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Sensor System Analysis of Robotic MIG Welding Process

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Abstract - *Welding is joining two or more metal parts together by melting the third material on adjacent surfaces. Welding is extensively used in metal industry like automotive and other manufacturing industries. Manual welding process is time and cost consuming. Hence, to improve production speed, quality and to save cost and time robot welding plays a vital role. Recently, sensors are predominantly used in automatic welding processes for various purposes that make automatic process more precise and increase productivity. This paper includes different sensor selection in automatic welding process in the existing problems and few analysis methods for the problem solving. It also elaborates about the changes that should take in consideration which ultimately helps to raise the productivity and reduce downtime for the system.*

Keywords - *MIG weld, Robot Welding, Sensor, Sensor Feedback.*

I. Introduction

Welding has made complex structure look easier and offers high tensile strength, shear strength and a long service life to the structure. The main application for welding is ships, cars, aerospace, construction, etc. Among different types welding process, mainly manual Metal Insert Gas (MIG) welding used in the metallic industry with material of thickness more than 3mm. MIG welding is process that uses a wire which moves through the gun with uniform speed and creates the spark and melts where the joining of metal is done [1, 2].

Robots and automation uses in industry create a major impact in different sectors. Industrial robots become necessary part for industrial welding for high productivity as manual welding is time consuming due to harsh environment and also less precise compared to automatic welding. Involving robots in welding industry helps to maximize products quality, rate of production with low damages, more flexibility and increase safety with many more advantages [3, 4].

For the better quality of manual or automatic welding, it requires fixture that hold the work piece. Fixture adaption has increased the range of possible motion where system can handle complex movements which ultimately help to increase adaptation of new work pieces [5].

Various sensors implemented in the fixtures for welding are used to detect the part presence and measure parameters like joint geometry, location and online control of process. Sensors are also used for quality check and weld defect inspection. The use of sensors is to address problems in welding processes [6].

Thus, the objective of the research is to study and analyze the actuating system for robotic welding. This will also bring focus on different sensor issues which lead their feedback problem and discussion of engineering changes that will help to boost up production [7].

II. SENSOR FEEDBACK

Any type of damage to the sensing devices leads to stop their normal functioning which causes the feedback problem in automation. Feedback device like sensor, reed switch, safety scanner, etc are used to monitor the actuator position or movement and the response is further given to robot through PLC and completes the cycle. When feedback devices does not generate the output signal in acceptable range for execution of next instruction in running program with PLC then it leads to feedback error in the system.

When D.C. output signal of sensor is not received at input module of PLC which interrupt the further operations and not complete the cycle then it generates sensor feedback error. The feedback fault will be shown on human machine interface (HMI).

III. COMMUNICATION IN ROBOTIC WELDING

Robotic welding has sequence of operations to be followed and all the operations are controlled through programmable logic control (PLC). Numbers of sensors are implemented in the fixture and signal from sensor confirming the part presence given to the bulking module (BK) and BK module connected to PLC through device net or ethernet as shown in Fig.1.

BK is two way communication modules which have power port, communication port and multiple ports for sensor connection from fixture. Inside fixture there is power tab, communication tab and BK module. Communication tab deals with signal communication and is connected to one port of BK module. On the other hand, power tab supplies power to BK module through other port. And multiple sensors from fixture are connected to BK module in the senor port. Therefore, when the target work piece found in electromagnetic field of inductive sensor it generates signal and is given to BK module and then to the PLC.

Along with sensors, fixture also consists of cylinders such as sliding and clamping cylinders which helps to hold the part. All the clamps can be controlled manually through the valve banks provided at the fixture. The output from the cylinders or clamps is given to the PLC through serial interface (SI) module. SI module is present in the valve bank and is mainly for the communication with PLC. Also, multiple sensors from fixture can be connected to BK module which further connected to PLC. After confirming signal from sensor and SI module, PLC enables the motion for robot and welding machine which starts the welding.

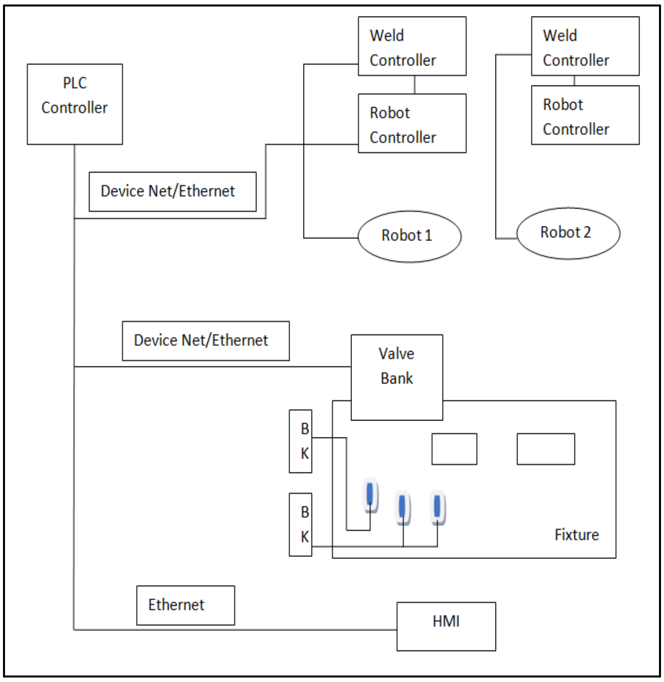


Fig.1. Working mechanism of automatic welding cell

IV. SENSOR FEEDBACK ERROR OCCURRENCE

In robotic welding industries, different sensors are used in automation and mostly for target object detection. Likewise, hydraulic or pneumatic cylinders like clamping cylinders and sliding cylinders are used. Automatic welding require fixtures to place the part which is implemented with sensors such as laser sensor, photoelectric sensor, and inductive proximity sensor while cylinders with magnetic sensors for piston position detection. Thus, the sensor feedback problem occurs mainly in the fixture and robot gripper. Fixture used to locate and hold the work piece in position during the welding process and robot gripper can pick and place the work piece as shown in Fig. 2. Malfunctioning of sensors by means of any reason leads to feedback issue [5].

Fig.2. Robot gripper

V. SELECTION OF SENSORS

There are many sensors designed for weld resistance, some work for longer functional life while some are not. Failure of single sensor can cause few minutes of downtime. But when multiple devices fail due to the challenging welding environment it make negative impact on the productivity of system. To deal with this dilemma, sensors are manufactured with rugged coating, better electronics, and other features make them withstand in harsh welding environment which increases sensor reliability and avoid frequent failure for sensors.

A. Short Distance Detection Sensors

Proximity sensors are made to handle harsh environments in welding cell like high temperature and welding fumes. Due to the low cost and rugged construction mostly proximity sensors are used in welding. Normally proximity sensors are of the low sensing range of few millimeters and therefore are used near the welding area. There are different types of proximity sensors which help in target detection but proper sensor selection for metal is important.

There are capacitive, optical and inductive proximity sensors available. All are mainly used for part detection. But they differ due to their working principle and application. The sensor mainly works on capacitive principle. Capacitive sensor has ability to sense through nonferrous materials, and it can detect fast moving small objects also as they give high switching rate for rapid response in object counting applications. They can even detect liquid through nonmetallic barriers like glass, plastic, etc. Therefore capacitive sensors are not endorsed to use in welding industry.

An optical proximity sensor consists of a light transmitter and receiver that detect the light. These sensors detect target objects which are in front of them by using the sensors own transmitted light reflected back from targets surface. The can be used to detect all types of material. The sensor is mainly used to detect plastic objects and can be used in mobile phones, alarm system, metal part detection on conveyor, etc. Optical proximity sensors are more expensive than inductive proximity sensors. So, optical sensors like photoelectric sensors are used in welding industry upto certain extend.

An inductive proximity sensor only detects metal objects with help of an electromagnetic field. When a metal target come near the electromagnetic field, the inductive characteristics of the target object change the field's properties. The target detection at greater or shorter distance also relies on the inductive nature of target material. The sensor can detect metal through plastic. It cannot detect non-conductive material where current cannot flow. The main use of this sensor is in automobile industry, metal industry to detect the metal objects in harsh environment with high moving objects, on conveyor line etc. Along with that, inductive sensor has low cost and robust nature to sustain the welding spatters. Therefore, inductive proximity sensors are widely used in metal and welding industry [8].

Inductive proximity sensors works on 10V-30V DC supply. The sensing range of sensors varies on sensor size. M12 sensor has 4mm while M18 sensor has 8mm of sensing range. And normally PNP type normally open sensors are used.

B. Long Distance Detection Sensors

Inductive proximity sensors are used to detect metal at short distance and can detect within their operating range only. Hence, these sensors are not capable to detect the target material at distance more than their sensing range. To overcome this, long distance sensors used for detection with detecting range of few meters.

There are ultrasonic, IR distance and laser sensors that can be used for long distance measurement. Ultrasonic sensors measure distance through reflected sound waves and it work on audio frequency more than human audible range i.e. 20 kHz. It is sensitive to surrounding noise and has limited sensing range. Similarly, IR sensors work on reflected light waves of 700nm to 1mm of wavelength. IR sensors have high power and can be hazardous for operations. So, ultrasonic and IR sensors are not advisable to use in industry due to their drawbacks.

Laser sensors measure the range of long distance targets through light waves. It works on 630 nm to 690 nm wavelength i.e. visible light. Laser sensors has detection range 60mm to 2000mm. Laser sensors with class 1 and 2 are safe to use while others can be dangerous. Laser sensors are most expensive in sensors so they are used only for long distance detection only.

Laser sensors used in metal and welding industry due to their advantages over other sensors. A laser sensor does not get affected by the part variation or small distance variation as it has availability to set the tolerance for detection range.

VI. SENSOR FEEDBACK ANAALYSIS METHODS

Any kind of damage to the sensor will lead to breakdown in the system which drastically affects the productivity. Frequent failure of the system components has become serious issue. Therefore to overcome this unwanted event, different types of analysis methods are adopted which includes study of baseline data, ISHIKAWA method, and Why-Why analysis.

C. Baseline Data

Baseline data is a measurement that is collected before start of investigation for the analysis. A baseline data study is useful in analysis of the situation to know the starting points of project. It focuses on the information that must be considered for analysis and comparison can be made with the future progress. The baseline data can be collected with taking some important parameters into consideration such as accuracy, frequency, duration and rate. The purpose of the baseline information is to study the effect of the analysis and to compare before and after changes in the program. Without baseline data it will be difficult plan the action plan and monitor the changes in system.

With the help of baseline data, the breakdown information can be categorized according to machine and priority of problem solving.

D. Why-why analysis

Why-why analysis is mainly conducted to find out root cause of the problem. It is an analytical method which helps to know the factors that contributing to the problem. The method is also known as root cause analysis method. This particular analysis will help to prevent recurrence of the system and to find out the basic cause of failure to take preventive action. It focuses on logical cause and gives the precise solution which helps to understand the chronic issues to avoid the future breakdown.

There are many advantages of this analysis over other methods as the method is very simple and helps to determine the relations of the causes. It also gives the root cause one by one so the differentiation can be done according to importance.

Why-why analysis detects the undesirable event and develops the understanding of causes of problems. It also helps to understand the origin of problem and the possible actions that can be taken so that it will not occur again and again. The activity is conducted by team and it investigates the cause that can be prevented.

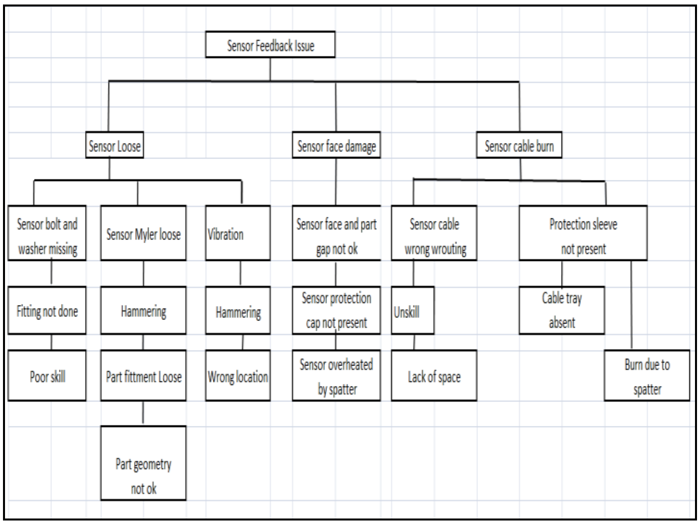


Fig.3. Why-why analysis

E. ISHIKIWA Analysis

It is cause and effect diagram which also called as fishbone diagram which help to know possible causes of a problem and can sort ideas into useful categories. A fishbone diagram is a visual method for categorizing causes of a problem as shown in Fig. 3. This tool is also used to find root causes of the problem. It is structured approach compared to some other tools to identify causes of a problem. In this analysis problem is displayed at the head of the fish.

With the help of ISHIKIWA analysis it is easy to describe the feedback error in main four categories i.e. human error, system error, material and methods. Sometimes lack of system flexibility and limitations of system over the period of time, system may leads to the errors. While wrong approach or method such as wrong setting or selection of sensor for problem handling can also contribute to the feedback error. Many times due to the lack of skill for person handling the problem may lead errors.

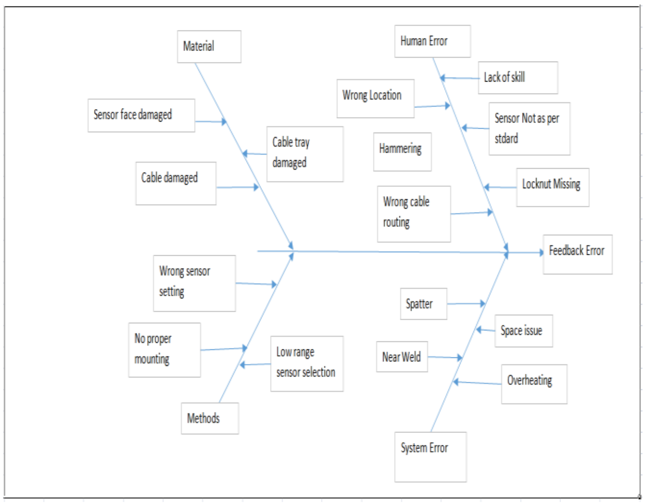


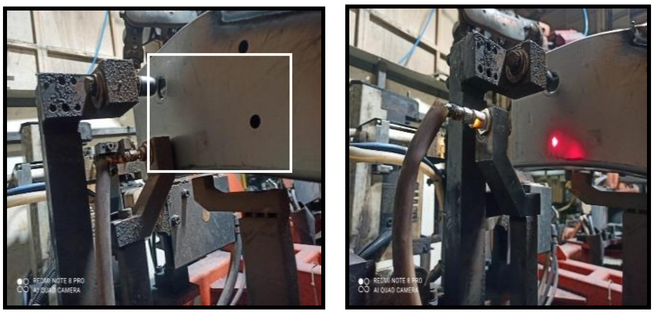
Fig.4. ISHIKIWA Analysis

VII. POSSIBLE ACTIONS TAKEN

Different types of analysis takes place to investigate the problem and it need actions to be taken to resolve the problem. The actions may include some permanent changes in the system or some temporarily actions. The action helps to kill the frequently occurring undesirable events.

F. Proximity sensor changed to photoelectric sensor

Inductive proximity sensor having low sensing range used majorly for target detection but due to lack of system flexibility sensors got damaged very easily and cannot sustain for long near welding area. Sometimes sensors are implemented close to welding area and got damaged due to spatter. So, inductive sensors can be replaced by photoelectric sensors that can detect from distance and frequent failure of sensor can be avoided as shown in fig.4.Photoelectric sesnors have more sensing range than inductive but less than laser sesnors. So, photoelectic sensors can be used to detect small parts where sensing distance is not more than few hundred milimeter.

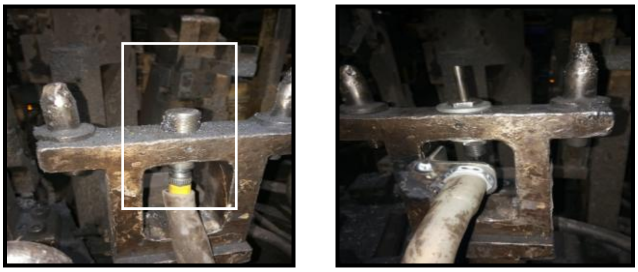


(a) (b)

Fig.5. (a) Inductive proximity sensor (b) Photoelectic sensor.

G. Use of Plunger

For the detection, metal part must be within sensing range but many times the surface of sensor touches the metal part and it damages the sensors face. While many times in vertical implementation of sensor, spatter fall on sensor face and it damaged the face which more sensitive part of sensor as shown in fig. 5 (a). Therefore, to make the best use of sensor at such places plunger makes a great impact. And frequent failure of sensor can be avoided as shown in fig. 5 (b).



(a) (b)

Fig.6. (a) Without Plunger (b) With Plunger

VIII. CONCLUSIONS

i. The sensor selection should be done as per application and sensing of the target object.
ii. There should be some distance between sensors face and target object.
iii. Sensors with small sensing range (1mm sensing range) should avoid for part sensing application.
iv. For part variation in the fixture or material, laser sensor can be used in place of inductive sensor.
v. Sensing target should not be in curvature or trim shape.
vi. Sensor must be away 10mm from heat zone / Hot environment

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