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Research Article

DESIGN AND MANUFACTURE OF A NEW TWO AXES WELDING SEAM TRACKING SYSTEM USING LASER SENSOR FUZZY LOGIC CONTROL

Hayrettin DÜZCÜKOĞLU[1], Ömer AYDOĞDU[2], Ahmet ÖZTÜRK[3], Harun AKKUŞ*[4]

[1]*Mechanical Engineering, Faculty of Technology, Selcuk University, KONYA;* ORCID:0000-0002-7016-6888
[2]*Electrical and Electronics Engineering, Selcuk University, KONYA;* ORCID:0000-0002-1961-2272
[3]*Machine Program, Artvin Coruh University, ARTVIN;* ORCID:0000-0002-5560-0578
[4]*Automotive Technology Program, Amasya University, AMASYA;* ORCID:0000-0002-9033-309X

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ABSTRACT

In this study, a welding seam tracking system that is unique to the three axes (X-Y-Z) controlled application with laser sensor was put into practice. In the study, the monitoring of the planar axes (X-Y) of the torch was done by Fuzzy Logic Controllers that best model the specialist information the. The height of the torch to the welding piece (Z axis) was arranged by classic proportional control method. In order to do the welding properly in welding implementations, the torch and the welding bend have to move along the predetermined way (Y) in a constant linear speed. In certain conditions, due to the shift in the piece to be welded or a sloped profile, the harmony of the welding bend and torch may be disrupted. Furthermore, in “S” shaped pieces with no linear welding line for which the welding point constantly changes and the motors providing tracking in the two axes (X and Y) to which the welding torch is connected cannot properly respond to these changes of these materials may become scrap, unwanted repairs could be required, quality may decrease and loss of time may occur. In this study, a higher quality welding process in planar surfaces was realized by combining the laser path tracking system with Fuzzy Logic control algorithm for each of the axes (X-Y) in order to prevent these undesired situations. The designed system ensures that the X and Y motors take positions swiftly for abrupt changes in the welding seams on the profile, thus tracking the profile to be welded in the best way possible for a proper welding practice. The welding intersection results show that the practiced system yields very good results.
Keywords: Welding, seam tracking system, fuzzy logic control.

1. INTRODUCTION

In the past decade, many novel techniques have been developed for automated welding process [1-3]. The success or failure of welding operation is influenced by many factors such as the thickness of the materials to be welded, the chemical element composition of the welded material, the surface treatment of the weldment, the thickness of the weldment, the width and the depth of the welded seam, the pre-heat treatment before welding, the welding path, the speed of welding, and the welding method [4].

* Corresponding Author: e-mail: harunakkus@windowslive.com, tel: (358) 260 00 60 / 6316

Sensors are required to de termine whether the workpiece is located correctly with respect to the welding torch, or whether distortion of the workpiece takes place due to thermal expansion during welding. Laser sensor systems are used for monitoring in the welding process because of their high speed, high resolution and high accuracy. Weld seam by monitoring the weld pool in pulsed Nd:YAG laser welding. The vision sensor observed the weld pool, and the weld seam was extracted from the image of the monitored weld pool. Experiments were carried out to find the appropriate moment of shutter triggering for relatively clear images. Seam tracking was successfully performed by using the information of the pool centerline in the edge joint, while the shape and brightness of the weld pool gave the first step toward the information on the status of weld quality [5].

A seam tracker for following the small gap between closed butt plates. A CCD monochrome video camera with a coherent fiber-optic bundle used to view the workpiece. Illumination is provided by an infrared laser diode mounted on the tracker head. The video signal from the camera is digitized and stored in a microcomputer which analyses the image to obtain the position and width of the gap [6].

A welding monitoring and control process was proposed as follows [4]. The initial step is to use CCD equipment to obtain images of the actual weldment and welded seam. Fuzzy theory and edge-operator-detection methods are then used to generate the gray level feature factors and the membership function of the image. This information is input into decision-making logic, which, through linear regression, determines the correct welded seam coordinates. These coordinates are transferred to the control code of the NC machine to correct the welding process. Laser beam light onto the welded seam and then captured the reflected image of the laser beam. Neural theory and fuzzy theory were used to judge the quality of the welded seam, so as to control the welding parameters [7].

Many studies use laser sensor to monitor and control in process. Nowadays, many academicians and companies are interested in welding processes to reduce cost, improve quality, and obtain high efficiency. Unfortunately, most computational methods for complex machining systems require significant computational resources to evaluate each parameter of a multi-variable subject function. No method currently results in the same level of efficiency for all process.

Artificial neural network method applications in welding processes were done to take the uncontrollable parameters under control [8]. Furthermore, image processing methods were developed by using artificial neural networks as well to improve the welding process [9-10].

Fuzzy logic control is fundamentally based on fuzzy set theorem [11]. Fuzzy logic controllers are used as non-linear elements in control systems that cannot be completely modeled but can be defined verbally [12]. Fuzzy controllers are effective approaches to the control of changing complex structured and inadequately defined systems. Besides, there is no systematic method in the design of fuzzy logic control systems. Therefore the success of the designed controller depends on the knowledge and skills of the specialist person. Since it is fairly difficult to fully and accurately model the physical systems, using fuzzy logic controllers that are not based on models in the control of these systems became very widespread in our day [13-14]. Similarly, welding processes are practices that have a lot of changing parameters and using fuzzy logic approach in controlling these systems is suitable.

The most significant advantage of using welding seam trackers is the improvement of the welding quality via high sensitivity automatic tracking. During the welding operation, the laser sensor constantly scans the welding area and ensures the welding electrode is always lined on the desired point. Consequently, the welding is applied to the target points with better results compared to the other methods. Thus, the errors on the welded materials can be decreased and the welding penetration on the intersection point yields results in expected standards.

In the presented study, the goal is to determine the optimal torch position by using laser seam tracking sensor and subsequently to follow the welding seam as accurately as possible via using fuzzy logic controllers. So, the most important aspect of this study is using the Fuzzy Control method in controlling the to rch position. The obtained results show that the proposed fuzzy logic control yields very good results compared to similar studies presented in the literature.

2. SYSTEM OF ORBIT FOR WELDING SEAM

The main purpose of welding seam tracking systems is actually determining the welding space's geometry by the laser sensors and controlling the torch position by following the welding seam via the x-y mobilizers (motors) on the plane. Furthermore, height of the torch from the surface to be welded is another important parameter to be controlled.

Affordable laser sensors were developed intensely in the last decade and these sensors have high sensitivity and reusability. Figure 1 shows the Scancontrol 2700-25 model laser sensor that was used in this study [15]. The Scancontrol 2700 sensors are the most economical sensors for static and dynamic applications. The sensor provides a profile frequency of 100Hz and up to 64,000 measuring points per second. The laser sensor has reading sensitivities between 5 cm on the X axis and 85 – 115 mm on the Z axis. The laser is connected to the welding torch, and it can be manually placed at the Z distance of 85-115 mm to the piece it will weld by the operator or it can be automatically located as well. On the Y axis, the torch can move on a constant linear pace depending on the welding speed.

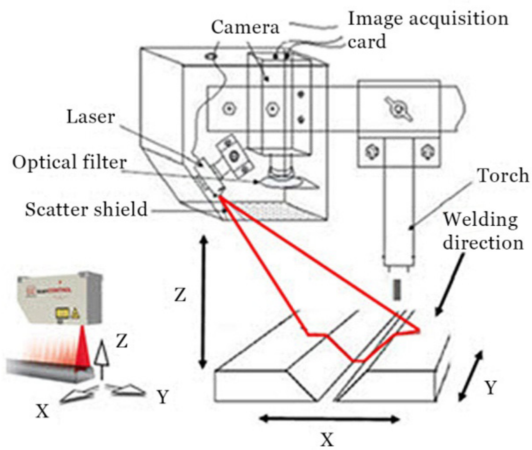


Figure 1. Laser seam tracking sensor and welding axes

The orbit the torch will follow in welding seam tracking and the relevant X-Y-Z reference coordinates are determined by the laser sensor and the torch focusing on the changes in the X-Y-Z coordinates is done by the Motor-x and Motor-y with fuzzy logic control and with Motor-z with proportional control. In order to determine the X and Y reference coordinates, the data read via the laser sensors are processed with seam identification algorithms and are transformed into reference data with respect to the starting point (0,0). When the welding seam is linear, the X and Y reference data is constant and therefore the positions of the X and Y motors are stable as well. If the welding seam path is constantly changing (angular or S shaped geometry), the fuzzy logic algorithm sends control signals to the motors, with the help of error changing amounts and change their speed as much as required. By doing so, the welding torch follow the welding seam as accurately as possible. Furthermore, the height is constantly measured and controlled by the laser sensor with respect to the reference values given in the beginning.

In the laser sensor seam recognition process, the first thing, as can be seen in Figure 2, is to obtain the refraction coordinates of the laser beam that falls on the piece to be welded as data, from the number 1 and 2 points on the piece to the left and number 3 and 4 points on the piece to the right. Later, these data are filtered and the middle of the points numbered 2 and 3 is calculated and determined as the reference seam to be used by the motors to always move in the middle of these points. The aim of doing this is to ensure the welding centers the welding bend. Even if the profiles on the refractions on points 1 and 4 are incorrectly angled, the laser will always be positioned by taking the middle of refraction points 2 and 3 into consideration.

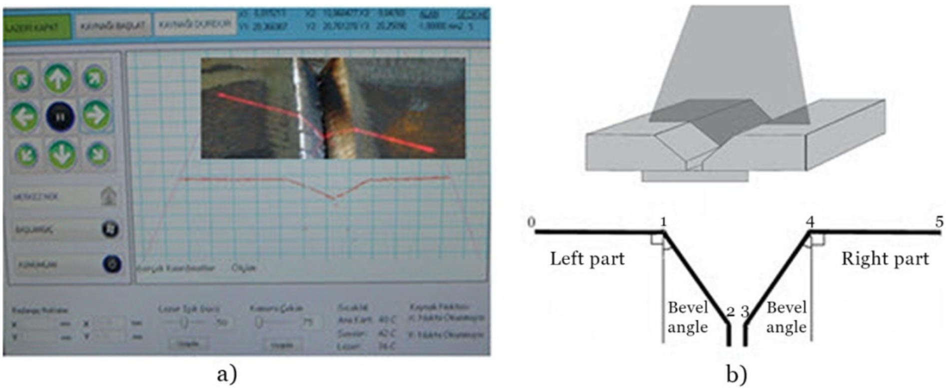


Figure 2. Weld groove and its laser strip profile feature (a) screen image, (b) profile and break points.

There are certain difficulties today in welding seam tracking, according to welding seam geometry, especially non-linear welding seam (S geometry etc.) tracking. Having an insufficient welding seam tracking concurrently with a welding bend that is not open according to the standards cause welding imperfections. Furthermore, especially the impermeability problem in high pressure cups and other errors in connection with this emerge in unexpected times during the operation.

As can be seen in Figure 3, there is a delay between the laser sensor and the torch in the application. Because the laser sensor pre-scans the item that will be worked on to determine the welding seam, and the torch follows this seam later. Especially in welding seams that have S geometry, before the welding process, the laser seam tracking piece can be located at the end of the piece or at any location on the welding area. At this position, there will be a certain distance on the X and Y axes and therefore the welding torch will be outside the piece or at the back of the initial point. This issue regarding the distance between the welding torch and laser sensor is resolved by applying a seam tracking delay. The modeling of this delay is shown in Figure 3 [15].

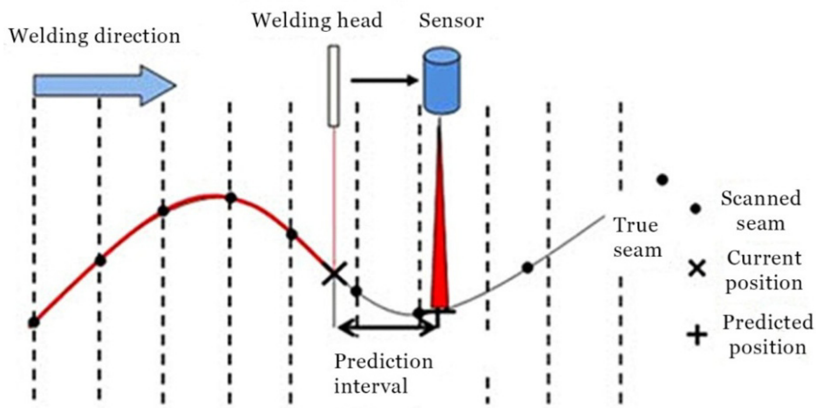


Figure 3. System delay guessing model

The welding seam can be identified by refracting the laser sensor beam from the nearest edges of the right and left pieces to be welded. The data showing these refraction points is used in the prepared program and the calculated mid-point of these two pieces are applied as reference entry to the Fuzzy Logic controlled X-Y motors. Afterwards, error changes (Δex notation is the error change for controller-x and Δey notation is the error change for controller-y) are calculated for both of the controllers that check the X and Y motors that the torch is connected to. The error and error change values that are calculated and applied to controller entrances are fuzzified by lingual identifications. Figure 4 shows the fuzzy approach models to welding points. Using laser seam tracking sensor, abrupt changes in the welding path are identified by the data obtained from welding edges. Laser sensor follows the welding torch from the front. The developed computer program will process the obtained data with the fuzzy logic algorithm to ensure the torch will always center the welding bend. Laser processes the data obtained from the welding orbit to calculate the path the welding torch will follow and ensures the movement of X and Y step motors at different paces to ensure following the orbit. Meanwhile, in accordance with the system delay model (Figure 3) prepared in advance, the torch moves with a lag.

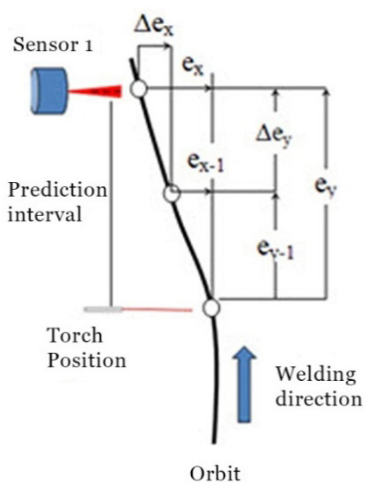


Figure 4. Welding seam tracking orbit

3. DESIGNING FUZZY CONTROLLERS FOR WELDING SEAM TRACKING SYSTEMS

The fuzzy logic control block diagram for the realized welding seam tracking system is shown in Figure 5. Initially, the line on the plane that the laser seam sensor and torch will follow is determined as f(f,x). Afterwards, from the planar f(x,y) seam information, the reference coordinates (xr, yr) are calculated separately for the x and y motors that enable movement on the x and y axes. Later on, each real engine position (xa, ya) is measured to receive feedback. Reference coordinates and the information obtained via feedbacks are compared to obtain planar errors (ex, ey) and error changes ($\dot{e}_x$, $\dot{e}_y$); for each error and error change are applied to Fuzzy Control-x and Fuzzy Control-y controllers. The controllers are producing control signals to the x and y step motors in order to eliminate the errors. The control signals move the x and y step motors and locates the torch on the welding coordinates. The Fuzzy Control-x and Fuzzy Control-y controllers used in the system are of similar structures.

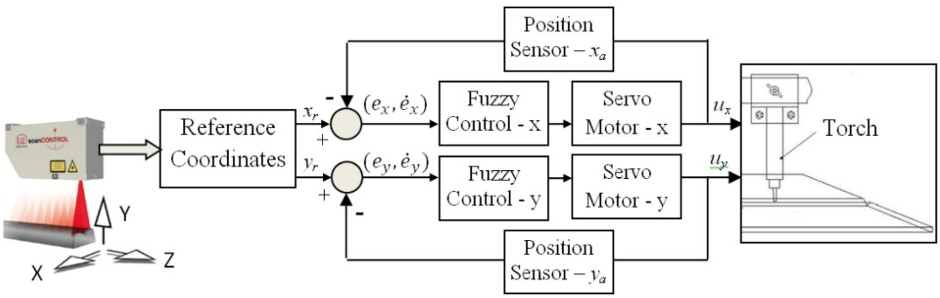


Figure 5. Fuzzy control block diagram

3.1. Structure of Fuzzy Controller

In this study, the Mamdani type fuzzy controller was used which was presented in Figure 6 with the normalization, fuzzifier, Knowledge base and Inference system, defuzzifier and de-normalization blocks. The fuzzy controller was designed for double input ($e_x, \dot{e}_x$) and single output (u).

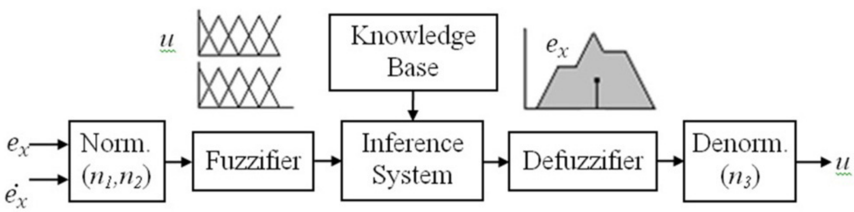


Figure 6. Block diagram of the fuzzy controller

In close cycle control systems, it is a universal approach to use error (e) and the derivative of the error ($\dot{e}$) for controller input. In this practical application, error and derivative of the error was used as input for X and Y fuzzy controllers as well. As Equation 1 shows, the error values applied to the inputs of X and Y fuzzy controllers are derived from the difference between the reference position and actual position on the x and y axes.

$$
\begin{aligned}
e_x(t) &= x_r(t) - x_a(t) \\
e_y(t) &= y_r(t) - y_a(t)
\end{aligned} \tag{1}
$$

Here, on the X-Y coordinates of the torch, ex(t) and ey(t) show position errors, xr(t) and yr(t) show reference positions and xa(t) and ya(t) show the actual position values. The change of errors ($\dot{e}_x$ and $\dot{e}_y$) is calculated as shown in Equation 2.

$$
\begin{aligned}
\dot{e}_x(t) &= \frac{d}{dt} e_x(t) \\
\dot{e}_y(t) &= \frac{d}{dt} e_y(t)
\end{aligned} \tag{2}
$$

In the Fuzzy Control System as shown in Figure 6, two normalization parameters for inputs (n1, n2) and one de-normalization parameter (n3) for output is determined. In the normalization process, input values are scaled in (±1) interval and in the de-normalization process, the output value is scaled on the tip control element input value interval. For system consistency, it is important to define the Normalization and de-normalization parameters in suitable values. In this study, for both fuzzy controller (x and y), these parameters were obtained as n1=3 n2=5, n3=8 via specialist knowledge and trial and error methods.

In the fuzzifier unit of the controller, sharp input values ($e, \dot{e}$), are transformed to fuzzy values. Later these values are used by the fuzzy extraction mechanism to produce fuzzy control outputs. Fuzzy control output should be transformed to actual values (crisp values) via the defuzzifier. Seven member fuzzy triangle functions shown in Figure 7 were defined in the fuzzifying of input values ($e, \dot{e}$) and in the clarification of output values (u) in the fuzzy controller that was actualized for this purpose. In the triangle membership functions shown in Figure 7, seven lingual variable names have been defined which are Negative Big (NB), Negative Medium (NM), Negative Small (NS), Zero (Z), Positive Small (PS), Positive Medium (PM) and Positive Big (PB). As can be seen from the figure, the membership functions identified for this study march 50%.

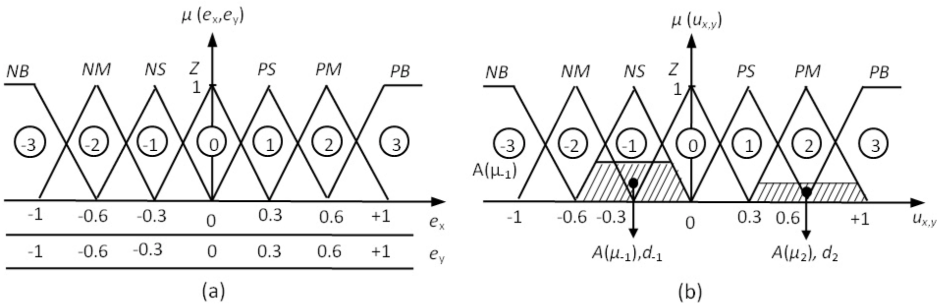


Figure 7. Membership functions of (a) input ($e, \dot{e}$), (b) output (u)

Basically, we can express a fuzzy controller as the sum of all control rules. Definition of the rule is unique and based on specialist's knowledge and experience. The rules in the fuzzy control systems are defined as conditional statements like "If …….Then….." and in this definition, the condition given with If yields the result given by Then. The part given with the Condition (if) is defined with the input variables of the controllers, the part given with the Outcome (Then) is defined with the output variables of the controller. In lingual definitions that have several variables, lingual conjunctions such as and, or are used. In double input $(e, \dot{e})$ single output (u) fuzzy controllers, a total of 7x7=49 fuzzy rules are defined and these fuzzy rules can be shown in a fuzzy rule table as well. Some of the fuzzy rules defined in this study are listed below.

Rule 1: **if** *e* is *NB* **and** *ė* is *NB* **then** *u* is *PB*,
Rule 2: **if** *e* is *NS* **and** *ė* is *NS* **then** *u* is *PS*,
Rule 3: **if** *e* is *Z* **and** *ė* is *Z* **then** *u* is *Z*,
Rule 4: **if** *e* is *PS* **and** *ė* is *PS* **then** *u* is *NS*,
…………………….
…………………….
Rule 48: **if** *e* is *NB* **and** *ė* is *PM* **then** *u* is *PS*,
Rule 49: **if** *e* is *NB* **and** *ė* is *PB* **then** *u* is *Z*.

The rule definitions given above are presented in a 7×7 matrix format in Table 1, in summarized form. When the x and y motors that work together on the X and Y coordinates are considered in the developed fuzzy controller, min-max extraction method was used in parallel working fuzzy controllers due to its simplicity. The extraction mechanism in fuzzy controllers is executed by the statement given in Equation 4. The μ notation used in the statement is the fuzzy membership value among the given seven triangle sets in the membership functions of inputs and outputs.

$$\mu_i(u) = \min\left(\mu_i(e), \mu_i(\dot{e})\right) \tag{4}$$

Fuzzy controllers have a non-linear structure due to fuzzifying, rule table, rational extraction and clarification processes.

Table 1. Symmetrical rule base for fuzzy control

	Input-*ė*						
Input-*e*	***NB***	***NM***	***NS***	***Z***	***PS***	***PM***	***PB***
NB	*PB*	*PB*	*PM*	*PM*	*PS*	*PS*	*Z*
NM	*PB*	*PM*	*PM*	*PS*	*PS*	*Z*	*NS*
NS	*PM*	*PM*	*PS*	*PS*	*Z*	*NS*	*NS*
Z	*PM*	*PS*	*PS*	*Z*	*NS*	*NS*	*NM*
PS	*PS*	*PS*	*Z*	*NS*	*NS*	*NM*	*NM*
PM	*PS*	*Z*	*NS*	*NS*	*NM*	*NM*	*NB*
PB	*Z*	*NS*	*NS*	*NM*	*NM*	*NB*	*NB*

A fuzzy controller working in actual conditions should produce actual values at its output for control processes. For this, the control flow in fuzzy controllers is obtained by clarification of fuzzy output. In the literature, many methods are proposed for clarification processes but the most commonly used method is the center of weight method presented in Figure 3 (b). In the application phase of this study, the center of weight expression given in Equation 3 was used in the clarification process of the fuzzy controllers.

$$\dot{u} = \frac{\sum_{i=1}^{m} d_i A(\mu_i)}{\sum_{i=1}^{m} A(\mu_i)}, \tag{3}$$

$$u = u + n_3 * \dot{u}$$

Here, du expresses the control output increase amount, u expresses the actual output value, di expression shows the distance of the ith fuzzy set to the center, A(μi) shows the shaded area values as shown in Figure 3 (b) for the ith fuzzy set. In Figure 8, the control surface curve for the realized fuzzy controller can be seen. As can be seen from the figure, the fuzzy controller has a non-linear control surface.

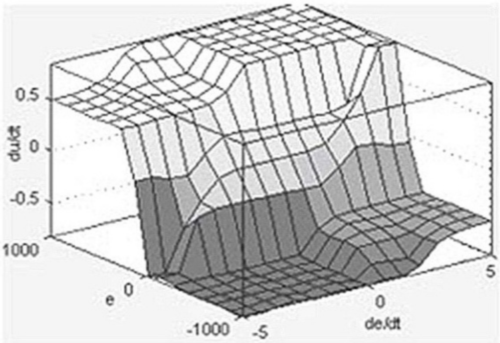


Figure 8. Control surface of the fuzzy controller

4. INTERFACE PROGRAM FOR THE WELDING SEAM TRACKING SYSTEM

One of the biggest advantages the conducted study provides is that it includes a fairly easy and efficient interface program for the operator to use. The interface program enables all control and tracking processes as well as historical statistical data collection and reporting processes. Furthermore, information that is gathered over time such as the tracking data can be easily applied to numerical sign processing algorithms such as different calculation and filtering. The outlook of the interface program that is developed for the welding seam tracking system can be seen in Figure 9. The interface program was developed via C++ visual programmer. As can be seen from the figure, the interface program is comprised of laser sensor control options, profile records and movement control options pages. In the laser sensor control options page, control actions such as turn on/off the laser sensor, manually place the welder, work in auto mode and torch position, torch speed, sensor output and other various data can be observed.

Figure 9. The interface of the developed program [15]

5. PERFORMED SYSTEM EQUIPMENT

The block diagram of the performed system is provided in Figure 10. The control loops provided in the figure are realized via fuzzy controllers on the X and Y axes and proportional controllers on the Z axis. The reference height that was initially entered by the operator is considered for the control of the torch height which is the Z axis. Accordingly, the height information obtained from the laser sensor is compared with the inputted reference height and a control sign that is proportionate with the obtained error is applied to the height adjusting motor.

As can be seen from the figure, there is a computer in which the interface software for the operator in the system was developed and executed. The operator can do manual positioning or automatic welding by the help of the interface. In the system, the laser seam tracking system data are transmitted to the computer over a FireWire or Ethernet interface. These data are processed in the software as reference coordinate data for the Torch head. These reference data and actual motor coordinate information are compared to obtain error information and control output for the motors are produced by using this fuzzy control algorithms and proportional control. In the system, control outputs are transmitted to the motor drivers via interfaces and servo motor location information are transmitted to the computer over the interface again.

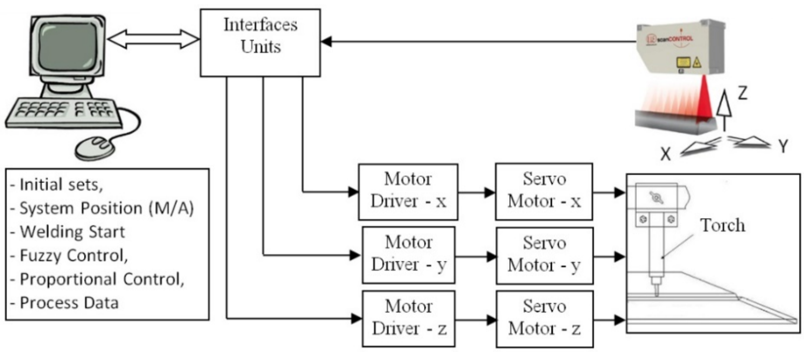


Figure 10. Actualized welding seam tracking system equipment

AISI 1040 steel material was used as experimental equipment, for the welding processes. Of the welding parameters, wire thickness was set to 1.2 mm, welding gas was defined as ArCO2 and wire speed was defined as 8.07 mm/s. In order to understand the efficiency of the fuzzy logic algorithm in the laser seam tracking sensor, an application on a welding seam with 2 different geometries was done. These pieces underwent welding with and without fuzzy logic control and evaluations were carried out accordingly. Figure 11a shows S geometry welding pieces and Figure 11b shows line geometry welding pieces.

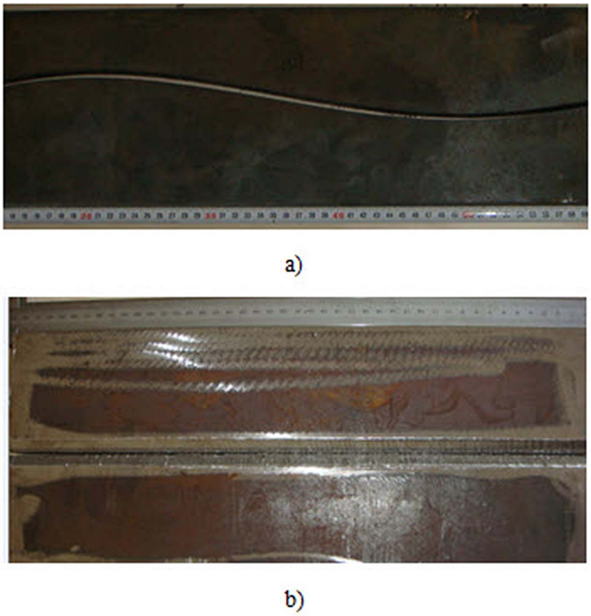


Figure 11. Piece to be welded, a) S geometry, b) straight geometry

The S geometry welding seam in Figure 11a constantly changes orbit during the welding process and this change occurred at different positions in the X and Y directions. Therefore, the speed responses of the X and Y motors would have different values. The sample line shaped work piece in Figure 12 is placed to form 30 degrees to the X axis. The purpose of placing the piece at an angle ensure that the welding bend always centers by providing outputs with different step motor speeds that will always center the welding bend by using fuzzy logic algorithms for different step motor speeds borne out of different slopes to be formed both in the X and Y axis on the welding seam. By doing so, the effectiveness of the fuzzy logic algorithm is researched.

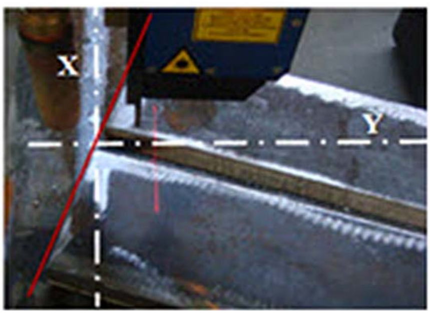


Figure 12. Line work piece location

Laser seam tracking sensor (Sensor 1) receives the source orbit data to follow during the welding process as data. For this study, a column boom system that will enable the movement of the torch and laser seam tracking sensor on the X, Y and Z directions. Through the developed software, the laser determines the place it will weld after an interval and makes periodical scanning to determine the starting position of the welding seam on the Z axis. The movement of the laser sensor on the two axes is carried out under computer control via three step motors on slides and step motor drivers connected to them. The laser sensor that is ready to track welding begins tracking the welding seam once the work piece begins to move or the system it is connected to becomes active. The X and Y coordinates obtained from the work piece is processed in the prepared fuzzy logic algorithms to arrange the movement coordinates of the step motors on the axes.

As can be seen in Figure 13, a second sensor was included in the system for the column boom welding robot. This sensor records the right and left width values of the welding. The data gathered from these two separate sensors are compared with the data from sensor 1 that track the welding orbit and sensor 2 that measures welding width. At the same time, sample pieces are intersected at different places in the X direction to investigate the ITAB region [15].

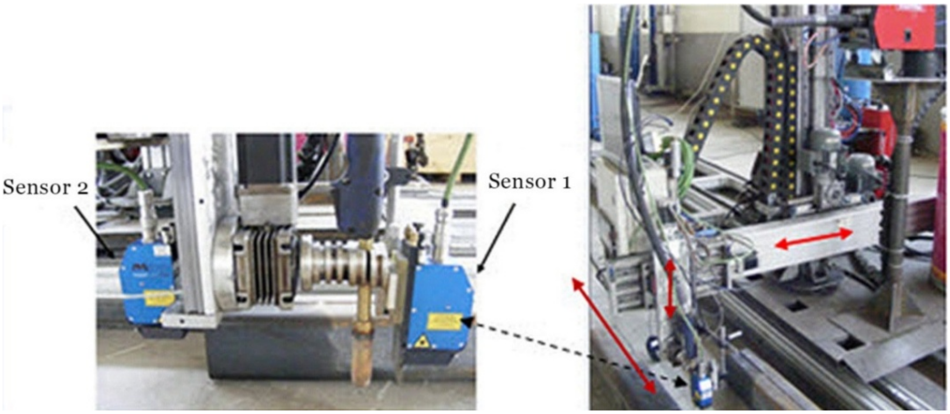


Figure 13. Laser seam tracking sensors used in the system

6. RESULT OF THE EXPERIMENT

6.1. Welding process of work piece with fuzzy logic algorithm application

Figure 14 displays a welding application with S shaped welding path tracking using fuzzy logic control whereas Figure 15 shows a welding application with a straight piece welding path tracking using fuzzy logic control. This experiment was carried out using fuzzy logic control algorithms. Abrupt changes on the axes and relevant data evaluated in the control algorithms are sent to the orbit motors as different speed signals using this controller,. Through this, the system does the welding by centering the welding torch according to the welding bend. Sensor number 1 determines the abrupt fraction points on the welding part (Figure 2) to arrange the speed of the X and Y speed motors and ensures the welding torch constantly centers on the middle of these points while moving. Later, the data obtained from the second sensor and the data from sensor 1 are controlled to check whether the welding bend centers or not. The controls done show that both data are overlapping.

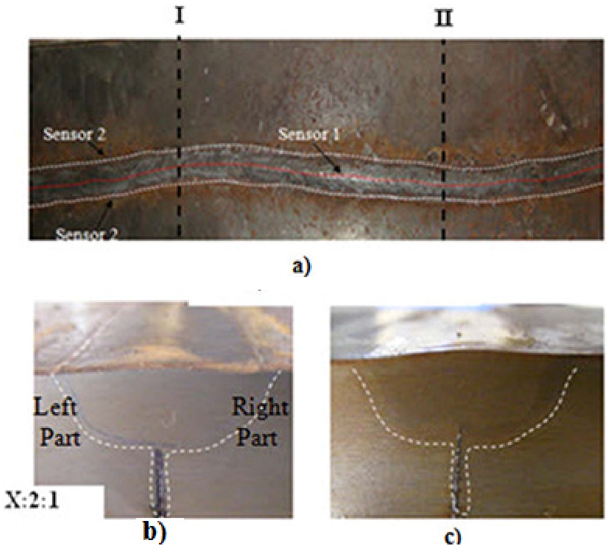


Figure 14. For a sample with S geometry in a fuzzy logic controlled a) Sensor 1 and Sensor 2 data after welding, b) ITAB Intersection of samples, c) Intersection II

When the data obtained from Sensor 1 and Sensor 2 are superposed on a piece on which fuzzy logic algorithms are applied, the data obtained from sensor 1 is always in the middle of the data obtained from sensor 2. This means that the applied welding process always centers the welding bend. When the welded pieces are intersected in Figure 14 and Figure 15, it can be seen that it centered the region that is named as region ITAB.

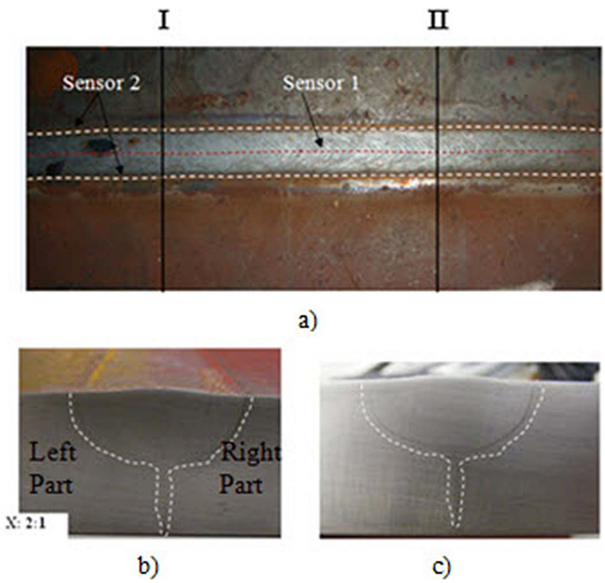


Figure 15. For a sample with line geometry in a fuzzy logic controlled a) Sensor 1 and Sensor2 data after welding, b) ITAB Intersection of samples, c) Intersection II

As can be seen from the experiment, both in S geometry and in line shaped welding processes, fuzzy logic algorithm responds to the smallest changes on the welding surface in a very fast and perfect way. By doing so, in the welding processes, the welding bend is centered and a welding process in accepted standards was actualized.

6.2. Proportional control application work piece welding process

Figure 16 and 17 show the welding samples done by turning fuzzy logic control algorithms off and are done via the classical proportional control algorithms. In the proportional control process, the errors obtained in contrast with the reference are applied to the engines based on a proportionate multiplier. So, here the data show that compared to the data obtained from the laser seam tracking sensor directly, the orbit is better tracked. When the fuzzy logic algorithm is turned off, it is sending constant change signals to the X and Y axes. Therefore, although the welding seam that has S geometry looks good with respect to welding quality and looking ideal, when the piece was intersected, the welding bend (intersection I-II) could not completely centered. Since the system is not linear, results that are good enough cannot be obtained.

The system in the fuzzy logic control system can follow the welding seam with lesser mistakes. Especially in pieces where the welding system is not linear, a very fast error correction process was implemented to increase quality. Due to the characteristics of fuzzy logic, the system is not affected by orbital shifts.

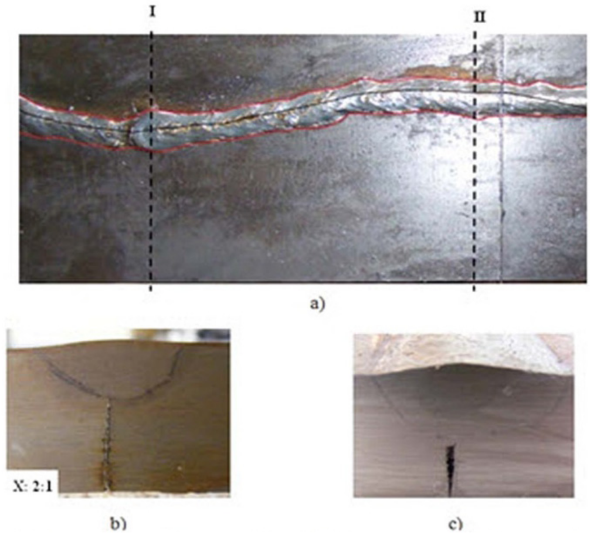
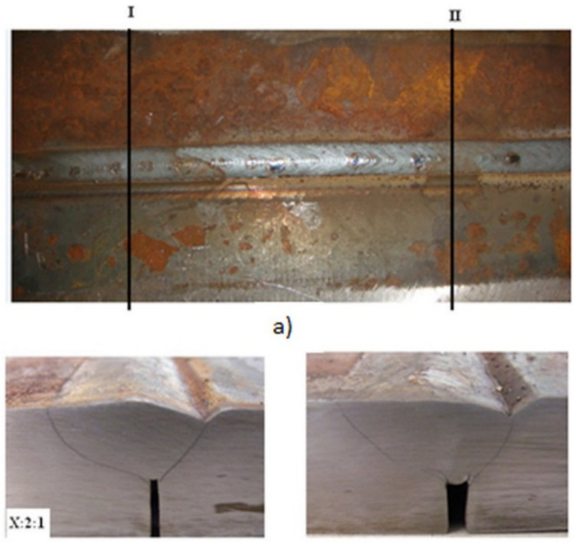


Figure 16. Fuzzy illogical control of the sample with S geometry, a) Post welding sensor 1 and sensor 2 data, b) ITAB Section I for samples, Section II

Along with this, the same problem is observed in the welding processes of samples that are 30 degrees to the horizontal axis. In both experimental samples, when the data from both sensor 1 and sensor 2 are overlapped, it was observed that sensor 1 data is a bit closer. When the pieces are intersected in the determined region, this mistake will be more apparent.



a)

b)

Figure 17. Line geometric sample in fuzzy logic uncontrolled, a) Post welding sensor 1 and sensor 2 data, b) ITAB Section I for samples, Section II

7. CONCLUSION

In this study, a unique welding seam tracking system which is laser controlled and can be used in the three axes controlled industry was successfully realized. A second laser sensor that is added to the system was used in the measurement of the welding quality and it was observed that fairly good results were taken. In tracking the seam of a straight line welding that is S shaped and has an angle, the welding seam tracking performance of fuzzy logic and classic control algorithms were compared. It was observed again that due to their non-linear structure, fuzzy controllers yield more successful results in non-linear processes. The fuzzy logic control algorithm laser seam tracking sensor applies different speeds to the axes motors to center the welding bend to complete the process. But, in seam tracking systems without fuzzy logic control algorithm, the axes motors (X, Y step motors) are sent constant signals; their motor speeds are constant as well, resulting in less than desired level of centering of the welding bend.

Experiment results show that using fuzzy logic algorithm in tracking welding seams can provide more reliable welding process at the desired quality levels.

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