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Development of Spot Welding and Arc Welding Dual Purpose Robot Automation System

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ABSTRACT

A dual purpose robot automation system is developed for both arc welding and spot welding by one robot within a cell. The need for automation of both arc welding and spot welding processes is urgent while the production volume is not so big as to accommodate separate station for the two processes. Also, space is too narrow for separate station to be settled down in the factory. A spot welding robot is chosen and the function for arc welding are implemented in-house at cost of advanced functions. For the spot welding, a single pole type gun is used and the robot has to push down the plate to be welded, which causes the robot positioning error.

Therefore, position error compensation algorithm is developed. The basic functions for the arc welding processes are implemented using the digital I/O board of robot controller, PLC, and A/D conversion PCB. The weaving pattern is taught in meticulously by manual teach. A fixture unit is also developed for dual purpose. The main aspects of the system is presented in this paper especially in the design and implementation procedure. The signal diagrams and sequence logic diagrams are also included.

The outcome of the dual purpose welding cell is the increased productivity and good production stability which is indispensable for production volume prediction. Also, it leads to reduction of manufacturing lead time.

Key Words : Robot Automation System, Arc Welding, Spot Welding, Position Error Compensation Algorithm

1. Introduction

In the industries of Korea, the population of robot automation system is growing very rapidly just as in the rest of the industrialized countries. Especially, in the electronic industries the assembly system built round SCARA or Cartesian types of robots and the material handling systems of big and heavy boxes of electronic goods are the amain application.

In the automative and machinery industries, the main application areas are tending of machine tools an

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welding of components and assembly.

From the experience of authors, except the automotive assembly line where most of the robots are for spot welding, about 45% of the robots working in welding areas, followed by machine tending of cutting tools. Also there are plastic drilling and routing systems, water jet cutting of car interior material, and drilling and deburring of steel, plastics, and aluminum products. This robot automation engineering requires that the engineer has profound knowledge of the products. In most cases, the robot automation system is designed to work in single application area and, therefore, a robot that has the best characteristics for the purpose should be selected[1]. However in some areas, in other to maximize the availability of the system and return of investment, it is required that one robot has to work for two different tasks.

First case is that the two takes are of the same application area such as a machine tending system where two or more grippers are exchanged using automatic tool change system[3] or a spot welding system where welding guns are exchanged automatically or manual[3,7]. Second is that the two tasks are different from each other such as two different arc welding application of TIG welding(GTAW)and MIG welding (GMAW), material handling and arc welding, or arc welding or cutting dual-purpose robot systems.

When a robot automation system performs more that kind of tasks, it is important to check whether the robot is equipped for all their application. Every application area demands some characteristics to a robot which are appropriate to the area[2,3]. In arc welding resistance to heat and proper motion accuracy (resolution and repeatability) are of primary importance as well as the proficient and compact supply of WAC(water, air, and current). In addition, shielding capability to high frequency noise is very important to TIG welding application. In deburring or grinding mechanical rigidity and dust protection of the wrist part are highly important as well as the motion accuracy.

This paper is on the development of spot welding and arc welding dual purpose robot automation system, where one robot is to perform two different tasks. The product of the system is the inside panel of the elevator cabin, for which broad plate is spot welded and then some arc welding is added. To build this system, we first should consider upon the most efficient system. First possibility is that we build separate system of robot and jig and fixture dedicated to arc welding and spot welding respectively. This is surely the most certain way of building the system, but we must consider the production volume, space in the factory, and most importantly the return of investment. Second possibility is that two independent robots for each purpose work on a common jig and fixture system. In this case, two robots should work on the common restricted area, which should naturally restrict the work envelope of the robots. Also, interlock between two robots for collision avoidance and safety, arrangement of WAC from the main source to the robot, and signal process make things more complicated. Third possibility is to build a literally dual-purpose common robot system. This concept may solve the space problem unless it conflicts the production cycle time. The robot may carry the spot welding gun and arc welding torch simultaneously all the time or exchange one by one by automatic tool change system.

In principle, the specification required for arc welding robot and spot welding robot is quite different. When we builded a system for dual purpose application then we need to confirm the robot to spot welding specification since spot welding asks for more rugged mechanical condition. We must somehow be satisfied with restricted functions for arc welding. Fortunately, arc welding is simple through a straight line on the product which has a better possibility for success of the system. From the survey of the similar robot automation system developed in the world. we could find aforesaid arc/arc welding and spot/spot welding application dual purpose systems in practice in the U.S.A, Japan, Europe, and Korea but could meet only one instance of briefly mentioning a newly developed arc/spot welding dual purpose robot system in Italy in 1994[4].

2. The Product and Manufacturing Process

The manufacturing process of elevator cabin panel consists of cutting, spot welding, arc welding, grinding, and assembly. Among these, the spot welding process has been by dedicated and manual work, and total of 72 kinds of panels and most of them are too big to be handled by workers and have big production volume.

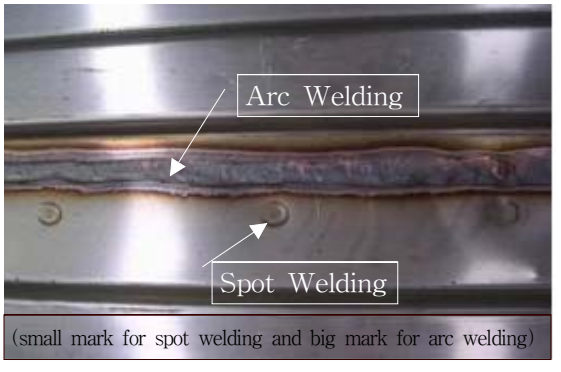


Fig. 1 The panel plate and locations for spot and arc welding

Typical panel is as shown in Fig 1. Two plates are spot welded together and stiffener member are arc welded to it. The arc welding is intermittent welding with the welding length of about 15-25mm and root gap of 4 mm.

3. Design of the System

3.1 Spot welding

In this system, the spot welding is performed by the conduction between the gun and jig and fixture where as most of the spot welding is performed by the gun itself. Therefore, the power supply system becomes complicated and too much pressure of the gun to the plate generates nugget on the other side. Also, in this type of indirect welding process from the gun through the plate to the jig and fixture, power efficiency gets lower due to the reactive power and power supply system may expect shortened life time due to the impedance generated by high current during welding.

Therefore, to increase the effective power rate and reduce the impedance effect, a transformer is adopted with inverter circuit whose output is DC. Also, the power cable is chosen to be of more than 200mm^2 of area and less than 5m of length[5]. The power cable is fed over the counterbalance mast to prevent from being

Table 1 Requirements for spot and arc welding robot

	spot welding robot	arc welding robot
load carrying capacity	-. big enough to attach welding gun and brackets -. usually greater than 100kgf	-. usually ground 10kgf
shock resistance	-. shock resistance against gun press -. employing servo error for external shock such as collision	-. overcurrent sensor using Hall Effect -. employing shock sensor such as collision
repeatability	-. with ±0.5mm	-. with ±0.2mm
welding power cable and polarity	-. within 5m length and diameter greater than 22mm^2 to reduce high impedance between welding power source(-) and welding gun(+) -. cable of diameter greater than 5.5mm^2 between power source and jig & fixture	-. no limitation to the length between the power source and welding torch(usually within 100m length and diameter greater than 52mm^2) -. diameter of greater than 52mm^2 between power source and jig & fixture
ground	3-rd level ground	special 3-rd level ground

twisted and tangled, and interfered with torch or the workpiece. Table 1 shows a simple criteria of gun type is more economical in making jig and fixture and provides with much easier power cabling.

On the other hand, the single type gun gives a better welding quality. The single gun is selected since the output quality is primary concern.

3.2 Arc Welding

The arc welding process attaching the stiffener member is an intermittent welding with short weld length of 15～25mm along a straight line and the tolerance for plate setting on the fixture is 0.1mm. Therefore, weld seam tracking device using arc sensor is not used but only the over current sensor using Hall Effect and shock sensor for collision detection arc applied[6, 8]. Also, for the output of voltage within the range of ±12 volts and current a D/A converting PCB with 2 analog ports is connected to the PLC and the power is generated in linear mode by the steps set by the sequence program.

3.3 Robot

The robot for this application should satisfy the specification for both arc welding and spot welding.

However, the spot welding requires more rugged mechanical condition and so the specification for the robot should conform with spot welding. In Chap 4. System Installation and Operation shows the specification for both spot welding and arc welding[1~3]. Fig 2 shows the spot welding gun and arc welding torch attached together at one robot wrist. Robots for arc welding has usually within 10kg load carrying capacity, high repeatability, and software and function that are indispensable for arc welding. The spot welding requires more rugged mechanical condition and so the spot welding robot is chosen in the case. However, in case robots for spot welding is to be used for the arc welding application, this robot does not supply

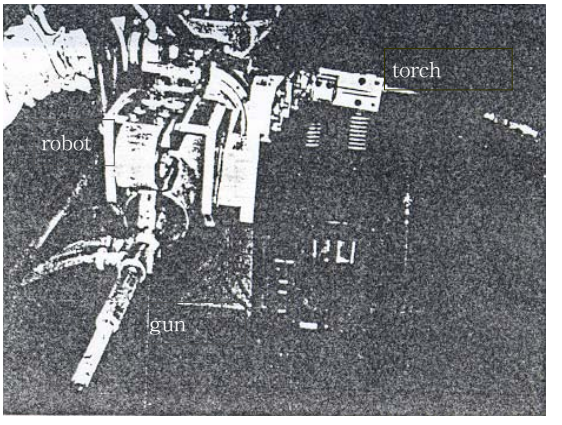


Fig. 2 Spot welding gun and arc welding torch attached together at one robot wrist

sufficient function and accuracy for arc welding. Fortunately, the arc welding in the case is rather simple straight intermittent welding. Otherwise, we have to expect more difficulty in engineering and programming. The robots for welding should be able to sustain the reaction force from the shock of the spot welding as wall as the weight of the welding gun itself. The robot chosen for this system is Fufikoshi Nachi 8607-03 from Japan. In the case, the reaction force from the welding is 450Kgf while the robot can stand up to 550Kgf of resisting shock. Also, the total weight of spot welding gun and arc welding torch attached is 23Kgf while load carrying capacity is 65Kgf. There are usually two ways of absorbing the resisting shock from the spot welding, which are servo-lock and brake-lock algorithm. In Fujikoshi robots brake-lock algorithm is adopted. Fig 3 shows the algorithm of compensating the position error due to the manipulator slip after stud welding. The algorithm is applied to the axis 2 because the shock from the welding affects the axis mostly. As mentioned before, the robot is equipped for spot welding. Therefore, some dedicated rearrangements are necessary for arc welding as follows. The necessary digital signals such as arc on/off, arc start error, shield

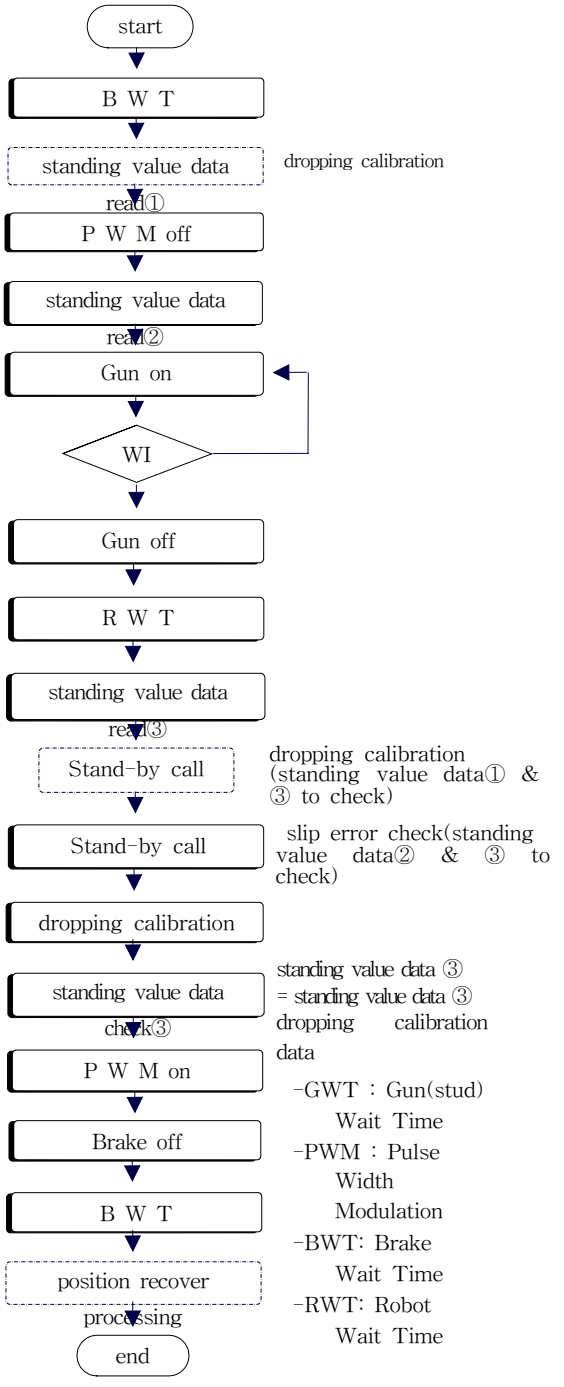
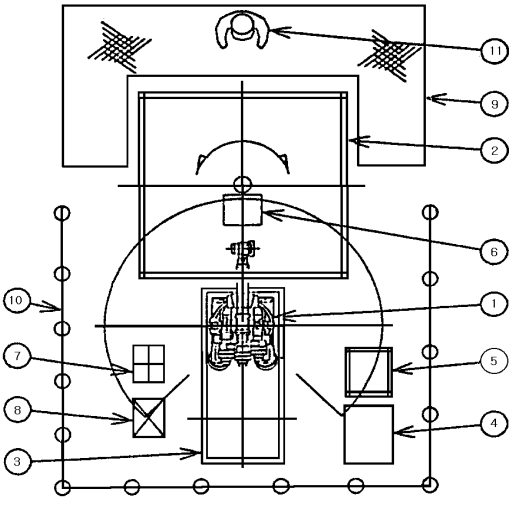


Fig. 3 Position error compensation algorithm for root after contact for spot welding



No	part name	maker	specs
1	robot	Fujikoshi. Japan	NACHI 8607-03
2	jig	local made	
3	carriage	local made	
4	robot controller	Fujikoshi. Japan	AP
5	system controller	local made	
6	spot welder T/R	Dengensha	NRHAH-160
7	spot welder T/C	Dengensha	WELCOM II
8	arc welder	Nastoa. Japan	350-II
9	safety mat	local made	
10	safety fence	local made	

Fig. 4 System layout and equipment specification list

gas on/off, and wire feed on/off are provided by sequence program using a PLC interfaced with digital input/output board of the robot controller.

The indispensable arc interlock between the robot and welding power source is checked only at arc start and during the welding process. In this system the weld length is so short that the robot outputs a digital pulse only at arc start and the PLC sets it as a dummy data, checks it after a preset time delay, and feed it back to the robot.

4. System Installation and Operation

The system consist of a robot, a spot welding power source, an arc welding power source, workpiece clamping jig and fixture, a robot carriage, and a system operation panel. Fig 4 shows the system layout and equipment specification list and Fig 5 shows the system signal diagram.

The problems encountered in system operation are as follows. First, the noise generated from the spot welding and arc welding power source would cause trouble in signal process. Second, setting the stiffener member after the spot welding process causes slight dislocation error of workpiece set on the jig and fixture. Third, rotating jig and fixture may collide into the robot and casual or accidental switching may start the robot at the wrong instance which leads into the collision. These possibilities lead us into more strict safety consideration. First, in order to prevent noise both power sources are 3rd-level grounded from the retaining frames. To prevent dislocation error, specially-made clamp screws are used to hold the work pieces.

Third, an interlock is provided so that the jig and fixture may rotate only when the robot is at ready position.

In robot teaching programming, the most difficult problem stems from the fact that the robot in use is for spot welding. Therefore in arc welding process, the important weaving should be programmed one by one manually. However, no matter how meticulously the weaving is programmed it is quite natural that the precision cannot be so good as the one from the software. Therefore, we should expect some welding

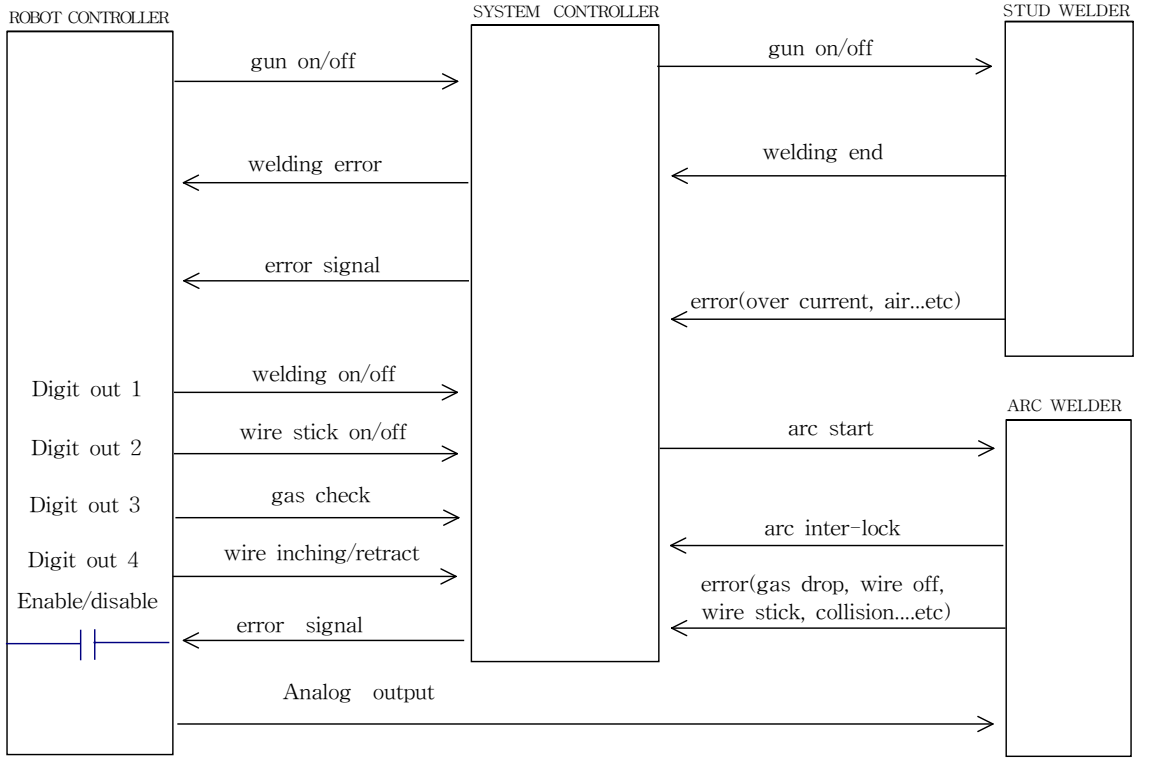


Fig. 5 Signal connection diagram

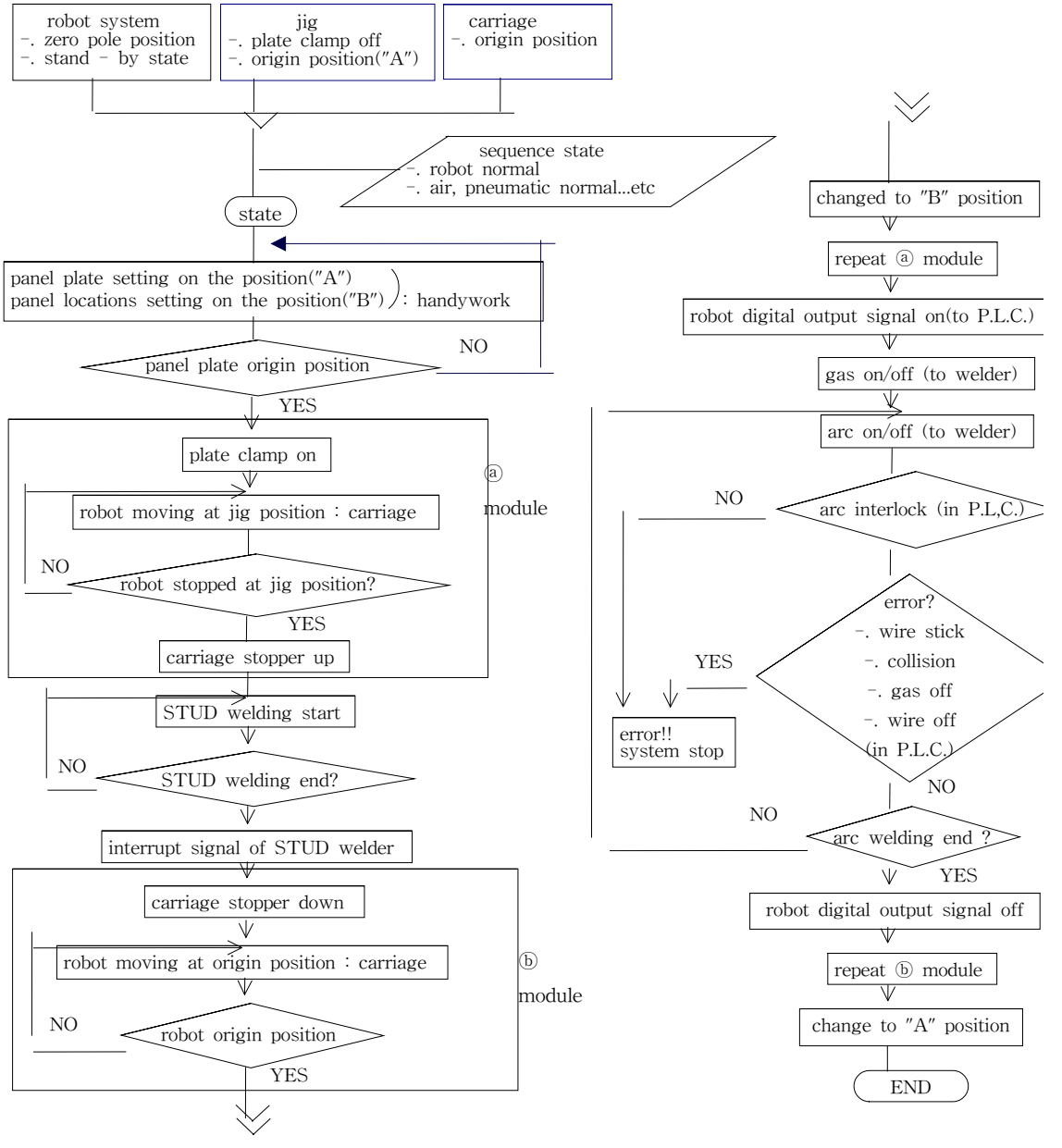


Fig. 6 System operation procedure flowchart

defect such as undercut and repeatedly have to modify robot position program during test. Finally, the whole system is operated in automatic mode but is equipped with manual operation mode using switches as a configuration plan, Fig 6 shows the system operation procedure flowchart.

5. Conclusion

A robot automation system with spot welding gun and arc welding torch attached together at one robot wrist is developed and solves the problem of restricted space and longer cycle time in case tool change is necessary. Therefore, spot welding and arc welding dual purpose robot system is developed for the first time. The system realizes saving of 3 personnels, reduction of manufacturing lead time, and achieving balance between stations. It is hoped that this paper transfers good working knowledge and knowhow to the interested researchers and convince engineers that this type of system is attainable.

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