IAAST
ONLINE ISSN 2277- 1565
PRINT ISSN 0976 - 4828

International Archive of Applied Sciences and Technology
IAAST; Vol 4 [2] June 2013: 27-35
© 2013 Society of Education, India
[ISO9001: 2008 Certified Organization]
www.soeagra.com/iaast/iaast.htm

CODEN: IAASCA ORIGINAL ARTICLE

Optimization of Spot Welding Process Using Digital Manufacturing

M.P.Mali [#1], **K.H.Inamdar** [*2]
[#1] Mechanical Department, Shivaji University
Walchand College of Engg., Vishrambag Sangli Maharashtra India
Email: mahesh42mali@gmail.com;my42kollection@gmail.com
[*2]Mechanical Department, Walchand College of Engg, Vishrambag Sangli Maharashtra India
Email: ikedar@yahoo.com

ABSTRACT
The simulation is a powerful tool for visualization, planning, and strategic decision making in different areas of research and development. The change in product design and/or production demand due to dynamic business scenarios, forces to visualize proposed modification on shop floor. The processes are validated and optimized prior to actual implementation on shop floor to ensure that it will yield the desired results. It can also be linked to shop floor hardware, such as programmable logic controllers (PLCs), machine controllers, computer numerically controlled (CNC) machines and others. In this paper, the optimization of spot welding station with the help of simulation tool is explained. The change in demand for a product pushed planning team to verify if robots on this spot welding station can be loaded with more weld spots. The simulation model validated reachability of robot to perform spot welding operation for given welding points. The robotic OLP (off line programming) program is also generated which can be directly loaded on robot with minor modification. Depending on fluctuating demand, cycle time of robotic station can be varied to optimize utilization using Digital Manufacturing Tools.
Keywords- *Process Planning, Robotic Simulation, BIW Weld path optimization.*

Received 09.04.2013 Accepted 14.06.2013 **© Society of Education, India**

INTRODUCTION

Ideally Digital manufacturing has been considered, over the last decade, as a highly promising set of technologies for reducing product development times and cost as well as for addressing the need for customization, increased product quality, and faster response to the market [1]. Digital manufacturing is the use of an integrated, computer-based system comprised of simulation, three-dimensional (3D) visualization, analytics and various collaboration tools to create product and manufacturing process definitions simultaneously. Digital manufacturing evolved from manufacturing initiatives such as:

i. Design for manufacturability (DFM)
ii. Computer-integrated manufacturing (CIM)
iii. Flexible manufacturing
iv. Lean manufacturing

Current initiatives in the development of digital manufacturing tools involve improving the user experience, so that information is presented in the context of tasks performed, allowing users to make better decisions faster. Steps are being taken to provide direct connectivity with shop floor hardware, such as programmable logic controllers (PLCs), machine controllers, computer numerically controlled (CNC) machines and others. Unified platforms have also been developed to manage both PLM and manufacturing execution system (MES) information [2].

Spot welds are the dominant joining method in the automotive assembly process. As the automated assembly process is not perfect, some spot welds may be absent when the vehicle leaves the assembly line. Furthermore, spot welds are highly susceptible to fatigue, so that a substantial number may fail during the vehicle lifetime [3].

Since the demand for new vehicles is increasing every year, Original equipment manufacturers are adding new models and variants by increasing the production capacity of their existing plant. Driven by the need to increase production capacity and shorten cycle time, manufacturers in numerous industries are taking advantage of various automation technologies. One of these automation technologies is Robotics [4].

Robotic simulation is widely utilized in the automotive industry as their BIW assembly line involves multiple robots, tooling fixtures, humans, etc. that needs to be validated and optimized prior to system build to ensure that it will yield the desired results. [4].

DIGITAL MANUFACTURING SOFTWARE

Here are examples of digital manufacturing software applications:
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. Built upon the open PLM (Product Life Cycle Management) foundation called the Team center manufacturing platform, Tecnomatix provides a versatile set of manufacturing solutions. NX CAM and CAM Express allow NC programmers to maximize the value of their investments in the latest, most efficient and most capable machine tools. NX CAM provides the full range of functions to address high speed surface machining, multi-function mill-turning, and 5-axis machining. CAM Express provides powerful NC programming with low total cost of ownership [2].

SPOT WELDING IN AUTOMOTIVE INDUSTRY

The Spot welds are the dominant joining method in the automotive assembly process. A spot weld is materialized by clamping the sheets with two pincers while applying force and transmitting current as depicted in Fig. 1. The electrical resistance of the contacting sheets generates sufficient heat at the faying surfaces to melt the metal; eventually a nugget develops and the interface locally disappears. When the parts are in contact, an electric current is applied and the result is a small spot, heated to the melting point, in which the parts are joined [2]. The positions of the spot welds affect many characteristics of the final product, and consequently also the geometrical variation of the final assembly. The variation in spot weld position is caused by:

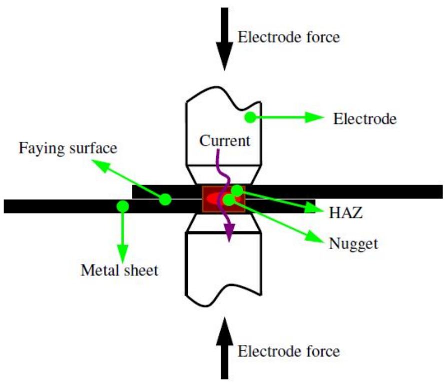

Figure 1 A schematic representation of the resistance spot welding process [2].

I. Geometrical variation on part level in areas where spot welds are located
II. Variation in the positioning of the parts to be assembled
III. Wearing of electrodes on the welding gun
IV. Lack of repeatability in the robot and the welding gun

The geometrical variation of a non-rigid assembly is affected by a large number of factors, and it is of course important to include as many as possible of the significant factors in the variation simulation, in order to achieve satisfactory agreement between simulated results and reality.

PRODUCT OF UNDER BODY-90 STATION

Table 1 Specification of R2000 ib-210 Fanuc Robot.

	Robot Specification	R-2000iB/210F	Robot Motor Speed
J1	95 °/s (1.66 rad/s)	Axes 6	±180°
J2	90 °/s (1.57 rad/s)	Payload 210kg (462.97lbs)	+75°,-60°
J3	95 °/s (1.66 rad/s)	H-Reach 2655mm (104.53in)	+230°,-132°
J4	120 °/s (2.09 rad/s)	Repeatability 0.3mm (0.01in)	±360°
J5	120 °/s (2.09 rad/s)	Robot Mass 1240kg (2733.7lbs)	±125°
J6	190 °/s (3.32 rad/s)		±360°

 © Society of Education, India

Chassis along with inner wheel house & under body floor comes from Under Body-80 Station, and on Under Body-90 Station front panel & back panel are welded by two R 2000ib 210 Fanuc Robots. Both Robots are having same controller R30iA Japan Type.

Figure 2 Front Panel.

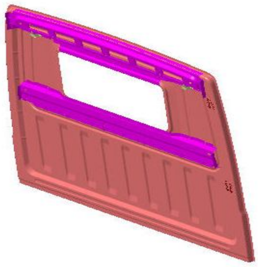

Figure 3 Back Panel.

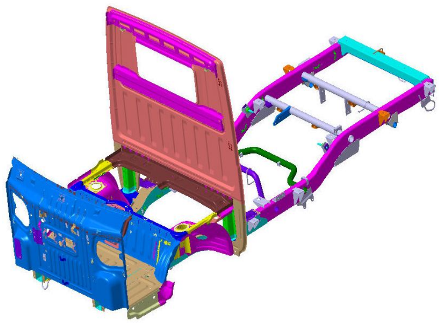

Figure 4 Product Assembled.

PROCESS PLAN

A. Process Plan for light commercial vehicle (LCV)-Body in White (BIW)-Under Body-90 Station, as shown in figure 4 the front panel and back panel are welded, location of spots on this assembly is shown in figure 6(a) and 6(b). In addition to these how many spots the robot can be loaded is decided through simulation.

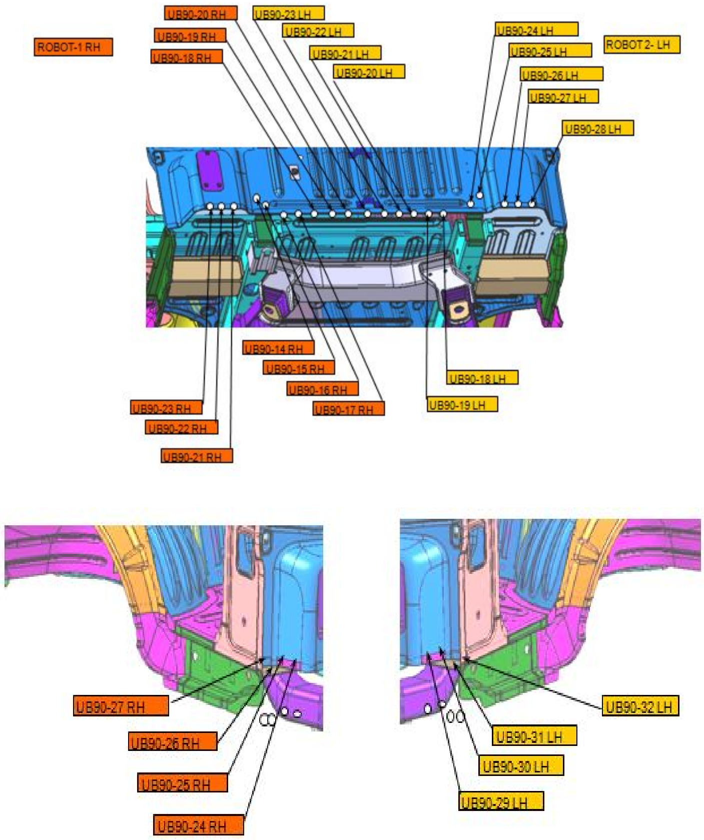

Figure 6(a) Location of weld Spots on Front Panel.

Gun available on Under Body-90 Station is X type Spot Weld Gun having throat depth of 900mm, Pneumatic Type with air pressure of 5bar and its weight is 161 kg. Demand is 22JPH on Under Body-90 station and for forthcoming months it is forecasted that it will go down from 22JPH to 12JPH based on the market requirements, it will affect the cycle time also on that station, and for utilization of that cycle time available on Under Body-90 we can add some spots to it from other stations. Currently number of spots welded on Under Body-90 station are total 55 (depicted in figs 6(a)-6(b)), on Under Body-90 gross 22JPH is available, considering 90% efficiency for 20 JPH net there's 162 sec Takt time Cycle Time is 150 sec (whole operation requires 150sec), Total Weld Spot are 55. Therefore 3sec/Weld spot, now requirement is 12 JPH net, considering 90% uptime, our gross

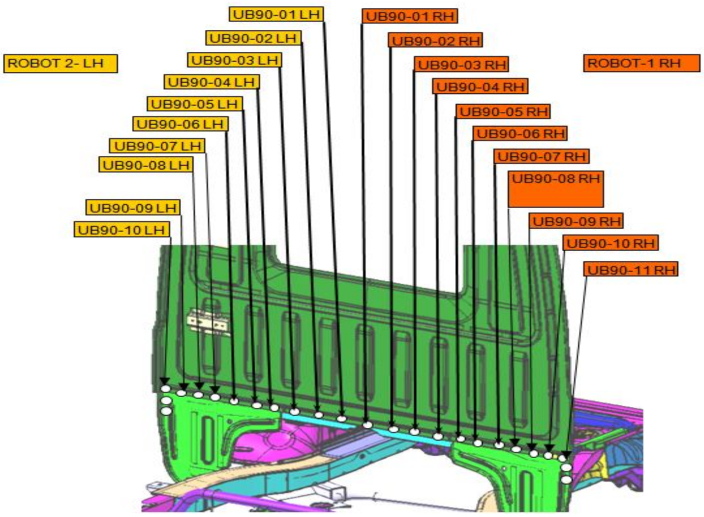

Figure 6(b) Location of weld Spots on Back Panel.

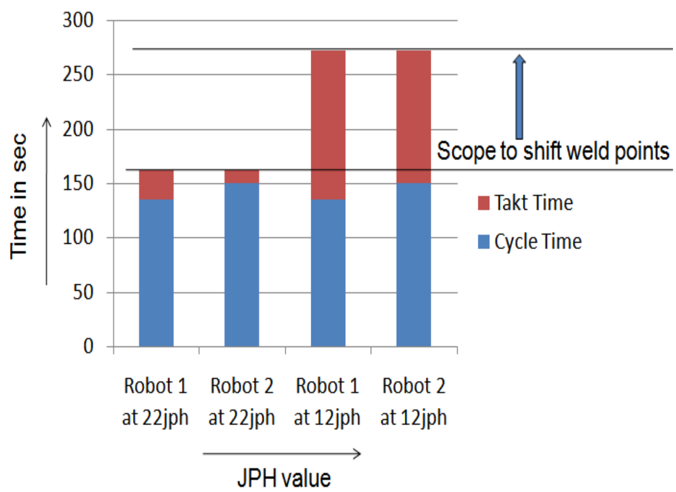

Figure 7 Proposed Plan to go from 22JPH to 12JPH.

JPH is 13.2, therefore our Takt Time is 272 sec, and therefore almost 110sec (272-162=110) for each robot is available to add on Under Body-90 station, approximately time taken to each weld spot from Under Body-90 stations process sheet is 5sec (considering all parameters), 220/5=44 weld points (For both RH & LH robot) can be added. Total Weld points that can be shifted to Under Body-90 station are 23 weld points. Now we need to simulate in Tecnomatix Software that which welds points can be loaded on Under Body-90 station without any collision to fixture and other facilities & need to create collision free path.

UNDER BODY-90 STATION SIMULATION RESULTS

Prerequisite for welding points from Station BP-30

- R1 Robot (which welds front panel) will wait till the R2 Robot (which welds back panel) completes its all weld spots and occupies home position along with back panel gripper.

- After that R1 robot will begin (i.e. no gripper on back panel).

With above mentioned condition it's possible to shift 14 weld spots from BP-30-S\A station to Under Body-90 Station of LCV BIW.

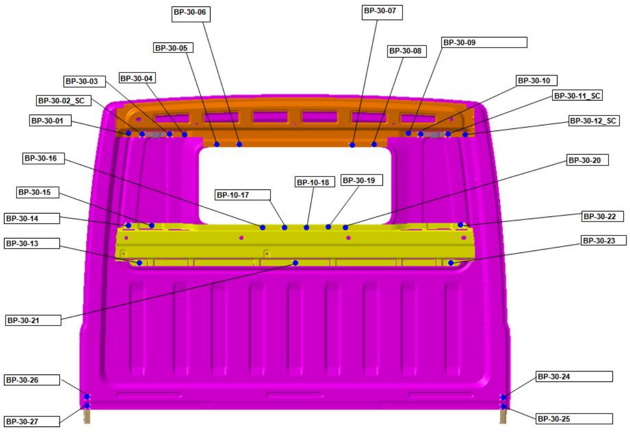

Figure 8 Weld points considered for simulation of station BP-30-S\A.

If 3 sec for each spot (Taken from Gantt Chart of Under Body-90 station), Cycle Time of 14 weld points will be 42secs.Therefore from 110secs, 68secs will be utilized. As per prerequisite, for each weld point maximum and minimum positions are recommended and feedback of plant engineering team is taken to implement the gun position on line. Feasible weld points are depicted in following fig11.

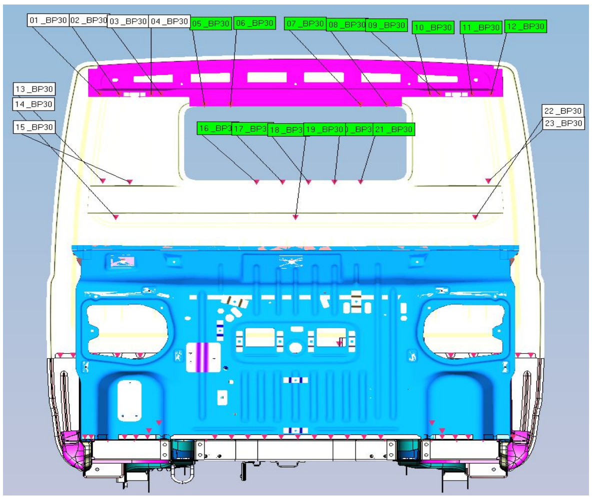

Figure 9 Location of feasible welds Spots on Back Panel.

Sr No.	Legend	Description
1	Weld point no. _BP30	Possible through R1 Robot
2	Weld point no._BP30	Not Possible through R1 Robot

Legend 1

ROBOT PROGRAM

Off-Line Programming (OLP) is the process of converting the "sequence of operations", which is the result of the robot simulation phase, and generating the robot program in the native language of the robot manufacturer (ABB, FANUC, Motoman, Kuka, etc). The OLPs which have been so generated can be downloaded directly to the robot controller and tested. Off-line programming benefits customers by Reducing the onsite programming time (thereby freeing up the robot to be used for production, rather than programming) and Reducing the downtime of equipment when programming new work pieces/variants Programming complex paths (for example, deburring, welding in tight spaces, grinding, polishing, etc, which are highly time consuming), after simulation we can get the co-ordinates of the

 © Society of Education, India

robot in the program through path editor ,which can be given as input to robots, thus the path will be followed by robot on station same as in simulated in process simulation environment.

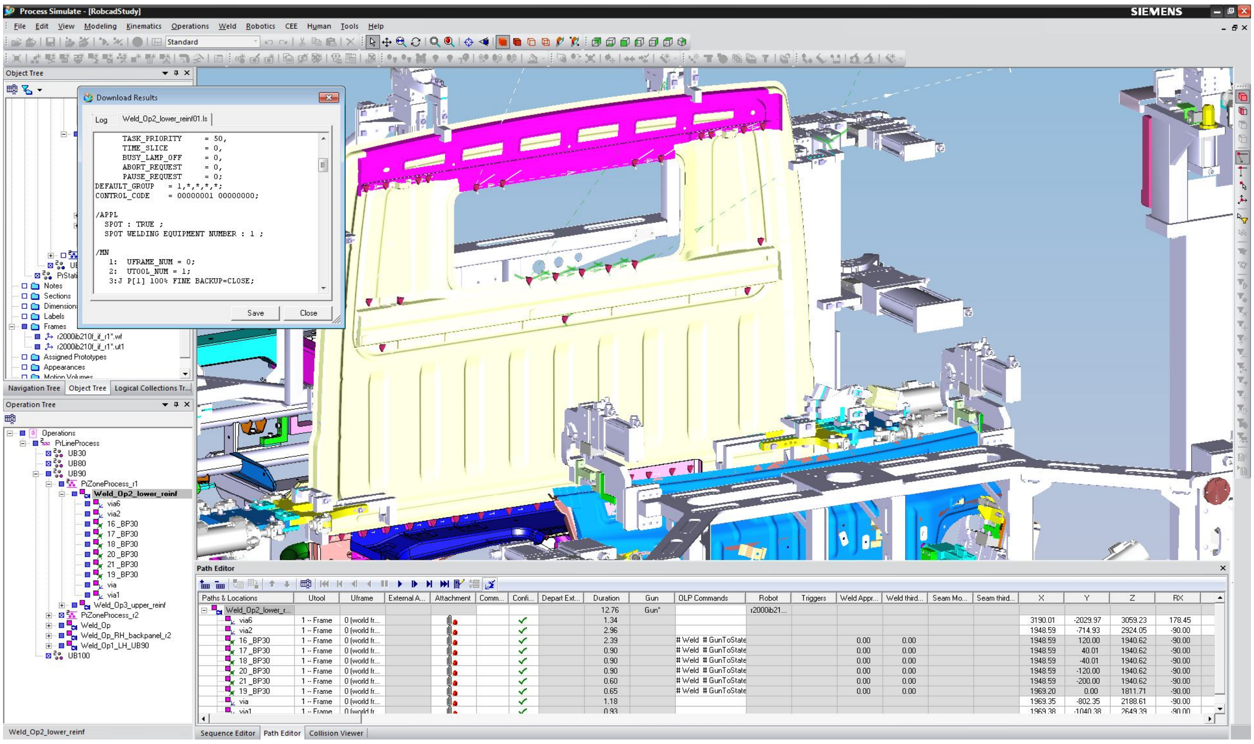

Figure 10 Simulation Results Downloaded.

Program format is shown below:

```
Spot welding equipment number:
 1:  UFRAME_NUM = 0;
 2:  UTOOL_NUM = 1;
 3:J P[1] 100% FINE BACKUP=CLOSE;
 4:L P[2] 0mm/sec FINE BACKUP=CLOSE;
 5:J P[3] 100% FINE BACKUP=OPEN;
 6:L P[4:16 _BP30] 0mm/sec FINE SPOT[S=1];
 7:  !# Weld ;
 8:  !# GunToState ;
 9:L P[5:17 _BP30] 500mm/sec FINE SPOT[S=1];
10:  !# Weld ;
11:  !# GunToState ;
12:L P[6:18 _BP30] 500mm/sec FINE SPOT[S=1];
13:  !# Weld ;
14:  !# GunToState ;
15:L P[7:20 _BP30] 500mm/sec FINE SPOT[S=1];
16:  !# Weld ;
17:  !# GunToState ;
18:L P[8:21 _BP30] 500mm/sec FINE SPOT[S=1];
19:  !# Weld ;
20:  !# GunToState ;
21:L P[9:19 _BP30] 500mm/sec FINE SPOT[S=1];
22:  !# Weld ;
23:  !# GunToState ;
24:J P[10] 100% FINE;
25:J P[11] 100% FINE;
```

```
/POS
P[1] {
  GP1 :
     UF : 0, UT : 1,    CONFIG : 'N U T,0,0,0',
     X = 3314.952 mm,    Y = 418.320 mm,    Z = 1126.225 mm,
     W = 178.446 deg,    P = 0.274 deg,    R = 179.993 deg
};
P[2] {
  GP1 :
     UF : 0, UT : 1,    CONFIG : 'N U T,0,1,-1',
     X = 2073.536 mm,    Y = 1733.359 mm,    Z = 991.047 mm,
     W = -90.000 deg,    P = -14.891 deg,    R = -90.000 deg
};
P[3] {
  GP1 :
     UF : 0, UT : 1,    CONFIG : 'N U T,0,1,0',
     X = 2130.085 mm,    Y = 2691.882 mm,    Z = 472.395 mm,
     W = -90.000 deg,    P = -14.891 deg,    R = -90.000 deg
};
P[4:"16 _BP30"] {
  GP1 :
     UF : 0, UT : 1,    CONFIG : 'N U T,0,1,0',
     X = 2073.531 mm,    Y = 2568.294 mm,    Z = 7.617 mm,
     W = -90.000 deg,    P = -14.891 deg,    R = -90.000 deg
};
P[5:"17 _BP30"] {
  GP1 :
     UF : 0, UT : 1,    CONFIG : 'N U T,0,1,0',
     X = 2073.531 mm,    Y = 2488.294 mm,    Z = 7.617 mm,
     W = -90.000 deg,    P = -14.891 deg,    R = -90.000 deg
};
P[6:"18 _BP30"] {
  GP1 :
     UF : 0, UT : 1,    CONFIG : 'N U T,0,1,0',
     X = 2073.531 mm,    Y = 2408.284 mm,    Z = 7.617 mm,
     W = -90.000 deg,    P = -14.891 deg,    R = -90.000 deg
};
P[7:"20 _BP30"] {
  GP1 :
     UF : 0, UT : 1,    CONFIG : 'N U T,0,1,0',
     X = 2073.531 mm,    Y = 2328.284 mm,    Z = 7.617 mm,
     W = -90.000 deg,    P = -14.891 deg,    R = -90.000 deg
};
P[8:"21 _BP30"] {
  GP1 :
     UF : 0, UT : 1,    CONFIG : 'N U T,0,1,0',
     X = 2073.531 mm,    Y = 2248.284 mm,    Z = 7.617 mm,
     W = -90.000 deg,    P = -14.891 deg,    R = -90.000 deg
};
P[9:"19 _BP30"] {
  GP1 :
     UF : 0, UT : 1,    CONFIG : 'N U T,0,1,0',
     X = 2094.145 mm,    Y = 2448.289 mm,    Z = -121.287 mm,
     W = -90.000 deg,    P = -25.179 deg,    R = -90.000 deg
};
P[10] {
  GP1 :
```

 © Society of Education, India

```
      UF : 0, UT : 1,    CONFIG : 'N U T,0,1,0',
      X = 2094.300 mm,    Y = 1645.939 mm,    Z = 255.609 mm,
      W = -90.003 deg,    P = -25.179 deg,    R = -89.997 deg
};
P[11] {
   GP1 :
      UF : 0, UT : 1,    CONFIG : 'N U T,0,1,-1',
      X = 2094.327 mm,    Y = 1407.905 mm,    Z = 716.392 mm,
      W = -90.003 deg,    P = -25.179 deg,    R = -89.997 deg
};

/END
```

CONCLUSION

The aim of the work was to utilize the robots available cycle time due to decrease in JPH value which varies according to market demand, 23 weld points from neighboring stations (BP-30-S\A) were considered and simulated, based on the results 14 Spots can be shifted without any collision with facilities like Fixtures, Clamps, Tool Post, Fence etc.
On Under Body-90 gross JPH is 22, Considering 90% efficiency for 20 JPH net there's 162 sec Takt time. Now for 12JPH available Takt Time is 272 sec, therefore almost 110sec (272-162=110) for each robot is available to add on Under Body-90 station. Now Cycle Time=150 sec (whole operation requires 150sec), Total Weld Spot are 55. Therefore 3sec/Weld spot. On BP30 for same JPH (20), 23 weld points can be considered for simulation, based on simulation results, 14 spots are feasible that can be done on Under Body-90 station. Therefore from 110secs, 68secs will be utilized. Still cycle time is available on Under Body-90 station as its GeoSpots station, any extra spots to add on will require part, which can't be added on Robotic Station.

ACKNOWLEDGMENT

The authors would like to express their appreciation to the Mahindra Vehicle Manufacturing Limited. For giving opportunity to do project work and to provide software facilities for simulation, also authors express their gratitude towards Walchand college of Engineering, for providing facilities to complete our research paper.

Nomenclature
UB= Under Body
Geo= Weld for Geometrical Stability
Respot= Weld For Strengthening Effect
JPH= Jobs per Hour
R1, R2= Robot 1 & Robot 2
BIW= Body in White
BP=Back Panel
LCV= Light Commercial Vehicle

REFERENCES

1. G. Chryssolouris, D. Mavrikios, N. Papakostas, D. Mourtzis, G. Michalos, and K.Georgoulias, "Digital manufacturing history, perspectives, and outlook," DOI: 10.1243/09544054JEM1241.
2. http://www.Plm.Automation.Siemens.com (Cited on: 3.28pm 13/09/12).
3. Stijn Donders, Marc Brughmans, Luc Hermans and Nick Tzannetakis LMS International, "The Effect of Spot Weld Failure on Dynamic Vehicle Performance," Interleuvenlaan 68, 3001 Leuven, Belgium; Noesis Solutions, pp.1709-1718.
4. http://www.automotivetechnology.com/articles/role-robotic-simulation-biw-assembly.html (Cited on: 4.5 pm13/09/12).
5. Martin Mellado, Carlos Correcher, Juan Vicente Catret and David Puig,(2004). "Virtual Robot: An open general-purpose simulation tool for Robotics," Vol.56, pp. 299-305.
6. G. Reinhart , U. Munzert and W. Vogl.(2012). "A programming system for robot-based remote-laser-welding with conventional optics," Vol. 9, Issue 4, pp.169-178.
7. Malvika Rao, Gregory Dudek and Sue Whitesides, "Randomized Algorithms for Minimum Distance Localization," Department of Computer Science McGill University, Montréal Canada H3A 2A7.

8. J.W.S.Chong, S.K.Ong, A.Y.C.Nee and K.Youcef-Youmi, "Robot programming using augmented reality: An interactive method for planning collision-free paths," doi:10.1016/j.rcim.2008.05.002.
9. K. D. Hardikar, D. J. Nidgalkar and Dr. K. H. Inamdar,(2012). " Prediction of welding sequence for minimum possible distorsion of an assembly like B-pillar of a car, with effect of parameters on distorsion while welding," International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 ,Vol. 2, Issue 3, May-Jun pp.1609-1613.
10. Rikard Soderberg, Kristina Warmefjord, Lars Lindkvist, Rolf Berlin,(2012). "The influence of spot weld position variation on geometrical quality," CIRP Annals - Manufacturing Technology, Vol. 61, pp.13–16.

Citation of Article: M.P.Mali and K.H.Inamdar. Optimization of Spot Welding Process Using Digital Manufacturing. Int. Arch. App. Sci. Technol., Vol 4 [2] June 2013: 27-35