Real time Diagnostics for Depth of Penetration in Laser Beam Welding Process : Review

[1]Rajesh V. Patil, [2]Ashok P. Tadamalle and [3]Dr. Pradeep J. Awasare

[1]Dept.of Mechanical Engineering, Sinhgad Institute of Tech. & Science, Pune, India
[3]Dept. of mechanical Engineering, Zeal College of Engineering, Pune, India
[1]patilraje@gmail.com, [2]ashok_ p_t@yahoo.com and [3]pgawasare@rediffmail.com

***Abstract* - Laser beam welding is very much popular in Microsystems technology by its precise parameters. Generally it is characterized by transient nature and very short duration of the process. For real-time applications, the model should be computationally efficient and relate critical but unmeasurable variables such as weld bead penetration to easily measurable variables such as the surface temperature. So for accurate real time tracking and inspecting, the wide range of reliable sensor, such as CMOS, CCD, Infrared, Ultra violet and Photodiode based with high performance are extremely demanded in laser welding process. Penetration depth is most important parameter to fulfill the criteria of expected weld bead in laser beam welding. This article describes research review on online measurement techniques is use for identify weld quality (i.e. penetration depth) in real time and control system control the geometry of the weld pool and to prevent defects in laser beam welding.**

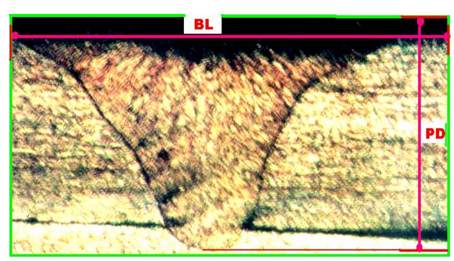
Keywords - Penetration depth, Photodiode Sensor, CMOS Sensor, Online Process, Control system, Literature Review

I. INTRODUCTION

Welding with laser beams is characterized by high specific power input into the work piece by focusing the laser beam in the vicinity of the work piece surface. Thereby the material is not only molten, but also vaporized forming a capillary with plasma in it. The result is a narrow seam with a higher penetration depth compared to conventional welding techniques. Innovations in the area of micro and nanofabrication have created opportunities to manufacture structures at the micro and nanometer scales. The opportunities can be used to fabricate electronic, optical, magnetic, and biological devices ranging from sensors to computation and control systems. Conventionally, the quality of the weld is ascertained only after the welding has been completed. A lot of time, material and manpower is wasted before one comes to know about the soundness of the weld quality and also when thick section welding is required, real-time quality monitoring is therefore a key issue in laser welding These limitations can be overcome if the weld is continuously monitored in real time for the assessment of defects using appropriate sensors So wide range of sensor has been popular for monitoring the laser welding processes with its unique advantages and limitations.. Weld monitor function is based on the collection of infrared light emission directly from the weld pool, and the conversion of these emissions to an electrical signal that can be analyzed by computer software and displayed in voltage amplitude versus time format. Main aim of weld monitor is to identify bad welds in real time and rejects them. For manufacturing, aerospace, automotive and electronic industry reliability of welding processes and monitoring becomes necessary for production of safety relevant parts.

II. DETERMINATION OF DEPTH PENETRATION

Laser welding formation process is the focal spot is targeted on the weld joint surface by adjusting focal length above or below the weld target, at the surface is subjected to the enormous amount of concentrated light energy, which is converted into thermal energy which results into melting of surface and progresses through the weld joint by thermal conductance, after this process finding out quality of bead weld and its totally depends on quality of weld bead geometry i.e. depth of penetration ,Bead length and bead width. So online monitoring process is efficiently work for the excellent quality of weld.



"Fig.1" Schematic of Bead Length and Depth of Penetration

III. LITERATURE SURVEY

Laser beam welding is a highly flexible tool represents in many applications. For accurate real-time tracking and inspecting, the high-performance sensors are extremely demanded in laser welding process. Generally the camera imaging techniques and photodiode based sensor technique are demandable in laser welding process. Camera images contain information on the two-dimensional spatial distribution of the emitted process radiation and photodiode in combination with an optical filter is a fast sensor which is sensitive to a specific spectral region.

A. Photo detector Based Sensor

The spectral regions that are analyzed mostly with this kind of sensor set-up are the IR-region and the UV and visible spectral region. The IR region is related to the surface emissions of the melt pool and the UV and visible region is related to the plasma/plume. Ultraviolet (UV), visible or infrared (IR) detectors, has been widely used to converted the flux density of the radiation emitted by the welding process into an electrical signal. Optical filter is often placed in front of the detector to confine the spectral ranges of the whole sensor system. Diode infrared and near-infrared lasers that can serve as an ideal heating source are particularly suitable for micro/nano texturing of sensitive materials because of the low thermal load on the components and the non-contact nature of the process. This type of detector is a high temporal resolution of the recorded signals and a low price compared to other devices like spectrographs or cameras

- IR Sensitive sensor with off axis viewing monitors the melt ejection from the weld pool and also correlated with the amount of porosities in the weld.[1],[2]
- UV and IR spectral range with off axis viewing detection of keyhole failure, overheating and lack of penetration.[3]
- Coaxially measured reflected laser radiation is correlated with the penetration depth and porosity formation.[4]
- Measured in the UV/ Visible spectral region were analyzed for their temporal frequency contents by Fourier analysis, During full penetration welding a smaller frequency band was found than during partial frequency. [5]
- Reflected laser radiation is measured at seven different off axis positions. The signals are correlated with penetration depth. Finally coaxial viewing is suggested. [6]
- Correlation of axis and coaxial measurements with penetration depth and full penetration welding detection at a spectral wave length of 300 to 680 mm. [7]
- Photodiodes to explain the relationship between the plasma and spatter and bead shape according to the welding variables. Through a correlation between these signals and weld quality, they developed a multiple regression analysis and neural network to estimate the penetration depth and width of the weld bead. [15]

B. Camera imaging technique as Sensor

CCD, CMOS camera or array sensor has been often used to monitor the continuous process.CMOS camera is advantageous because of to use defined regions of interest on the chip and conversion of light intensity to voltage is not linear but logarithmic. By using high resolution, digital CMOS sensors and high-speed, real-time image processing technologies monitored signal reliability can be significantly increased.

- Plasma radiation was measured coaxially using a high speed CCD camera .The two dimensional spatial intensity distributions allows for monitoring of the weld depth, full penetration, seam defects and spatter. [8],[9]
- In this model, the absorbed laser power is based on the power meter reading, assuming 100% power absorption, to obtain penetration depth estimates. This assumption would lead to errors in depth estimates because the power absorbed is usually unknown.[10]
- In this paper, the problems associated with power measurement are eliminated by measuring temperature on the bottom surface of the work piece and relating **it** to the penetration depth. For *this* purpose, the depth estimation model proposed by author is extended to construct a relationship between penetration depth, weld bead width, welding speed, and temperature distribution. [11]
- Measured temperatures along the weld bead using an infrared camera and compared the results with an analytical model obtained using Green’s functions. They concluded that the measured temperatures depend on weld penetration but did not indicate how to estimate penetration from the measured temperatures.[12]
- The keyhole stability was investigated using a high speed camera to determine the weld Quality.[13]
- Light emissions from plasma plume were monitored using photo sensors to determine the laser weld quality.[14]

C. Control system in Laser Welding Process

Using on line monitoring of geometry of the weld pool by computer vision can detect tiny defects of the weld pool, and then control system is able to control the geometry of the weld pool and to prevent defects.

- Using the laser power as input to the process used a temperature measurement (pyrometer) at the back side of the work piece in CO2 laser welding. With PI controller the authors where able to prevent the weld from penetrating the material. [17]
- Developed a feed back control system based on CCD images. The penetration depth was controlled by keeping the weld pool length constant and using the laser power as input. The system was able to control the penetration depth during an artificially applied laser power disturbance. However the response time of the system was approximately 1 s, which is too slow. Faster camera systems are suggested by authors.[18]
- Demonstrated a feedback control system for CO2 laser welding. The frequency response of the welding process was estimated and with it a PI controller was designed and turned. The system was able to minimize the influences of focal shifts and mechanical defects in the weld[20]
- Applied a predictive control scheme to control the penetration depth, using the laser power as input. A neural network with as external model was trained to predict the necessary laser power, based on the intensity measurements from a coaxial camera ,the desired penetration depth and the welding trajectory. [16]
- Developed closed loop system by using the average plasma intensity from a CCD image of the keyhole front. Applied a CCD camera to estimate the penetration depth. with a controller the weld depth during bead on plate laser welding was maintained. The laser power as input power as input on the laser welding process.[19]

IV. DISCUSSION

- It is observed that using a camera system, reliability of prediction of the weld bead quality and monitoring precision can significantly be increased as compared to conventional system.
- Ability of control system is to fulfill the criteria of control the geometry of the weld pool and to prevent defects.

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