Distance monitoring applications, angle and speed between nozzle and work piece: Ultrasonic detection sensor system of Gas Metal Arc Welding (GMAW)

M H Amiruddin, S Sumarwati*, S N J Shah and S A Jalil

Faculty of Technical and Vocational Education, University Tun Hussein Onn Malaysia, Johor, Malaysia

*Corresponding email: sri_fatoni78@yahoo.com

Abstract. The use of human resources in Gas Metal Arc Welding (GMAW) can cause defects, such as lack of penetration and uneven moldings due to the long distance between the blowpipe nozzle to the workpiece. The purpose of this study is to develop the distance monitoring applications, angle, and speed between nozzle and workpiece for GMAW by using an ultrasonic detection sensor system. The distance monitoring tool between the nozzle and workpiece for GMAW was developed based on the ADDIE model. Respondent included two experts of wiring and electronics, three experts of software and quality, and two experts in the mechanical field, selected by using purposive sampling methods. Monitoring tool developed using Arduino Uno programming technology. Besides, high-quality electronic components such as Ultrasonic HCSR04 and MPU6050 Gyroscopes are used. Based on the analysis, the whole application of distance monitoring, angle, and speed between the nozzle and workpiece for the GMAW can work well and suitable for GMAW with excellent ergonomic features that are easy to maintain and used. The study results will provide benefits in the welding industry as it can reduce defects in GMAW, and thus saving the cost of welding errors.

1. Introduction

Welding is the most important process in manufacturing industries, such as automotive, aerospace, and shipbuilding. Technology advances in the welding industry have evolved to meet industrial needs. Welding is a process of adding a substance with other materials which are by using special material, for example, a metal or thermoplastic. Welding also involves the melting of metal to serve as a binding medium between one structure and another [1]. Gas Metal Arc Welding (GMAW) or is an arc welding process between the feed electrode and a continuous weld pool which results in a combination by the arc heat generated by the molten metal electrodes with the original [2]. This process uses a separate inert gas supply as a protective gas [2]. GMAW was originally used to weld aluminum type metals with the use of an inert gas as a protective gas [3]. GMAW is produced from processes performed on various types of metals using gas mixtures that are separately supplied as carbon dioxide (CO2). There are several aspects in the GMAW process which are not properly considered and detailed, causing a defect in the welding results.

Damage or defects occur means that there is a need for more cost to produce the welding work, especially in the context of GMAW. According to David [4], almost 68% of the welding result defects or damage is due to the lack of skills that exist in a welder. Skills refer to the capabilities of an individual to do something or activity through his knowledge to meet the challenges, various problems, and
competition [5, 6]. Welding defects that often occur in the process of GMAW consist of lack of sketches, uneven (bad) moldings, and poor connection. Incomplete fusion or lack of fusion of distance is not a fixed electrode with the workpiece surface. In other words, a high and low prevailing cause penetration welding is not perfect and gives a negative effect on the welding results [1]. The low level of welding skills was one of the causes of unstable distances between the ends of the pile and workpiece [4]. In the industry, this problem can be a tremendous impact, especially in the operation of a system or system of work.

Human resources with competence can be a catalyst for new concepts to solve problems [7]. However, the use of manpower in GMAW can cause defects such as lack of penetration and uneven moldings caused by too much distance between the blowpipe nozzle and workpiece. The welder finds difficulty to determine the appropriate distance while doing the GMAW work because there is no suitable method or device. The traditional methods in use have the potential to drastically increase production or production costs. Therefore, a tool for monitoring the distance between the ends of the pin and the workpiece for GMAW was developed to determine the appropriate distance between the nozzle and workpiece while the GMAW work was performed. The purpose of this study is to develop the distance monitoring applications, angle, and speed between nozzle and workpiece for GMAW by using an ultrasonic detection sensor system. To achieve the study purpose, the following scopes were developed based on the ADDIE development model:

i. To design distance monitoring applications, angle, and speed between nozzle and workpiece for GMAW by using the ultrasonic detection sensor system.

ii. To develop distance monitoring applications, angle, and speed between Nozzle and workpiece for GMAW by using the ultrasonic detection sensor system.

iii. To test the functionality of distance monitoring applications, angle and speed between the ends of the nozzle and workpiece during the GMAW process is carried out.

2. Methodology
This research focuses on the development of distance monitoring applications, angle, and speed between the ends of the nozzle and the workpiece during the Gas Metal Arc Welding (GMAW) process. This distance monitor uses a type of ultrasonic sensor for uniform distances during the GMAW process. The appropriate distance between the tip of the pile and the workpiece determined using Arduino Uno where the distance is programmed into it and then sent a signal to the detector to detect the specified distance. It is also designed to help users improve the welding quality and save on the cost of repeated training and the cost of welding error.

Development is one of the most important phases in a project to determine whether the project development objectives are achieved. The development process of distance monitoring applications, angle, and speed between the ends of the nozzle and the workpiece for GMAW requires systematic planning so that the tool can function properly and according to the set objectives. The entire review process will include a justification for the choice of model development, design sketches of projects, sketches of electronic boards, software and hardware being used, the product development cost and engineering elements that are used while developing the application to monitor the distance, angle, and speed of the nozzle tip with the workpiece for welding GMAW. These aspects are important to ensure that the development process is carried out smoothly, systematically, and produce products that can achieve the study objectives.

Therefore, the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model [8] selected as a guide and basis in developing the distance monitoring applications, angle, and speed between the nozzle and the workpiece for GMAW. The ADDIE model guides the highest level for the design development direction [9]. ADDIE model is described and summarized by Molenda [10] as a systematic approach in the development process and work instructions, as well as a model that provides an orderly process for the development. Data collection was involved with welding and instructors' experts in teaching GMAW. The study experts included two wiring and electronics experts, three
software and quality experts, and two experts with mechanical skills. They selected using purposive sampling methods.

3. Results and discussion
The production and development in this research are based on the ADDIE model. The monitoring tool was developed by using Arduino Uno programming technology as well as affordable and high-quality electronic components, such as Ultrasonic HCSR04 and MPU6050 Gyroscope.

3.1. Analysis
Sketches are defined as the production of paintings that are simple (spontaneous), simple and fast [11]. The purpose of the sketch is similar to the production of the final drawing, to express ideas quickly and provide additional understanding of the initial idea. Design is a process that uses elements in engineering, mathematics, graphics, and scientific principles to produce and contribute to technical needs [12]. The design of the project chosen to develop a product must include those elements so that the project developed works according to the objective and is suitable for use by users. The design of the distance monitoring tool between the nozzle and the workpiece for Gas Metal Arc Welding (GMAW) has three main components, namely the detector, Arduino Uno, and electronic board.

Table 1. The sketch of the distance monitoring tool between the nozzle and the workpiece for Gas Metal Arc Welding (GMAW).

| No. | Explanation                                                                 |
|-----|-----------------------------------------------------------------------------|
| 1   | Preliminary sketch of the distance monitoring tool between the nozzle and the workpiece for GMAW. Sketch of the distance monitoring tool between the nozzle and the workpiece for GMAW. The initials are 6.0cm x 2.3cm x 4 cm in size for the Arduino Uno components and electronic boards. The size of the detector is 4cm x 2cm x 1cm. |
| 2   | The actual drawings are made by using the Auto Cad software for the built-in distance monitoring tool. The drawing has a size of 13cm x 10cm x 5cm for the Arduino Uno component and electronic board, while the detector size is 5cm x 4cmx 4cm. The drawing size is from the actual size of the distance monitor that is completed through the development phase. |
| 3   | Overview of the distance monitoring tool based on three different views includes top, side, and front view. These views provide an overview according to different positions to provide a clear and accurate picture of the overall design of the distance monitoring device that has been developed. |
3.2. Design
In this step, the researcher produced the design of the distance monitoring device between the nozzle and the workpiece for Gas Metal Arc Welding (GMAW) that is suitable for the welding work performed and the design should be relevant to the main purpose of the development of this project. The distance monitoring tool uses an ultrasonic sensor detector to obtain a uniform distance during the GMAW process. The appropriate distance between the tip of the blower and workpiece is determined using Arduino where the distance is programmed into it and then sends a signal to the detector to detect the set distance. The hardware and software needed for the development of GMAW monitoring tools are shown in Table 2.

Table 2. The hardware and software in the development of the distance monitoring tool.

| No. | Hardware & Software | Figure | Explanation |
|-----|---------------------|--------|-------------|
| 1   | Arduino Uno         | ![Arduino Uno & Breadboard](image) | This board has 14 digital output/input pins used for PWM (pulse-width modulation) output. It also comes with six analog inputs, 16MHz quartz crystals, USB connections, ICSP heads, and a reset button. "UNO" is one of the Italian languages used in conjunction with the release of Arduino (IDE) 1.0. |
| 2   | Breadboard          | ![Breadboard](image) | Breadboards are the key ingredient in producing circuits for developing functional electronic tools |
| 3   | HC-SRO4 Ultrasonic sensor | ![HC-SRO4 Ultrasonic sensor](image) | HC-SRO4 Ultrasonic sensor is a detector that uses a sonar system to determine distances between objects. This detector provides excellent object tracking functionality with high precision of precise readability in easy-to-control shapes. The ideal distance to measure by using this detector is approximately 0.5cm up to 400cm. |
| 4   | LED lamps           | ![LED lamps](image) | LED lamps have a higher life expectancy and efficiency as compared to "incandescent lamps" and are far more efficient than fluorescent lamps. The LED is also equipped with several chips that can produce over 300 lumens per watt. For the built-in distance monitoring device, this lamp serves as a marker to signal the appropriate and inappropriate distances between the pile ends and the workpiece as programmed. |
These connector wires are commonly used to establish a connection between the breadboard and electronic components without a soldering process. For the built-in distance monitoring device, this wire serves as a connection between the breadboard and electronic components. The electronic components are the HCSR04 Ultrasonic detector and the Arduino Uno.

Arduino software is the software required to enter all the instructions to ensure that the detector works according to the rules set using the programming language. The software used on the computer is useful for transferred all data and information to the Arduino Uno via a USB connection.

AutoCAD is a software that is commonly used to create and design objects in either a 2-dimensional or a 3-dimensional computer-assisted drawing. It is better known as the Computer-aided drafting and design program (CAD) [13]. This software can be used in all fields of work, especially in areas that require the use of sketches or engineering drawings, such as mechanical, public, architectural, and graphic design.

### 3.3. Development

Developmental procedures are steps taken to complete a task or project that is accomplished. The development process is a step to complete a task or project. It determines each action that needs to ensure that the task or project developed can be carried out efficiently and effectively [14]. Table 3 refers to the steps during the development of the distance monitoring tool between the pile end and the workpiece for Gas Metal Arc Welding (GMAW).

| No. | Figure | Explanation |
|-----|--------|-------------|
| 1   | ![Perspective deduction](image1) | The cutting process measures 12cm x 9cm with respect to the site for Arduino Uno and "breadboard", which are 13cm x 10cm x 5cm for housing and 5cm x 4cm x 3.5cm for housing sensors. Prospects cut to produce housing in the glue stick by using the "3 seconds" for an act swiftly and firmly attached. |
| 2   | ![housing](image2) | Arduino Uno and "breadboard" attached to sites cut to facilitate wiring works implement. |
| 3   | ![Wiring using a connecting wire between Arduino Uno and "breadboard". LED lights are installed by design predefined. Wiring process between the "breadboard" and the Ultrasonic HCSR04 detector using the connecting wire based on the wiring system predetermined.](image3) | Wiring using a connecting wire between Arduino Uno and "breadboard". LED lights are installed by design predefined. Wiring process between the "breadboard" and the Ultrasonic HCSR04 detector using the connecting wire based on the wiring system predetermined. |
| 4   | ![Wiring activity is performed between the "breadboard" and the Ultrasonic HCSR04 detector by using the connecting wires based on the wired wiring system that has been set.](image4) | Wiring activity is performed between the "breadboard" and the Ultrasonic HCSR04 detector by using the connecting wires based on the wired wiring system that has been set. |
| 5   | ![The process of entering into the Arduino Uno programming code is by using computers to give directions to the electronic component to detect a preset distance.](image5) | The process of entering into the Arduino Uno programming code is by using computers to give directions to the electronic component to detect a preset distance. |
6. Conduct tests on electronic components installed to ensure that all components function according to the instructions as programmed. This test was conducted to check the functionality of each connection of wireless electronic components.

7. Spray the external electronic components neatly. The paint used is of "quick-drying spray paint" type and in black.

8. Components inserted into the housing during painting. A 9V dry cell power supply is installed to supply the electronic component power to ensure that the component function with excellent. Locking rings of diameter 3cm are put in pairs on the housing HC SR04 Ultrasonic sensors to facilitate the binding sensors at the end of the blowpipe.

9. Test on the GMAW process using a monitoring tool to ensure that the developed tools can function with excellent and suits with objectives planned.

In the process of product development, the cost is an element that should be emphasized to control the flow of budget used in producing products that use low cost and can produce high-quality products. At this stage, the cost of the element to produce the product is also emphasized.

**Table 4.** The costs of developing distance monitoring tools.

| No. | Components                        | Quantity | The unit price | Total    |
|-----|-----------------------------------|----------|----------------|----------|
| 1   | Arduino Uno                       | 1        | RM 93.00       | RM 93.00 |
| 2   | HC-SR04 Ultrasonic sensor         | 1        | RM 8.00        | RM 8.00  |
| 3   | Breadboard                        | 1        | RM 3.90        | RM 3.90  |
| 4   | Mini breadboard                   | 1        | RM 2.30        | RM 2.30  |
| 5   | LED lamps                         | 2        | RM 0.50        | RM 1.00  |
| 6   | Connector wires                   | 1        | RM 8.00        | RM 8.00  |
| 7   | A4 3mm lens                       | 1        | RM 11.50       | RM 11.50 |
| 8   | “3-second” glue                   | 1        | RM 2.50        | RM 2.50  |
| 9   | Ø3cm locking ring                 | 1        | RM 1.00        | RM 1.00  |
| 10  | 9v Energizer Battery              | 1        | RM 9.00        | RM 9.00  |
| 11  | 9v battery holder                 | 1        | RM 3.20        | RM 3.20  |
| 12  | Quick “dry drying” paint          | 1        | RM 6.00        | RM 6.00  |

Total: RM 149.40

3.4. Implementation and evaluation

At the implementation stage, improvements are made to redesign, modify, and improve the quality of the tools developed during operation. The implementation level refers to the actual delivery that indicates that this distance monitoring device is manufactured using an ultrasonic detection system because of the detector used by Gas Metal Arc Welding (GMAW). While the evaluation process is implemented to evaluate the distance monitoring tool to obtain the best results so that it can function and achieve the objectives that have been set. Once the distance monitoring tool between the nozzle and instrument for GMAW is developed, it will go through an expert process evaluation and verification to test the functionality of the built-in distance monitoring tool. An expert verification form is provided to
seven experts and who are required to evaluate the functionality and provide insights on the built-in distance monitoring tools. Therefore, improvements created to the distance monitoring tools developed based on the opinion and evaluation of experts. An expert value can be anyone with experience or skills related to the product developed [15].

3.4.1. Designing distance monitoring applications, angle, and speed between nozzle and workpiece for GMAW is by using the ultrasonic detection sensor system. The design of this distance monitoring device created using an ultrasonic detection sensor system because of the detector by the Gas Metal Arc Welding (GMAW). Some of the factors that led to the success of the design of this monitoring device are:

   a) The ultrasonic HCSR04 detector is small-sized and suitable for installation at the nozzle.
   b) The components used to produce this distance monitoring tool are not too complicated.
   c) The design produced is compatible with the functionality of a distance monitoring tool that is used for GMAW.

   The design of this distance monitoring device created using an ultrasonic detection sensor system because of the detector used by the GMAW. The detector size is blocked with the tip of the chopper and does not interfere with the visor of the welder. This finding supported by Nussey [16] stated that the Ultrasonic HCSR04 detector is user-friendly and easy to operate for a variety of tasks.

3.4.2. Developing distance monitoring applications, angle, and speed between nozzle and workpiece for GMAW by using the ultrasonic detection sensor system. Distance monitoring applications, angle, and speed between the nozzle end with the workpiece during Gas Metal Arc Welding (GMAW) are developed based on the ADDIE Instructional model that starts with the analysis phase, design phase, development phase, and evaluation phase. The distance monitoring tool between the coil ends and workpiece for GMAW developed using an ultrasonic detection system due to several factors:

   a) The cost of using the Ultrasonic HCSR04 detector is considerably lower than the use of other detectors.
   b) The HCSR04 Ultrasonic detector is capable of detecting distances or objects in smoky and hot conditions, such as during GMAW.
   c) The size and weight of the Ultrasonic HCSR04 detector are lightweight and are ideal for placement at the nozzle.
   d) There is less complicated wiring work to connect the HCSR04 Ultrasonic detector with the Arduino Uno.
   e) Programs are not too complicated to insert instructions or codes into the Ultrasonic HCSR04 detector.

   Distance monitoring applications, angle, and speed between the nozzle and the workpiece during GMAW developed by using an ultrasonic detection sensor system because of several factors, such as the cost is much lower than the use of other sensors. This statement was supported by [17] who stated that the cost of the HCSR04 detector is significantly lower than that of other detectors available in the market. Besides, the Ultrasonic HCSR04 detector is capable of detecting distances or objects in smoke and hot conditions such as during the GMAW. This is because sound waves can penetrate smoke and steam heat [18].

3.4.3. To test the functionality of distance monitoring applications, angle and speed between the nozzle end with the workpiece during GMAW carried out. Evaluation data were collected from two experts in wiring and electronics, three experts in software and quality, and two experts in mechanical skills. Based on the analysis of expert validation, the overall distance monitoring applications, angle, and speed between the nozzle and workpiece for the Gas Metal Arc Welding (GMAW) have worked well and met the product development objectives. Besides, the expert also believes that developed products are
attractive and suitable for GMAW. From a mechanical element, the expert believes that the products have excellent ergonomics, easy to maintain, and easy to use for GMAW.

a) The experts of wiring and electronics.
The experts evaluated the wiring and electronic systems that were used to monitor the distance between the blowpipe tip with the workpiece for GMAW. According to experts, the wiring process must be under the electronic components used for products produced to function as designed. Besides, the wiring type emphasized so there is no occurrence of short-circuit current supplied to the power tool. Overall, the wiring and electronics experts stated that the produced monitoring tool has worked as designed and met the product development objectives.

b) The experts of software and quality.
The experts evaluated the software used to monitor the distance between the blowpipe tip and the workpiece for GMAW. The experts also evaluated the quality of products in development. According to experts, the software used must be appropriate and easy to change, particularly codes that provide instructions on sensors to function. Besides, distance monitoring tools that are developed must also have their unique quality and suitable for GMAW, as stated in the objectives of development. Overall, the expert noted that the software and the quality of the built-in distance monitoring tool are attractive and suitable for use in GMAW.

c) The experts of mechanical.
Experts were selected to assess the mechanical elements present in the distance monitoring tool between the pin ends and the workpiece for the GMAW. According to the experts, a product developed must have a design that suits the type of product performance. Besides, the product developed is simple for maintenance and will not damage any of the components during maintenance. The mechanical experts also stated that the distance monitoring device that developed has excellent ergonomic features and is easily used for GMAW. Overall, a mechanical expert specified that the built-in distance monitoring tool is a good review and appropriate to a bachelor's degree level.

4. Conclusion
Development is one of the most important phases of a project to determine whether the project development objectives that have been set are achievable. The development process carried out must be guided by the development model so that the entire development process can proceed smoothly with the selected development model. The ADDIE model was selected as a guide and foundation in developing distance monitoring tools between the blowpipe end and the workpiece for Gas Metal Arc Welding (GMAW). The design for the project selected to develop this distance monitoring tool must include elements, such as engineering, electrical and electronic elements projects that developed to function following the objectives and suitable for consumers. Besides, the wiring system is one of the key elements in the process of developing distance monitoring tools between nozzle and workpiece for GMAW so that the products produced will work in line with the goals that have been set. After all, the cost is a necessary element emphasized for controlling the budget flow that is used to produce products at a low cost and is capable of producing high-quality output. The results of this study will provide benefits and advantages, especially to welders who use the GMAW to determine the appropriate distance between the nozzle and the blowpipe workpiece. It will also provide benefits in the welding industry as it can reduce defects in GMAW, especially disability due to the incompatible distance between the nozzle and the workpiece. This can be saving the cost of welding errors. Besides, time can also save and do not interfere with the scheduling system for any industrial operations.

Acknowledgement
The author would like to express appreciation to the Ministry of Higher Education is supporting this research through PPG VOT K011.
Reference

[1] Jeffus L 2011 Welding: principles and applications 4th edition (Albany: Delmar Publishers)

[2] Christena S B 2014 Learn to weld: beginning GMAW and metals fabrication basics (Beverlly, USA: Quayside Publishing Group Reference)

[3] Keifner J K 2009 History of line pipe manufacturing in North America (Pennsylvania: American Society of Mechanical Engineer)

[4] David S A 2009 Trends in welding research (Georgia, USA: ASM International)

[5] Sumarwati S, Yunos J M and Ibrahim B 2017 Advanced Science Letters 23 (2) 968-971

[6] Amiruddin M H, Ngadiran I A, Zainudin F L and Ngadiman N 2016 GEOGRAFIA OnlineTM Malaysian Journal of Society and Space 12 Themed Issue on Technological, Vocational and Educational Empowerment of Malaysia’s Human Resource 3 111-121

[7] Abdullah N S, Sumarwati S, Abd Aziz M I, Ziden A A, Razak N A and Jalil, S A 2020 International Journal of Innovation, Creativity and Change 11 (12) 637-654

[8] Larson M B, Lockee B B and Streamlined I D 2014 A practical guide to instructional design (Oxon: Routledge)

[9] Welty G 2007 Journal of GXP Compliance 11 (4) 40-48

[10] Molenda M 2003 Performance improvement 42 (5) 34–37

[11] Hosking A K and Haris M R 1983 Applied Mechanical Design (Victoria, Australia: H and H Publishing)

[12] Manaf A R A 1999 Mechanical mechanics and design (Kuala Lumpur: Universiti Malaya)

[13] Fane B 2016 AutoCAD for dummies 1st edition (West Sussex, England: TJ International)

[14] Noor A 2009 Development of automatic program verification for continuous function chart based on model checking (Kassel, Germany: Kassel University Press)

[15] Krueger K, Tobias T, Trevor P, Klaus H, Laurence S and Kevin H 2012 Environmental Modelling and Software 36 4-18

[16] Nussey J 2013 Arduino for dummies (West Sussex, England: TJ International)

[17] Mcgowan K 2011 Semiconductor - from book to breadboard (Clifton Park NY, USA: Denmar CENGAGE learning)

[18] Kurniawan A 2015 Arduino – Uno: a hands on guide for beginner (Depok, Indonesia: Indonesian Publisher)