. The by-products can contaminate the protection glass and adversely affect its functional properties [4]. Undesirable absorption of the laser beam on a contaminated glass causes its local overheating and can lead to a change of optical properties or complete damage of the glass. It can be also connected with significant financial losses due to the possible laser system damages or final products quality decreasing. An early detection of a protection glass contamination is therefore significant especially in the case of mass-production facilities, where a quality of whole production series of product can be affected.

Quality inspection of the laser heads protection glasses is generally performed during their production. An inspection in the course of their operational service in a production process is performed mostly visually at the time of production shutdowns. However, the visual inspection has disadvantages and is not effective in some cases. Our experiments have shown a possibility of using active thermography [5] for a laser glass inspection. The used method is based on a flash-lamp thermal excitation with a simultaneous infrared camera analysis of the inspected object. The method is fast and non-contact and a simple inspection system arrangement is expected. Thus, it gives a possibility of an industrial use of this technology. The inspection principles based on a thermal excitation and infrared detection have also an advantage compared to a visual inspection, because glass transmissivity defects in the infrared wavelength range are more important than in the visible range for considered applications. A higher detectability of the active thermography method is therefore expected compared to a visible inspection.

An experimental study focused on possibilities of laser glass inspection by the active thermography method was therefore performed and the results are presented in this contribution.

2. REMOTE LASER WELDING AND PROTECTION GLASS CONTAMINATION

Laser beam welding (LBW), which is more in detail described in [3] or in [6], is the advanced technology of fusion welding. It is the popular technology in both scientific research and industrial applications. Laser beam welding expanded the possibilities for design and manufacturing of new products, which could not be produced by conventional methods. LBW can produce sound welds of different types, both extremely thin and thick blanks. The laser beam welding is frequently used for example in automotive industry [7], where a continuous innovation enables rapid implementation of advanced technologies to a mass production. Using LBW makes it possible to weld aluminium alloys [8], plastics [9], different types of steels [10], copper or titanium. Thus, it can be used for various applications in mechanical and electrical engineering.

Laser beam welding is based on complex physical-metallurgical processes, which are derived from the interaction of the laser beam of defined properties with welded objects materials. Laser causes heating of these materials over their melting point. The locally melted materials are then fused and solidified after passing through the laser beam.

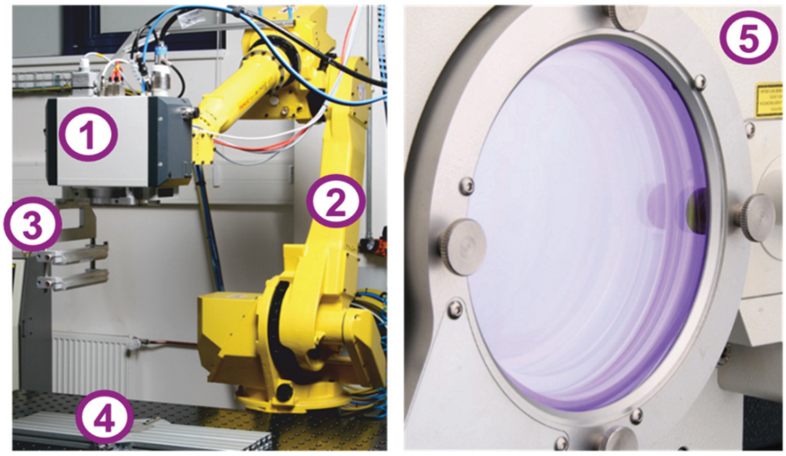

Figure 1 RLBW robotic system: (1) laser scanning head, (2) industrial robot, (3) cross jet, (4) welded parts, (5) laser scanning head protection glass detail.
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The laser beam is guided on the workpiece surfaces along a weld trajectory during the welding process. A conventional robotic laser welding uses a robotic arm, which moves the laser processing head along the weld trajectory. Remote laser beam welding (RLBW) [7], which uses technological laser scanning heads, extended significantly flexibility and accuracy of the conventional robotic LBW. RLBW uses scanning heads with dynamically positioned optical parts, which makes it possible to scan the laser beam along the weld trajectory. The technological laser scanning heads are usually mounted on a robotic arm as well, as shown in

(**Figure 1**). It allows to produce welds of spatial trajectories even at very high processing speeds and on positions, which would be not accessible for the conventional laser welding heads.

The laser scanning optics inside the head should be protected against a contamination or damage caused by the by-products produced during the welding process. Thus, the scanning heads are equipped with an air cross-jet (active protection) and protection glass (passive protection), which are shown in (**Figure 1**) - parts (3) and (5), respectively. The protection glass should have specific properties, especially a maximum transmissivity in the wavelength range of the laser beam. Even if the active protection is used, the contamination of the protection glass can take place. It is mainly caused by condensation of fumes of molten welded material on glass surface and also by weld spatter particles.

The contamination can change optical properties [4] and affect the transmissivity of the glass. Increased absorption of the laser radiation on the glass can cause a local overheating, which leads to degradation of the glass or to its complete damage. In the case of industrial applications it results to a poor weld quality and time consuming breaks in a production process. In extreme cases a damage of internal components of laser processing head can take place. A visual inspection or special sensors are therefore applied for the glass transmissivity and contamination monitoring. However, these inspection procedures are sometimes not efficient and other inspection methods are therefore developed.

3. ACTIVE THERMOGRAPHY INSPECTION

Infrared thermography [11] is an analytical technique for non-contact measurement of temperature fields. The thermography can be classified as qualitative or quantitative and passive or active. In the case of passive thermography, temperature contrast or the temperature changes are of natural origin. An external excitation source is applied on analyzed objects in the case of active thermography [12]. The excitation causes a temperature contrast connected with thermal properties local differences, surface and subsurface defects or local heat sources concentration. These differences can be quantified directly or using advanced evaluation techniques, for example lock-in or flash-pulse thermography. The active thermography is the basic technique in materials inspection and defects detection, i.e. material infrared non-destructive testing (IRNDT). Theory and practice overview of the infrared thermography using for non-destructive testing is widely written in [13], reviews of thermography temperature measurement methods and infrared non-destructive testing procedures are in [14] or [15] for example.

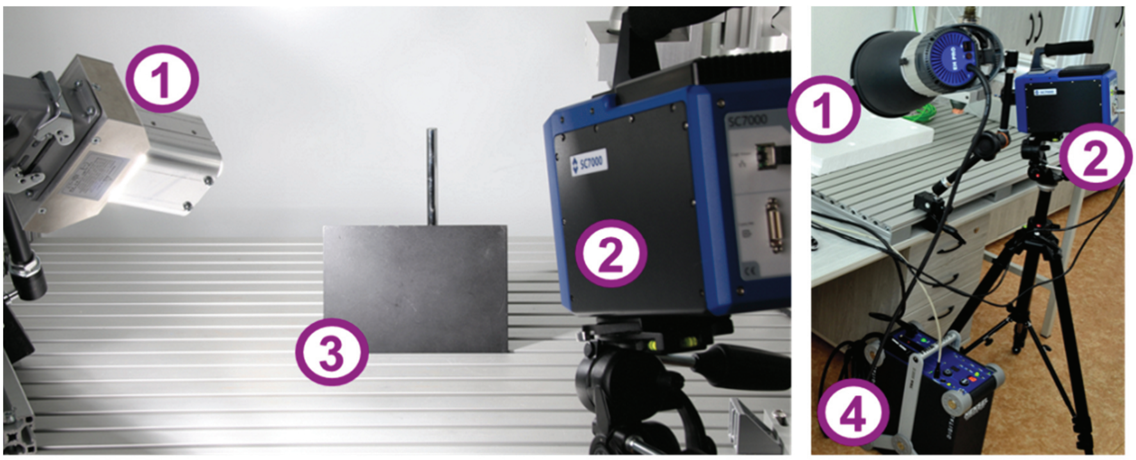

Figure 2 Flash-pulse system for non-destructive thermographic inspection: (1) different types of flash lamps, (2) high-speed infrared camera, (3) tested sample, (4) high-power flash-pulse generator. (*University of West bohemia, New Technologies - Research Centre*)

The excitation of an inspected sample can be external or internal. A direct heating using a continuous, modulated or pulsed source is one of commonly used excitation methods. Halogen lamps or lasers with amplitude and frequency adjustable light power are used for lock-in thermography (see [16] or [17]), lasers or flash lamps are used for flash-pulse thermography (see [18] or [19]). The flash-pulse thermography is based on the inspected object excitation by a very short light/thermal pulse produced by a flash lamp or laser. The pulse length is normally a few milliseconds and the material response should be detected by a high-speed high-sensitivity cooled-type infrared cameras. However, the flash-pulse thermographic methods allow to inspect very different materials in depths from the surface up to several millimeters under the surface [20]. Thus, the flash-pulse inspection system could be suitable for detection of a thin dirt layer on the protection glass. An example of a system set-up for thermographic flash-pulse inspection is shown in (**Figure 2**).

4. LASER GLASS INSPECTION EXPERIMENTS AND RESULTS

Laser welding experiments were performed on an industrial laser welding system. The system consists of a disk laser Trumpf TruDisk 8002, Scanlab IntelliWeld 30 FC V technological scanning head and an industrial robot Fanuc M-710ic. The Trumpf TruDisk 8002 is diode excited solid-state disk laser with a maximum output power 8 kW emitting laser beam at wavelength 1030 nm. The laser beam is transmitted to the technological head by a flexible optical fiber. Different technological heads can be connected to the laser: a cutting head, a welding head or the scanning head for remote welding. The scanning head is mounted on the robotic arm and the whole assembly is controlled and synchronized by the control system, which allows both static and on-the-fly welding. The scanning head optics is protected by a fused silica glass protective window of the diameter 134 mm and thickens 3 mm, which is shown in (**Figure 1**) - part (5).

Several protective glasses with a different level of contamination were analyzed. We performed the analysis using an IRNDT flash-pulse thermography system, which consists of flash lamp with a flash-pulse generator of maximum output power 6 kJ, high-speed high-sensitivity cooled infrared camera with a maximum frequency 100 Hz at "full window" and up to 600 Hz in a sub-window mode (values for the IRNDT system), synchronization and control unit and a control software, which makes it possible to evaluate the flash-pulse measurement by different methods.

Each sample was illuminated by a flash pulse from the outer side (the contaminated side) and its thermal response was detected by the IR camera and analyzed by different evaluation methods. The flash-pulse energy was absorbed differently on a clear and contaminated glass surface. The sample thermal loading from the flash-pulse is very low - the sample is usually heated in the order of tenths of Kelvin or of several Kelvins. However, the small temperature response differences caused by the flash-pulse absorption differences could be detected and evaluated using the high-speed high-sensitivity IR camera and advanced evaluation methods offered by the measurement system control software. The IRNDT results are compared with photo-records made using an optical scanner device.

An example of results of the protection glass inspection performed by the optical scanner and IRNDT flash-pulse technique is presented in (**Figure 3**). A contamination of the glass together with a laser irradiation influence resulted in a number of dark spots on the protection glass. These spots formed due to local overheating of the glass cannot be removed. The spots decrease transmissivity of the glass and thereby affect the laser welding process. Their higher absorptivity also causes further local overheating of the glass and its progressive degradation. The spots can be found on the photo-record made by the optical photo-scanner. However, their evidence is not too expressive and also the inspection using the optical scanner could be more complicated. The spots are very contrast and clearly detectable on the IRNDT evaluation record (the longitudinal structures on the IRNDT record are caused by a background and have not connection with the inspected sample). The IRNDT inspection is very fast - the measurement including the evaluation takes a few tens of seconds only. Another advantage is that the measurement and evaluation procedure in not too complicated.

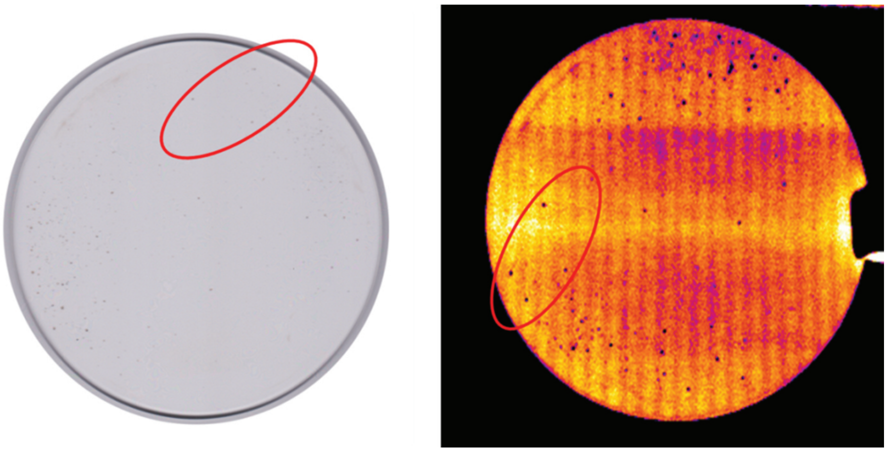

Figure 3 Contaminated protective glass: picture made by an optical scanning system and IRNDT inspection evaluation results. Scanner made photography is left, IRNDT record is right: dark spots are dirt; longitudinal structures are caused by a background and have not a connection with the inspected sample.

5. CONCLUSION

The remote laser beam welding procedure and the related problem of a laser head protective glass contamination were briefly described in the contribution. A visual inspection of the glass is not so evident and has higher requirements for an operator skills or experimental configuration. The flash-pulse active thermography (flash-pulse IRNDT) was introduced as the alternative inspection technique. It was shown, that the flash-pulse IRNDT inspection is capable to identify a contamination of the inspected glass. The results example presented was very evident with a high contrast of contaminated positions. The flash-pulse IRNDT method is effective and the evaluation is relatively simple. Thus, the IRNDT method could have a potential for an industrial implementation.

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