DESIGN AND SIMULATION OF ROBOTIC SPOT WELDING SYSTEM FOR AUTOMOTIVE MANUFACTURING APPLICATION

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Abstract: *Spot welding process for automotive manufacturing application is moving towards automation and robotic level. The transition process from manual to automation system need a proper planning and know how. Simulation is the best solution for predicting, comparing or optimizing the performance of a process without the risk of disrupting existing operations or cost of implementing a new actual process. This paper presents the application of simulation and statistical analysis for replacing a manual welding system of a body shop assembly with a robotic spot welding system (RSWS). Initially, the RSWS developed uses a minimum number of robots for producing the same number of output as before. Robot selection analysis was performed using Multi-Attribute Decision Making method. The CAD model was built using Solidworks software and simulation was performed using Robotworks software. The data that was acquired from robot workcell simulation were transferred to Witness software for purpose of shop floor simulation. The results from Witness simulation show that the new welding layout is capable of achieving the manufacturer's target. The analysis shows results of lower operational cost and the break event point will be achieved by the third year of operation. The implementation of RSWS for automotive application is reasonable because of efficiency, accuracy and cost effective.*

Keywords: *Robotic spot welding; robot simulation; manufacturing automation*

Introduction

The automotive industry heavily relies on welding process, especially spot welding, in the manufacturing of automobile car bodies. The process of spot welding for example, produces strong welds in a relatively short amount time, allowing for the automobile body to be welded together in under a few minutes. It is very important to ensure the quality and consistencies of welding processes. Since welding is a critical process in automotive manufacturing, the need to use more reliable welding system is highly recommended. Robotic spot welding system (RSWS) was identified as an approach to improve quality and productivity of welding process in automotive manufacturing.

For the purpose of study, a manual body assembly line in an automotive manufacturing company in Malaysia was taken as model to be robotized. This line contains of 13 workstations with 17 operators. Nine out of thirteen workstations dealt with spot welding operation. Simulations of robotic spot welding were also finding the optimum combination of the system that is capable of achieving manufacturer's target with minimum number of robot. The shortages of high-skilled labors for spot welding also encourage the automation of the process.

In this paper, three different softwares are used to design and simulate robotic spot welding workcells. Solidworks software is well known as a powerful software for 3D design and modeling. This software is used to model workcells that contain spot welding robot, components to be weld and fixtures. To simulate the workcells model, Robotworks software is used. Robotworks is a robot simulation software that works on Solidworks software as its platform. Then, the full simulation of layout is performed using Witness software.

Model Development

Robotic workcells are important elements in RSWS for performing spot welding operations with industrial robots and associated peripheral devices. Rapid design and deployment of a robotic workcell require the successful applications of concepts, tools, and methods for fast product design, manufacturing process planning, and plant floor support. An important technology for achieving this goal is robotic workcell simulation.

Robot selection is another issue in design of the workcell. It is become more complex regarding to the number of parameters that to be considered. Selection of appropriate industrial robot for a particular spot welding process in an automotive manufacturing company was made based on considered parameters. Multi-Attribute Decision Making (MADM) method that consist of Weighted Sum Model (WSM), Weighted Product Model (WPM), Analytic Hierarchy Process (AHP), Revised Analytic Hierarchy Process (RAHP) and Technique for Preference by Similarity to the Ideal Solution (TOPSIS) were used to analyze and select an optimum robot. MADM method was widely used for decision making applications. For robotic and technology selection, this method was used by Jones (1986), Nnaji (1988), Khouja (1995), and Triantaphyllou (2002). The final selection was made on the basis of rankings obtained by all five techniques above.

Robotic Workcell Development

Robot modeling process is made with the basis on engineering drawing of actual robot that had been selected in previous section. The engineering drawing that was acquired from the robot manufacturer contains the important dimensions of robot. Generally, the selected robot had nine main components with six degree of freedoms. Every component is modeled and assembled in Solidworks software until a complete robot is ready.

The new design of body assembly line reduced the spot welding process to include a minimum number of workstation. In robotic welding workcell design, the selected spot welding operations from manual method are transferred to robotic welding workcells. The selection of operation is made based on operation that can be performed on a single fixture. However, the operation must follow the precedence of operation.

After studying the manual welding system, the major operation of this process can be divided into two workcells. The first workcell welds the underbody components which are assembled to become a vehicle floor. Basically, this workcell is combining the operations from three different workstations. The second workcell performs the spot welding operation for vehicle mainbody. This workcell is assembling the vehicle floor, side panels, back and front panels and roof. Previously, these components were assembled in separated workstations.

Layout Model Development

The robotic welding layout that had been designed contains five workstations. Two of the workstations have industrial robot to perform spot welding operation, while the other three workstations were operated manually. The purpose of applying both robotic and manual workstations is to minimize the investment and setup cost while producing similar output rate with better quality. In the new body assembly layout, the work elements in workstation were rearranged and restructured to fit with new robotic workcells.

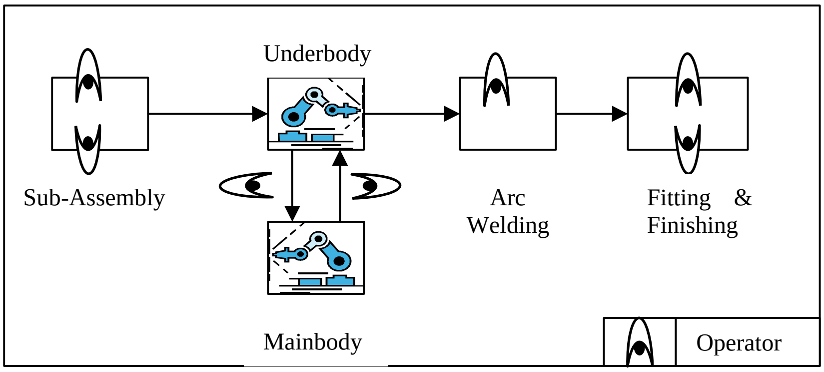

FIGURE 1: Layout of Robotic Spot Welding System

Referring to Figure 1, the process in RSWS starts with sub-assembly process where the assemblies of small components are made manually. Then the components are sent to underbody workstation for floor assembly, then to mainbody workstation. In underbody and mainbody workstations, the operation of spot welding is performed automatically where one robot is allocated for each workstation. After performed an operation in mainbody workstation, the vehicle body was sent to underbody workstation back for some touch up before transferred to arc welding workstation. In arc welding workstation, the arc welding process is carried out. Finally, the body fitting and finishing is made to the vehicle body.

Simulation and Results

The first stage of simulations was simulation of robotic welding workcells, which are named Underbody and Mainbody workcell. The simulation was performed by using Robotworks software. The graphical simulation of spot welding robot in robotic workcell shows the physical movement of robot and welding gun that had been programmed before.

The simulation started by running the first workcell which welds the underbody components and followed by mainbody assembly in the second workcell. The observation on the simulation model is made to ensure that every movement followed the actual precedence. At the same time, collision checking was performed to detect any collision in simulation model. The assumptions of the simulation are:

i. Cycle times for operators loading or unloading are same as in current manual welding
ii. Robot movement speed consistently at 130 degrees/second
iii. Turntable is used for material handling

Simulation was performed separately for Underbody and Mainbody workstations. The cycle time for the operation was recorded as the output. After running the simulation for five times, the average cycle time was calculated as 5.75 minutes for Underbody workstation and 4.27 minutes for Mainbody workstation.

The result of cycle time from graphical simulation was used for the second stage of simulation, where the layout of RSWS is simulated. The simulation model was built in Witness simulation software. Before simulation model is developed, time study was conducted in body assembly line to record the cycle time of each workstation. The simulation model of spot welding layout was developed base on workstation cycle time. The assumptions for layout simulation are as follow.

i. No part supply shortage
ii. Operator works with 90% efficiency
iii. No machine breakdown or setup
iv. No scrap
v. Constant cycle time for every workstation (discrete event)
vi. Pull technique in production system
vii. Each station only hold one operation per cycle

The simulation model in Witness software is shown in Figure 2.

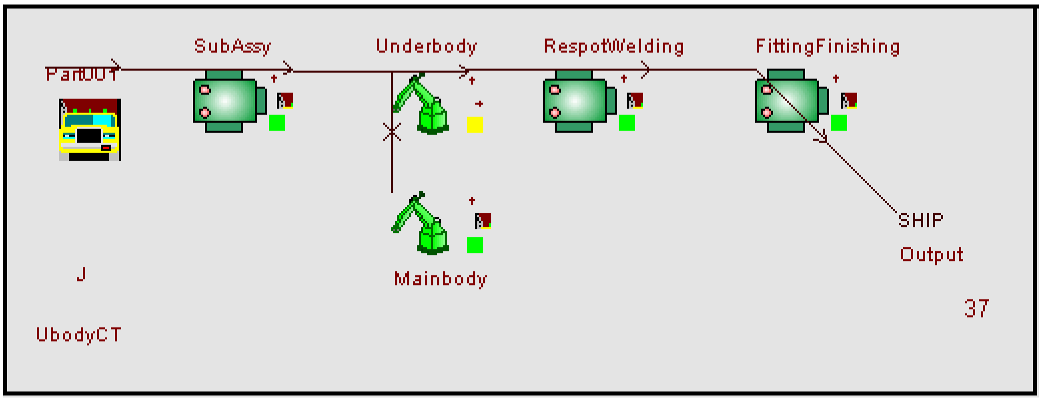

FIGURE 2: Witness Simulation Model of Robotic Spot Welding Layout

Simulation of the robotic spot welding layout was run for 480 minutes which resembles working duration for a day. After running the simulation for a few times, the result present the number of output for a working day is equal to 37 units, while the manufacturer's target is 36 units per day. Therefore, the system is capable of achieving the manufacturer's target.

Model Verification and Validation

In simulation, verification and validation of simulation model are important to ensure the model is built rightly and represent the real system being studied. For this study, verification of simulation model is made through inspecting the flow of part that being process in this manufacturing layout model. The part flow should go through to the correct workstation, with the correct number of part and follow the right sequence. By checking the statistic of each workstation which provides the number of parts that had been operated, the simulation model is verified.

The validation of the simulation model was made by performing the simulation for current manual spot welding system at body assembly line. The simulation model was built based on actual workstations and cycle time of each workstation. A study was conducted at body assembly line to collect cycle time data and output per day. The result of study shows that the current manual spot welding produces 36 units per day. The cycle time data then were transferred to Witness software to be simulated. After a few times of running the program, the simulation model presents the result of output as 37 units per day. With 2.8% of discrepancy, the simulation models were validated.

Break Even Analysis

The proposed RSWS requires quite a large amount of investment. The main consideration for adopting advanced technology in manufacturing system is the investment cost. Break even analysis is made to study the break even point between applying RSWS and staying with conventional spot welding system. In this case, the break even point is presented in time-scale, where the optimum operational period is achieved.

For this purpose, the considered fixed costs for applying RSWS are investment of robots, material handling system and setup cost. Beside that, the variable cost such maintenance and power consumption for implementing this system also need to be considered. By implementing the RSWS, the reduction of 10 operators can be achieved, where they were replaced by two robots. In this section, the analysis was made by comparing the cost of implementing RSWS and labor cost for 10 operators that were eliminated in RSWS. The summary of related costs are shown in Table 1.

TABLE 1: Cost for Implementing RSWS (RM 1 = USD 0.263)

Fixed Cost	RM	Variable Cost	RM/year
Robot cost	240,000	Maintenance	20,000
Material handling	120,000	Power consumption	9,984
Setup	20,000		
	380,000		29,984

If the manufacturer prefers to continue performing spot welding operation with manual welding system, they need to pay for 10 extra labors which cost them;

Total cost = *labor cost/hour* x *working hours/year* x *number of labor*
= RM 8.20 x 2080 x 10
= RM 170,560 per year

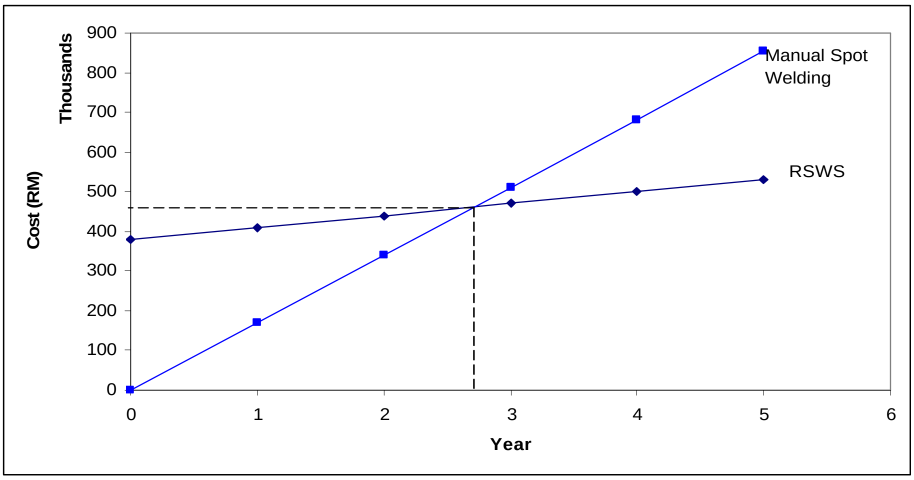

FIGURE 3: Break Even Chart

Conclusions

In this paper, the simulations of robotic spot welding system were successfully made. The simulation objective to replace manual spot welding with robotic spot welding system was achieved by producing the same number of output. Referring to Figure 3, the break even point will be reached by the third quarter of the second year of RSWS implementation. After that point, the operational costs for spot welding process are reduced. The implementation of RSWS gives more benefits to the manufacturer in term of quality and operational cost.

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