SIMULATION AND MANUFACTURE OF CLOSURE COMPONENTS FOR AN AUTOMOTIVE INDUSTRY

MURUGAN N.
Department of Robotics and Automation Engineering, PSG College of Technology, Coimbatore, India
* nmn.rae@psgtech.ac

NAGA DHATSHANA R.
Department of Robotics and Automation Engineering, PSG College of Technology, Coimbatore, India
* nagadhatshana@gmail.com

ABSTRACT
Manual welding and hemming processes don't deliver higher speeds and efficiency resulting in reduced production rate. Hence, robotic hemming and welding processes are to be implemented to overcome the risk involved in manual welding and achieving greater efficiency. Based on the present system layout in a local automotive industry, a virtual work cell was created with various robot models, fixtures and work tools like clamps, welding guns, rollers, etc. The robot operations were simulated and checked for collision, zoning and the cycle time which was estimated for both the virtual and real work environment. The simulated work cell was replicated in the real environment and checked for any discrepancies with the virtual work cell. The estimated total process time of various processes carried out in the closure panel assembly line by both the automated method and conventional method was compared and the percentage reduction in the total process time was determined.

INTRODUCTION
Manufacturing activities in an automotive industry comprises of different segments like design, development, manufacturing, sales, etc. The manufacturing rate is decided by the assembly line of the automotive industry. The assembly line existing in a local automotive industry includes the process of spot welding and hemming of inner and outer closure panels together. As the output efficiency of conventional methods for hemming and spot-welding is low, robots are being implemented to accomplish the processes [Babak Saboori et al (2009), Sezgin Ersoy et al (2017)]. In order to avoid trial and error analysis method, robotic hemming and spot-welding process are performed [Babak Saboori et al (2009), Jonkers (2006)]. Robotic hemming and spot-welding should be simulated before installing it in the production line to ensure the enhanced productivity and efficiency [Pedro Neto et al (2010)]. Software tools like Delmia Igrip, Roboguide, Robcad, RoboSim, Process Simulate are utilized for the simulation of robot operations performed in the assembly line of automotive closures [Pedro Neto et al (2010)]. Selection of robots are done considering the payload, space constraints and the production target to be achieved. Apart from the robot model, various inputs like the process flow, space availability of layout, cycle time of the line, number of jobs or panels to be produced in one hour are required to develop the virtual cell.
Tecnomatix is a comprehensive portfolio of digital manufacturing solutions that link all manufacturing disciplines together with product engineering from process layout and design, process simulation and validation, to manufacturing execution. Simulation was performed using the Tecnomatix Process Simulate software which rendered the verification of manufacturing process in 3D environment. The simulation work-cell was designed and developed in such a way that the desired cycle time was achieved [Mali& Inamdar (2013)]. All the robot operations were simulated and checked for collision, zoning and the cycle time. The proper sequence of all the operations was set according to the Method Analyzer sheet (MA sheet). The cycle time was then checked using threshold value specified in the MA sheet. The virtually created work cell was replicated in the shop floor. After a successful test for collision and zoning the simulation of the assembly line was performed. The process time of each process of the assembly line was estimated and compared with that obtained by the manual method.

COMPONENTS OF CLOSURE PANEL

Closure panel is made of two major parts: inner and outer panel. An outline of a typical front door panel of the car is shown in Figure 1. The child components that are added to the panel vary as per the requirement of the company. However, there are certain components that are essential for any closure of a car irrespective of the car model.

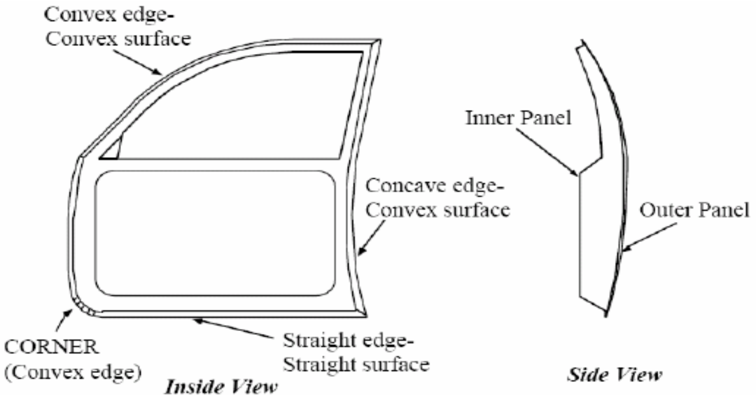

Figure 1: Outline of a typical Closure Panel

The mandatory child components of a door panel are beltline bar, sash area bar and reinforcement bars. Figure 2 shows the typical child components of a front door panel. The beltline bar supports the attachment of window glass with the inner and outer panel respectively. The sash area joins the inner and outer panel at the top of the door. The purpose of reinforcement bars in the inner panel is to absorb the vibrations and prevents the damage of the inner panel.

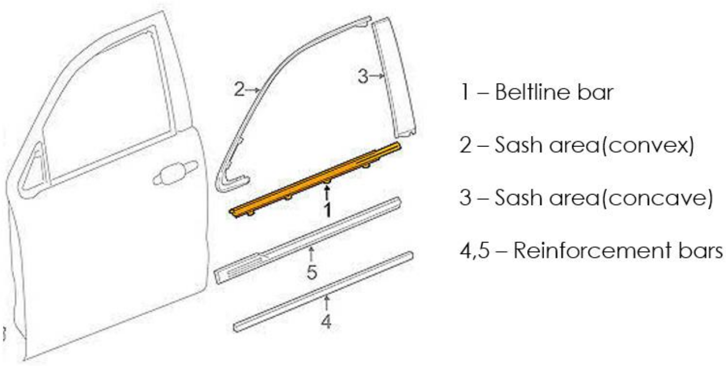

Figure 2: Child Components of Front Door Panel

SYSTEM LAYOUT AND OPERATION STATIONS

Figure 3 shows the system layout of the door production line having the space allocated for the assembly line as length 2000 mm and width 1500 mm.

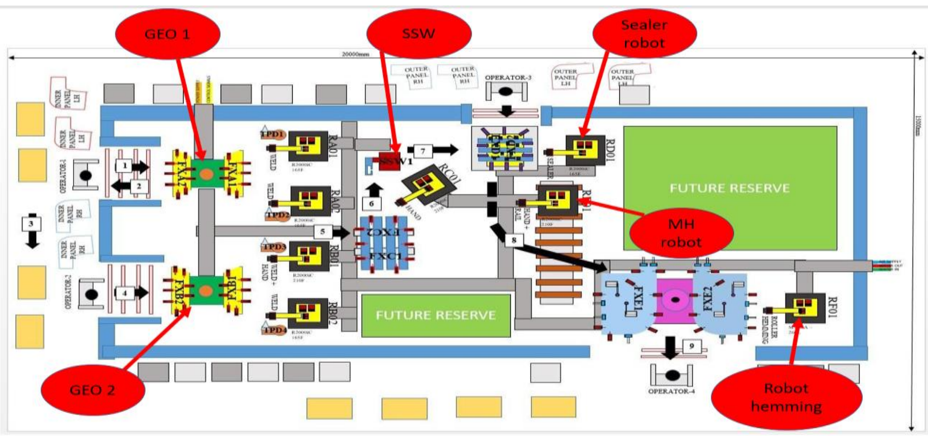

Figure 3: System Layout of the Door Production Line

Figure 3 also highlights the various operating stations in the assembly line. The process stations and the main elements present in the work cell are given below:

- **GEO 1** – Geometric Welding Station 1
- **GEO 2** – Geometric Welding Station 2
- **SSW** – Pedestal (or) Stationary Spot Welding
- **Sealer Robot** – Robot applies sealer (glue to attach inner and outer panel) upon he edges of the outer panel.
- **MH Robot** – Material Handling Robot
- **Robot Hemming** – Hemming process is accomplished by this robot.

PROCESS FLOW

The process flow in the production of the closure panel was identified using the Method Analyser (MA) sheet which included the time and sequence of all operations [Yuvraj & Vigneshwaran (2020)]. The flowchart shown in Figure 4 displays the flow of operations performed in the assembly line for the production of Front door RH (right-hand) and LH (left-hand) closure door panels.

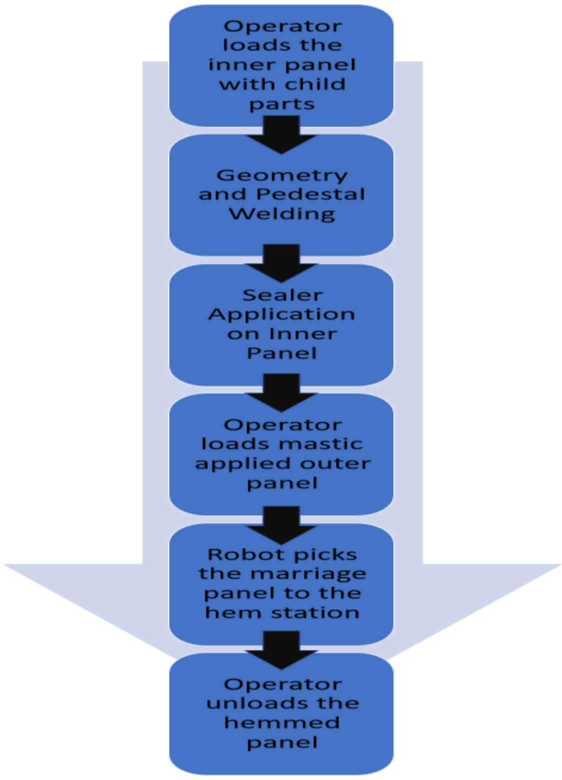

Figure 4: Flowchart of Process Flow

ROBOT SELECTION

Selection of robots was performed based on the consideration of parameters, availability of robot in the plant and budget expenditure estimate for the robots. The four major factors to be considered in selecting an industrial robot for the production line of automotive parts are payload, accuracy, work volume and repeatability. Payload is the first criteria that are considered in deciding the robot for various operations in the production line. Payload is the total weight that an industrial robot can carry. It includes the weight of the end effector (or) the End of Arm Tooling (EOAT). The maximum payload a robot can lift varies from robot to robot.

For an industrial welding robot, the payload is calculated by summing the weight of gun and the weight of the end effector.

Payload of welding robot = Weight of Welding Gun + Weight of End Effector
For an industrial material handling robot, the payload is calculated by cumulative addition of weight of gripper and that of the panel.

Payload of material handling robot = Weight of Gripper + Weight of the automotive closure panel to be picked up.
In some cases, the robots in addition to a gripper also contain a welding gun for spot welding. In such cases, the payload is calculated as follows:

Payload of multi-tasking robot = Weight of gripper + Weight of the closure panel to be picked up + Weight of the servo welding gun.
Considering the above mentioned four parameters, FANUC R2000iC – 165F, FANUC R2000iC – 210F, FANUC 900iA – 260L were chosen for welding, material handling and hemming process respectively.

PROCESS AND DESIGN VALIDATION

Once the process flow and the robot selection were done the simulation of the assembly line was carried out. The layout, robots and other components were imported into the software and were assembled according to the operation sequence. The various operation stations of the assembly line were simulated using the software. Through the simulation design of the fixtures, pass stands, risers, sealer stands, grippers and other tooling were validated.

Cell Building as per the Layout

System layout details in the *.cost format was imported into the simulation software. By referring robot matrix robot models were downloaded into the Process simulate software. Downloaded robots were placed in the simulation layout. The essential fixture tooling and other utility items were designed and placed in the virtual cell.

Robot Reach Check

Robot reach check was done for 100 mm extra reachability to avoid reach issues in the real time applications. In robot reach and range check, all other error checks like singularity and robot zoning were carried out. Robot Gun mount and gripper mount fixing were performed along with the reach and range check. Figure 5 shows the reachability check performed for the welding robot.

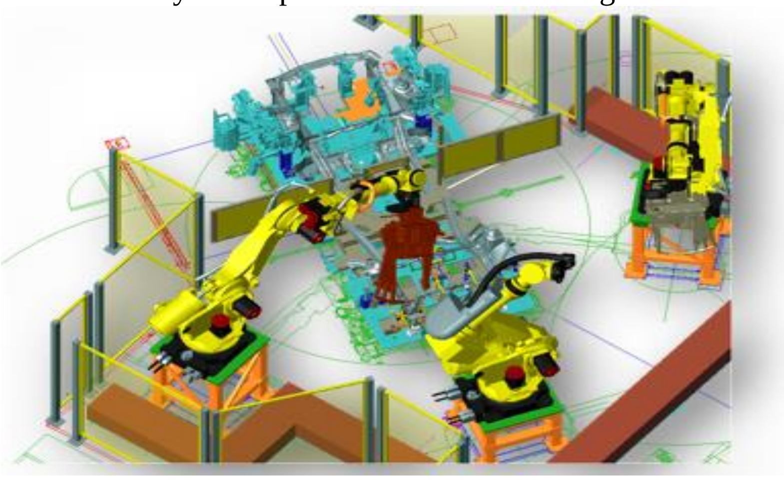

Figure 5: Reachability Check performed for the Welding Operation

Weld Spot Projection

Weld matrix is an excel sheet that consists of spot ID, panel number, gun number, station number & robot number. X, Y, Z spot values & spot IDs obtained from the weld matrix were converted into *.csv file and imported inside simulation software. Figure 6 shows the simulated welding spot projection and orientation in the panel.

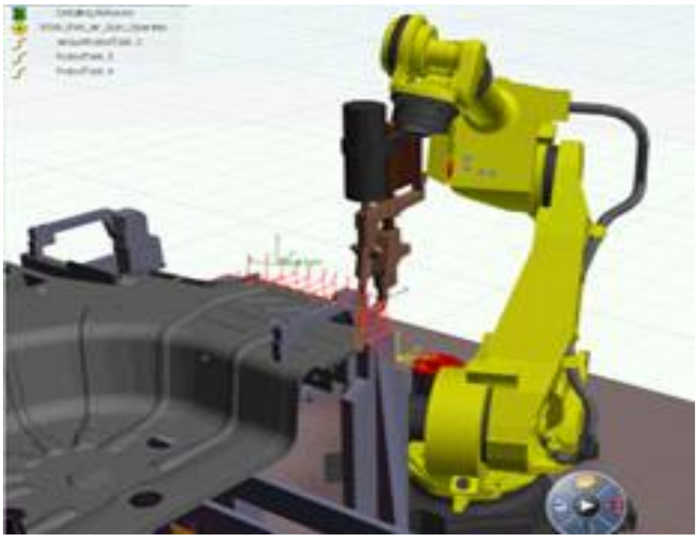

Figure 6: Weld Spot Projection

SIMULATION

Robotic workcell simulation is a modelling-based problem solving approach developed for the design, analysis, and offline programming of robotic workcell [Cheng (2000)]. The simulation of the assembly line provided the preview of the operations in a virtual environment. In the simulation, the motion to the robots and other tooling was given with the aid of geometric modelling and kinematics of the joints. The designed and validated work-cell was simulated with the help of Process simulate software and was visualized to confirm the achievement of the desired cycle time. The offline program was exported from the simulation module of the software and the operations were performed with the actual robot. Figure 7 shows the snapshot of the front door assembly line simulation that was done in the Process Simulate software.

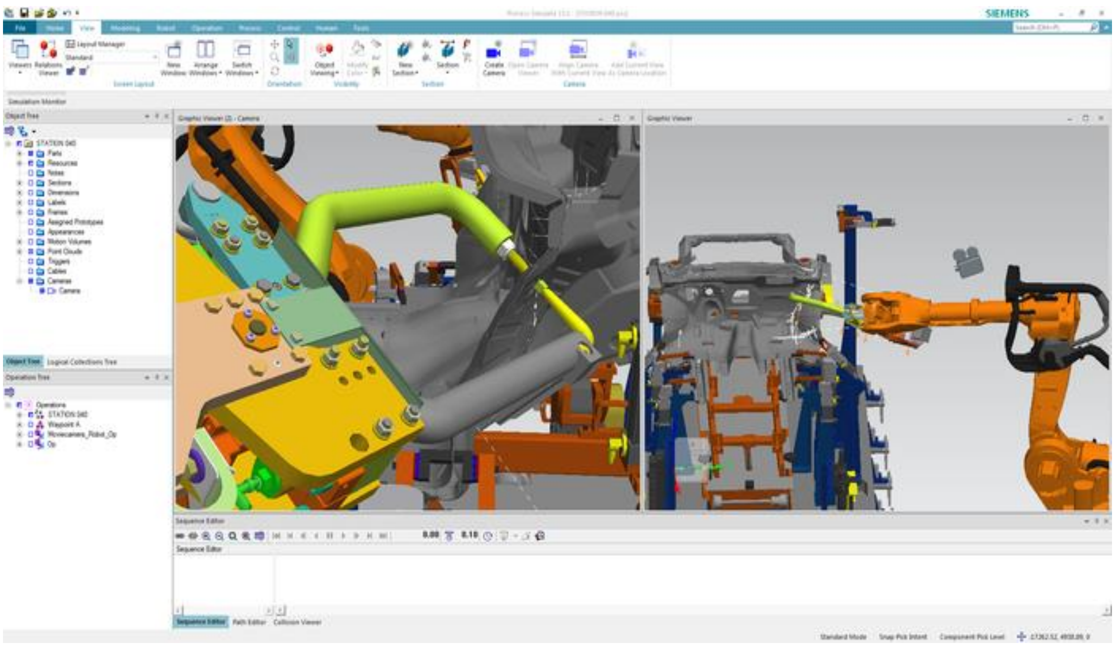

Figure 7: Simulation of the assembly line using Process Simulate Software

RESULTS AND DISCUSSIONS

The assembly line was simulated and cycle time for each operating station was estimated. The operating station perofrmed various operations that included operator loading and unloading of the panel, turn table movement, opening and closing of clamps, welding, material handling of the panels by the robots, etc. The cycle time estimated in the actual shop-floor and the simulated time obtained from the software was compared and presented in Table 1.

Table 1. Comparison of Simulated and Actual Cycle Time for the Process Stations

STATION TIMINGS	CYCLE TIME (secs)	
	SIMULATED (secs)	ACTUAL (secs)
Geo_Weld_1	80	79
Geo_Weld_2	80	76
MH_SSW	80	79
Sealer	80	73
Roller_Hemming	80	80

The assembly was initially performed by conventional method that included manual welding and manual hemming process. After the installation of the automated assembly line, the estimated process time for the various operations was compared with that of the manual method.

Table 2 shows the comparison of the process time for all the process stations of the closure panel assembly line performed by the robot with that of the manual method. From the table, it can be found that the decrease in process time leads to an average decrease in the overall cycle time of 76.35%. Hence, automated production process resulted in significant reduction of the total process time of the assembly process.

CONCLUSION

The installation of robots for spot welding and hemming made the process easier and the quality of weld and hemming was good. The total process time of the project was also decreased drastically. Comparing the total process time of the manually operated cell, the total process time of automated operated cell was reduced by 76%. Uniform hemming was obtained throughout the edges of the panel. Robot spot welding was very accurate at the desired point where the welding was required. The whole cell was built in the manner to achieve good production without any human interference. To make it easier, the whole process was simulated using software before robot programming and installation. The off-line programming was generated and installed to robots later. Finally, the robot cell was installed and desired cycle time was achieved.

Table 2.Comparison of Process Time of Automated and Conventional Method

PROCESS	FIXTURE	PROCESS TIME (Sec)		PERCENTAGE DECREASE IN CYCLE TIME (%)
		ROBOT	MANUAL	
Geo_weld_1	FXA1	21	37	76.19
Geo_weld_1	FXA2	21	37	76.19
Geo_weld_2	FXB1	15	26	73.33
Geo_weld_2	FXB2	15	26	73.33
SSW_welding	FXC1	18	32	77.78
SSW_welding	FXC1	18	32	77.78
Sealer_Mastic	FXD1	17	30	76.47
Sealer_Mastic	FXD2	17	30	76.47
Roller_Hemming	FXE1	23	41	78
Roller_Hemming	FXE2	23	41	78
Total process time		188	332	Average = 76.35

REFERENCES

1) Babak Saboori, Behzad Saboori, Johan S. Carlson&Rikard Söderberg (2009), "Introducing fast robot roller hemming process in Automotive industry", International Journal of Industrial and Manufacturing Engineering 3 (10), 1233 – 1236.
2) Cheng, F S, (2000), "A methodology for developing robotic work-cell simulation", Proceedings of Winter Simulation Conference, DOI: 10.1109/WSC.2000.899095
3) Jonkers B, (2006) "Simulation of the Robot Roller Hemming process", Voestalpine Polynorm Automotive, Bunschoten.
4) Mali, M.P, & Inamdar, K.H. (2013), "Optimization of Spot Welding Process Using Digital Manufacturing", International Archive of Applied Sciences and Technology (IAAST) 4, 27-35.
5) Pedro Neto, ; Norberto Pires, J & Paulo Moreira, A (2010), "Robot Path Simulation: A Low Cost Solution Based on CAD", 2010 IEEE Conference on Robotics, Automation and Mechatronics, 28-30 June 2010, DOI: 10.1109/RAMECH.2010.5513169.
6) Sezgin Ersoy, Ashak Ertugrul & Ebuzer Aygul (2017), "The Methods Used in the Automotive Production: Hemming Operations Planning", Engineering and Applied Science 2(6): 103-106.
7) Yuvraj, K &Vigneshwaran S, (2020), "Investigation on Spot Welding and roller hemming by Robots", Materials Today: Proceedings: DOI: 10.1016/j.matpr.2020.03.185