CHAPTER 7

RESULTS AND DISCUSSIONS

The research reported in this thesis consists of three parts;

1. The first part has elaborated the identification of minimum spots required to set geometry between the sheet metal parts. Results are obtained with L27 Taguchi experiment and derived the critical factors to include for spot allocation calculation. Discussed in detail in chapter 7.1.

2. Developed a Geometry Spot Distribution Model (GSDM) to calculate minimum number of spots to set geometry. The developed model has been validated through experiment analysis. Discussed in detail in chapter 7.2

3. Effectiveness of the GSDM implementation in productivity and cycle time reduction is discussed. Discussed in detail in chapter 7.3

7.1 MINIMUM SPOTS REQUIRED TO SET GEOMETRY

The primary objective of this study was to find an optimized spot quantity to set the geometry in geometry welding stations.

Accordingly, the following were observed in the thorough experimental analysis:

- After geometry stage welding, the variations were observed to be high in the larger dimension part with three surface contacts and the same were observed to be within the tolerance range after re-spot stage welding.
- Number of surfaces plays a significant role in deciding the number of spots for any assembly.

- There is no significant effect observed due to spot sequencing.

- Based on the above observations, and by considering the concept of setting the geometry in the geometry station, the following recommendations are arrived.

  1) Two spots are recommended for the parts of surface contact area up to 100 Sq-cm.

  2) Three spots are recommended for parts of surface contact area between 100 Sq-cm and 860 Sq-cm.

- The proposed Geometry Spots Distribution Model (GSDM) is simple to use for the process planners during any new product planning and this can also be used for optimization of any existing cells of the body shops.

- The planner must deploy the cell/assembly wise parts details in the given model and assign the value for the variable “X” & “Y” satisfying the two conditions stated.

- The model will recommend the practitioner, the minimum spots required per part assembly with mother part.

- Lower spot distribution will lead to inferior quality and excess spot distribution will lead to lower productivity.

### 7.2 IMPACT OF GSDM GEOMETRY SPOTS DISTRIBUTION METHOD

The application of GSDM produces multiple results in improving quality, productivity and shop floor space reduction. The key results are

- The GSDM methodology has resulted in reduction of Geometry spots in Geometry Stations
- Re-Spot percentages are increased in the applied models

- Spot weld stations for the given assemblies can be reduced with the effect of GSDM method implementation.

- The proposed methodology is ready for use in real world applications.

The developed method provides valuable results for appropriate spot allocation among the welding stations. It is important to reduce the number of fixtures in the sub-assembly cells to effectively utilize the available floor space in any shop floor during a new model introduction. GSDM enables the reduction of fixtures in the planning stage. Therefore, it is clearly understood from the case study that cell wise optimization results in reduction of the equipment.

The following outcomes can be obtained from the reduction of Geometry stations:

(1) **Effective floor space utilization:**

Large number of models are to be produced in a single plant [103]. Fixture reduction by applying GSDM helps to implement a new model in multi model manufacturing facility with a smaller floor space as compared to the current, generally followed process planning method. It is to be noted that the fixture reduction in the center floor sub-assembly discussed in this study cleared additional floor space, and the same can be extended to any other sub-assembly cell for optimization.

(2) **Capital investment:**

Fixture reduction in a new model introduction reduces the capital investment considerably. Fixture cost is one of the major cost items in any body shop equipment list and the second-highest value item is weld gun.
With this optimization, capital costs of both equipment will go down considerably.

(3) **Effective time utilization:**

It was observed that 82 seconds were saved when GSDM was applied to the existing cell by optimizing three stations to two stations. 82 seconds saving per vehicle is a worthy figure, when the cumulative production is considered. This line set up was planned for 15 jobs per hour and hence the total savings per hour can be extrapolated as 1230 seconds (20 minutes). The projected 20 minutes is a potential saving opportunity that exists in the conventional method. It may vary from case to case with respect to the cycle time calculation method of the industry. But, the time difference between geometry spot and re-spot is always within the range of 1.5 to 3.0 seconds. The difference observed in our study by considering MOST calculation is 2.5 seconds for the center floor cell. It may vary in other cells due to fixture unit arrangement and weld access constraints of those respective stations.

(4) **Manpower optimization:**

Reduction of non-value-added cycle time will help reduce resources directly required for the production; which include mainly the corresponding manpower in the manual welding sub-assembly line. Hence our result will help optimize the manpower requirement of the cell considerably.

It can be noted that 2 out of 3 stations were geometry in the discussed case study of Center Floor line fixture in section 6.4.

After the application of GSDM, this scenario has changed to one Geometry and one Re-spot station; thereby reducing the ratio of GEOMETRY STATION: RE-SPOT STATIONS from “67%: 33%” to “50%: 50%”
Comparison of conventional method with GSDM method is given in figure 7.1

Conventional Gs (67%) Rs (33%) ↔ GSDM Gs (50%) Rs (50%)

Figure 7.1 Comparison of conventional method VS GSDM method

The number of geometry stations (Gs) of any body shop should be lesser than or equal to number of re-spot stations (Rs), Gs ≤ Rs for better utilization of the resources; irrespective of production volume.

7.3 EFFECTIVENESS OF GSDM IN QUALITY AND PRODUCTIVITY IMPROVEMENT

Effectiveness of the proposed model is studied with industrial case studies. Various assemblies of multiple models in multiple body shops have been considered to generalize the study. Rear Floor, Head Lamp, Dash and Floor assemblies are the major assemblies of a BIW and cumulatively constitute a high number of parts and spot welds in the over BIW.

Existing process sheets of the given assemblies are modified according to GSDM method with the calculation of optimal number of spots for geometry stations and re-spot stations. The outputs such as distribution of spot welds in geometry and re-spot distribution, difference in work time and difference in number of stations are recorded.
Figure 7.2 represents the assemblies considered for the study. Work content of the entire assembly welding reduced from a minimum of 88 sec to a maximum of 180 sec. Process time savings of 16%, 17%, 14% and 11% are obtained in the given models 1 to 4 respectively. Number of stations reduced from a minimum of one to a maximum of two stations. The percentages of geometry fixture reduction observed from conventional to GSDM are 20%, 20% and 33% for models 1, 2 and 3 respectively, represented in figure 7.3. Reduction of number of stations is not observed in model 4 due to complications in product assembly architecture.

Figure 7.2 Models considered for study and results

Across the four models, geometry spot percentage reduced from a minimum of 9% to a maximum of 42%. Figure 7.3 represents the comparison between conventional method and GSDM in geometry spot distribution. The potential benefit of spot reduction is high in model 2. The maximum potential for geometry spots reduction is 42% from the conventional planning method. In model 5, the potential of percentage reduction is 9%, which is
comparatively lesser to other models of same in nature. Product structure of model 5 is complicated and designed in a way with less flexibility for spot distribution in various stages. The total number of spots of the sub-assembly needs to be consumed in same level due to non-accessibility of spots in the further stages in the build. Since, GSDM implementation is advanced in initial phase of design, the non-accessibility spot welding condition can be minimized or eliminated completely.

![Comparison of GSDM and conventional method geometry spot distribution](image)

**Figure 7.3** Comparison of GSDM and conventional method geometry spot distribution

Figure 7.4 represents the comparison of re-spot percentage between GSDM and conventional method. The method had achieved 65% of re-spots in model 2 against 23% of re-spots planned in conventional method. Re-spot percentage increased from a minimum of 9% to a maximum of 42%. Out of 4 models considered for study, 3 models have gained maximum advantages which indicates the possibility to achieve geometry spots percentage of 35% to 45% against the existing percentage of 70% to 80% in semi-automated and manual. The re-spot percentage improves between 56% and 65%, which is a considerable amount of improvement.
The improvement percentage will be in upper side, when GSDM methodology is considered as one of the critical Design for Manufacturability (DFM) input.

In the current scenario, reduction of product development cycle time is critical for the survival of the automobile industries. Searching for various solutions to shorten the long implementation timing of new manufacturing lines is key for reducing product development cycle time [104]. Implementation of GSDM in product development improves the accuracy of appropriate spot distribution in the planning stage. The appropriate process planning is critical to eliminate reworks in manufacturing during execution phase.

The existing integrated design and manufacturing structure is given in figure 7.5a. The proposed integrated design and manufacturing process structure for effective implementation of GSDM methodology is given figure 7.5b.
Figure 7.5a Existing integrated design and manufacturing structure
Figure 7.5b Proposed integrated design and manufacturing structure
Figure 7.6 Comparison of GSDM and conventional method work content

Figure 7.6 represents the comparison of GSDM work content against conventional method. Reduction of additional geometry spots from geometry stations and moving to re-spot reduces the work content considerably.

Reduction of work content improves the productivity of the shop in all aspects. With the application of GSDM, 11% to 17% work content reduction is achieved. Reduction of work content in a body shop directly reduces the manpower utilization in manual and semi-automated shops.

Figure 7.7 represents the trend of spot weld station reduction against conventional method. In the study, 20% to 33% of welding fixtures (or) stations are reduced with the application of GSDM methodology. Work content reduction by welding optimal weld spots in geometry stations enable to add more parts in geometry station than the conventional method. The re-spot station can be utilized for maximum with adding sequential spots for the weld guns. Sequential weld spots reduce the unwanted gun movement over the body sub assembly or assembly. Gun insertion and taking out from the assembly increase the non-value-added cycle time in the process. Reduction
of spot weld station in model 4 is nil due to the product design constrain, designed to consume total spots in one stage due to box section layer construction.

![Comparison of GSDM and conventional method spot weld station](image)

**Figure 7.7** Comparison of GSDM and conventional method spot weld station

### 7.4 DEVELOPMENT OF SOFTWARE PROGRAM FOR SPOT WELD ASSIGNMENT

A spot weld assignment software program has been developed in product design environment. This method has been implemented using CATIA V5. This spot assignment methodology will change the geometry spot assignment responsibility from process design to product design.

As soon as the product structure is ready, the designer must select the parts to be assigned for spot weld points. Figure. 7.8 represents the input window for selection of assembly to be processed. The parts to be assigned spot weld needs to be selected from the product family tree, is given in figure 7.9. The option of selecting 3 parts for spot assignment is given in the window. In BIW assembly structure, there will be two or maximum three parts that will be joined together in geometry welding stage in common. No other manual inputs are required for calculations.
Figure 7.8  Input window for selection of product assembly for spot weld assignment

Figure 7.9  Input window for selection of mother and child parts to be assigned spot welds
Figure 7.10 Selection of “Run” program for calculation

After selection of the parts to be assigned spot welds, the designer must run the program for automatic calculation, figure 7.10. The spot weld macro software will calculate the area of the part and linear dimensions to assign geometry weld spots.

Figure 7.11 represents the output window of the spots weld assigned for the selected parts. There are three weld spots identified by the software by considering the given conditions in the program.

The selected parts meet the criteria 1, which is given in chapter 6.

- Number of surfaces in contact is more than 2 - **NO**
- The surface area of the contact of the part with the parent part is more than 100 cm² - **YES**
- If the linear dimension of contact in any of the three co-ordinate is more than 10 cm – **YES**
The geometry spots will be populated in the screen with annotations, as represented in figure 7.12. The outcome of the program will be saved in CATIA software and extract of the selected information will be exported to “EXCEL” file for process planning automatically.

The optimal geometry weld spots get assigned for each part in the product design phase and the geometry spots will be annotated with a symbol for manufacturing process planning. The process planner must extract the geometry spot details from the product structure for the preparation of process sheets for manufacturing.
This enables the project team to ensure the same geometry spot is considered for the assemblies, when produced in multiple locations (or) countries. Globalization of automobile given the opportunity to produce a common model in multiple countries.

7.5 SUMMARY

The product architecture plays a critical role in the distribution of spot welds among geometry and re-spot stations. Both, the percentage reduction in geometry spots and the percentage increment of re-spots in model 4 is 9%. The difference in other three models 1, 2, 3 is 37%, 40% and 42% respectively. The work time reduction in model 4 is 88 seconds but the time reduction is almost double in the other three models. Reduction in number of stations is nil in model 4. In the other three models, the reduction in number of stations is up to 2 stations due to the simplicity in product architecture. This significant difference has thrown a light to focus on the integration of product and process design to resolve this issue completely and to get maximum benefits.
In the existing product architectures, the spots are denoted with a common annotation as per available data source, which lacks in providing classification between geometry and re-spots. Introduction of classification annotations for geometry spot and re-spot differentiation in product design along with automatic selection of geometry spots, will ease the calculation of number of stations for the process designer.

The outcome of the study indicates that the implementation effect of GSDM produce significant improvements with the integration of product and process design.

The developed weld spot assignment has been used for different sizes and all the three surface parts. It is producing appropriate results in weld spots assignment. The developed software is ready to use in real-world applications.