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# Stereo vision based measuring system for online welding path inspection

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ABSTRACT

A welding path measuring system (WPMS) is developed in order to achieve better understanding of the welding execution of the critical welds or weld deposits in multi-pass and repair welding. The developed WPMS system measures the arc position in 3D space based on the stereo vision principle. The time sequence of arc positions shows a 3D welding path in time, which bears information on how the weld or deposit was welded. Test welding was carried out in order to validate the developed system and to demonstrate how the welding path reveals simulated irregularities in the groove shape and in the electrode motion. The simulated irregularities are visible as anomalies in the welding path. A method for their automatic detection based on the welding path distribution along the weld was proposed.



## 1. Introduction

For maintaining the quality of the critical welds and weld deposits, significant welding parameters should be monitored on-line and recorded in welding diaries according to the ISO 15609-1 standard. To automate this task, on-line monitoring of electrical welding parameters e.g. voltage and current is widely spread and already embedded in more advanced welding systems. If not, welding systems can be upgraded with voltage and current sensors, microcontroller based data acquisition and signal processing as was demonstrated by Lebar et al. (2012). The correct welding path is also important in multi-pass and reparative welding, where each weld pass should be properly shaped and positioned with respect to the previous deposit to ensure mechanical properties and to prevent the occurrence of slag, cracks and other defects. Ensuring the correct welding path is not problematic in automated welding systems, where the set-up of welding parameters, welding paths and speeds are well-defined and small deviations from the specified path are corrected by seam tracking systems. However, automated welding systems with seam tracking are not always a suitable choice in deposit welding and especially in one-of-a-kind production of large parts. There still exists a lot of manual welding where the welding path is entirely dependent on the welder and thus subject to irregularities. Current market trends urged the need for on-line measuring and inspecting the welding path in non-automated and manual welding. In order to resolve the issue of the unknown welding path, an additional on-line welding path measuring system was needed. The welding path should be measured with contactless method, operating from a safe distance to prevent damage of measuring equipment and not disturbing the welder. When observing the open arc welding from a distance much larger than the arc size, e.g. more than 1 m, the motion of the electrode tip is virtually the same as the arc motion. By measuring the arc motion the welding path can be acquired.

A camera based imaging system is the most advantageous choice for measuring the arc motion. In this paper, a stereo vision based welding path measuring system operating as a supplement to the established on-line monitoring of electrical welding parameters was developed (see Fig. 1). The combination of the welding path measuring system and on-line monitoring of electrical welding parameters has several advantages: a better understanding of weld execution, on-line identification of the welding path non-conformities and consequently, targeted post welding non-destructive testing where irregularities occur.

Ogawa (2011) reviewed the application of high speed imaging to aid the understanding of arc welding phenomena. The imaging systems primarily monitor the phenomena related to the arc, weld pool and electrode tip. The measuring equipment they employ typically consists of a single camera, lens and a narrow pass light filter in front of the lens. The role of the filter is to cut off extreme light

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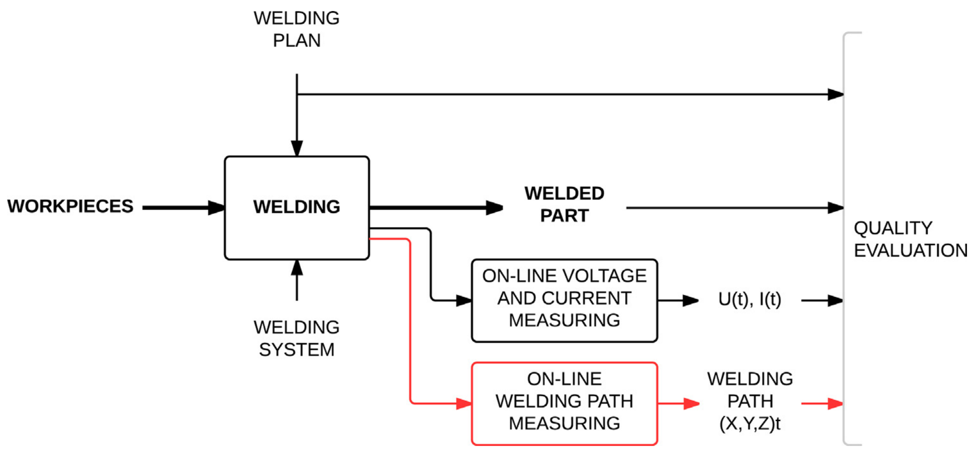


**Fig. 1.** Welding path measuring system (WPMS) is a supplement to on-line monitoring of electrical welding parameters.

flashes of the arc and to pass only specific wavelengths, typically in the infrared part of the light spectrum emitted by melted metal. Filter based systems are monochromatic systems because they only observe the wavelengths of interest from the emitted spectrum. A color camera is used when an analysis of the entire emitted spectrum is desired. Defect detection with CCD-spectrometer and photodiode-based arc-welding monitoring systems was studied by Mirapeix et al. (2011).

Saeed (2006) summarizes the use of imaging systems in sensing the weld pool state. The ability to observe and measure weld pool surfaces in real-time is the core of the foundation for next generation intelligent welding that can partially imitate skilled welders who observe the weld pool to acquire information on the welding process. Zhang et al. (2013) developed an innovative vision system to project a dot-matrix laser pattern on the weld pool surface in order to measure a three-dimensional weld pool surface in real-time. Wu et al. (2004) developed a vision-based sensing and determination of the weld pool geometrical appearance during the gas-metal arc welding process in order to correlate the surface geometrical appearance of weld pool to the weld penetration and to calculate the prerequisites for process control. Ma et al. (2010) developed a measuring system based on binocular vision sensor to detect both the weld pool geometry and root gap simultaneously for robot welding process.

Additive manufacturing based on gas metal arc welding is an advanced technique for depositing fully dense components with low cost. Techniques to achieve accurate control and automation of the process, however, have not yet been perfectly developed. The online measurement of the deposited bead geometry is a key problem for reliable control. Xiong and Zhang (2013) developed a passive vision-sensing system, comprising two cameras and composite filtering techniques, in order to achieve real-time detection of the bead height and width through deposition of thin walls.

Sun et al. (2005) developed a real-time imaging and detecting system to detect weld defects in steel tube. In the extracted weld seam, based on spatial characteristics near defects—variance and contrast, defects such as slag, blowholes and incomplete penetration are automatically detected using the method of fuzzy pattern recognition. Li et al. (2008) developed visual measurement and inspection of weld bead and defect detection in multilayer welding based on laser structured light vision. The imaging applications play an important role in automated welding systems for seam tracking.

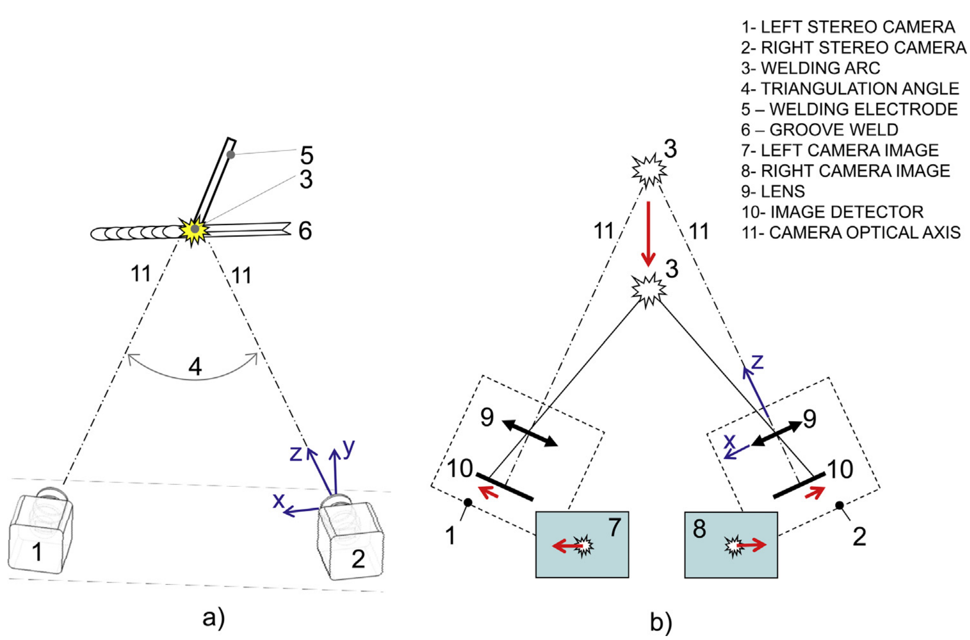


**Fig. 2.** Measurement setup (a) and operation principle (b).