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Optimization of Spot Welding of An Assembly Like B-pillar of a Car For Minimum Distortion, By Sequencing Technique

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Abstract - The aim of this paper is to achieve optimisation of spot welding sequence to minimise the distortion of a sheet metal assembly. The distortion of the assembly involving number of spot welds is different for different sequences of welding. The assembly consists of sheet metal components which are joined by using various welding sequence schemes. The components are manufactured in quantity and welded with various sequences. After welding the distortions in an assembly due to welding sequence change are worked out and compared. The sequence with minimum distortion is suggested a solution for the quality manufacturing with minimum distortion induced in it.

Key words - component; Spot Welding, Weld Sequence, Distortions

I. INTRODUCTION

In automotive industry, the body in white of a car consists of hundreds of sheet metal parts that are joined together. A typical automotive body has about 4000-5000 weld spots in it which joins about 200 sheet metal parts together. During the joining process many factors affect the final geometrical quality. One of the many geometrical factors affecting the final geometrical outcome of the sheet metal assembly is the spot welding sequence used when the parts are welded together. It is of course desirable to choose a welding sequence that minimizes both variation and deviation in critical dimensions of the final assembly. During the welding process the sequence by which the welding is carried out is of important. For deciding the sequence with minimum thermal distortion the assemblies are welded with the different welding schemes and distortions are worked out from the physical results. The technique involving sequence which yields the minimum distortion is the technique for optimization of spot welding sequence. The assembly selected is an sample assembly having a cross section like B-Pillar of passenger car. The assemblies are welded with 7 different sequences of welding by spot welding process and then compared for the distortions induced. The sequence which yields minimum distortion will be the optimized way of welding the assembly and is suggested as a solution.

II. SAMPLE ASSEMBLY

The assembly selected is an assembly having a cross section like B-Pillar of passenger car. Standard cross section of B-Pillar of a car body is as shown in the Fig.1. The **B-pillar** of a vehicle is the second pillar of the passenger compartment, after the A-Pillar. The B-pillar plays a key role providing strength to the midsection of the vehicle. They also play an important role in protecting the occupants in roll-over incidents.

A. Modelling

Modelling of B-Pillar is carried out by using CATIA V5-R18 software. Modelling is done for 1mm sheet of material AISI 1045 Steel Sheet which is used for manufacturing of components of assembly.

1. Total available span over which weld spots are distributed is 500mm.
2. Upper B-pillar width is 80 mm while at the bottom it is 100mm.
3. Perpendicular inter-distance between 2 components of a sample B-Pillar is 69.062mm.

III. SPOT WELD LOCATIONS AND SEQUENCE OF WELDING

The weld spots are located on the flange are as shown below in Fig. 2. On the right flange 6 weld spots are located with inter distances as (All distances

specified are cumulative distances from free upper edge of sample B-pillar) 1st – 30 mm , 2nd – 110 mm, 3rd – 210 mm, 4th – 300 mm, 5th - 380 mm, 6th – 480 mm as shown I the Fig. above. On right flange 5 weld spots are located with inter distances as (All distances specified are cumulative distances from the free upper edge of pillar) 1st – 10 mm, 2nd – 120 mm, 3rd – 230 mm, 4th – 340 mm, 5th - 450 mm.

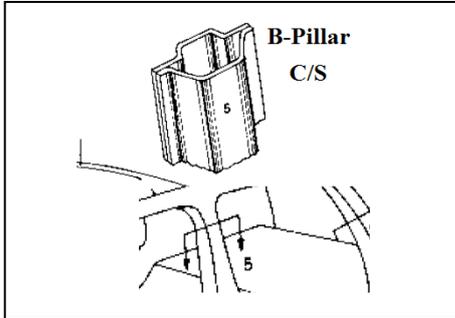


Fig. 1: B-Pillar C/S of B-pillar of a passenger car

A. *Actual welding Sequences for spot welding of components*

(With reference to Fig. 2.)

1. (1-2-3-4-5-6-11-10-9-8-7)
2. (1-2-3-4-5-6-7-8-9-10-11)
3. (4-3-5-2-6-1-9-8-10-7-11)
4. (1-7-2-8-3-9-4-10-5-11-6)
5. (1-6-11-7-2-3-4-5-10-9-8)
6. (1-6-11-7-2-3-4-5-8-9-10)
7. (1-6-11-7-2-8-3-9-4-10-5)

Spot weld made in two sheets, each 1 mm in thickness, would generate a nugget 5 mm in diameter. The weld time is measured in cycles of line voltage as are all timing functions and hence in a 50 Hz power system. So total welding time is 80ms for each weld and 110VAC, 30A input power system is used for welding. The snapshot of actual welding is as follows in Fig.3.

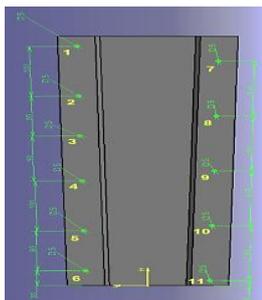


Fig. 2 : Spot welds and their locations



Fig. 3 : Actual assembly after welding

IV. **MARKINGS FOR THE MEASUREMENT PURPOSE**

(The markings are made on the manufacturing components (7Nos.) as shown in Fig. 4, so that the distortion can be predicted by measuring those points for all the components with the particular sequence of welding.)

A. *Deflections considered*

1. Bending in a horizontal plane. (For this ΔY of points 26-35 is measured on the side edge from a ref. point).
2. Bending in a vertical plane. (For this ΔZ for points 6-17 is measured on the middle flange from welding plane).
3. Torsional distortion or twist (for this points I, J, C, D are measured for the cross-sectional deflections).

The measurements for ΔY are done by Trimos while those for ΔZ are done by CMM. The components are welded according to the various sequences. The various timings are recorded for welding time and cooling time as per the sequence of welding. The welding time being constant taken as 80ms for each weld. The timings in between two spots i.e. cooling time is taken from physical welding constraints. The spot temperature on flange i.e. 1550⁰C. The uniform reference temperature provided is 30⁰ for the complete analysis shown in Fig.5. The overall minimum and maximum deflections and stress are worked out for all the sequences from which deflections at the marking locations can be found out. The values of distortions are also found at the nodes located at the location of marked points.

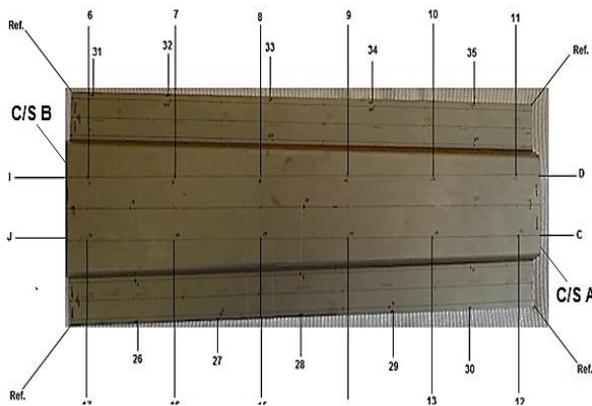


Fig. 4 : Markings for the measurement

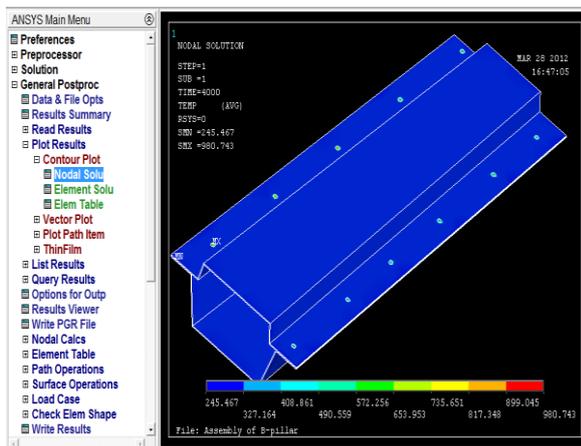


Fig. 5 : Sequence analysis for spot

IV. SOFTWARE AND PHYSICAL ANALYSIS FOR DISTORTIONS INDUCED

A. Bending in a horizontal plane:

For this ΔY of points 26-35 is measured from a ref. point. The measurements for bending in horizontal plane i.e. ΔY for points 26-35 is done by using Trimos. From these physical measurement readings the graphs are then plotted for prediction of the optimum sequence of welding and compared with the software results.

i. Analysis of Actual Results:

The graph is plotted with physical measurements for the comparison purpose and is as follows in Fig.6.

(a) Analysis of Software Results:

The graph is plotted with software measurements for the comparison purpose and is as follows in Fig.7.

(b) Comparison between Physical and Software Distortions at marked points:

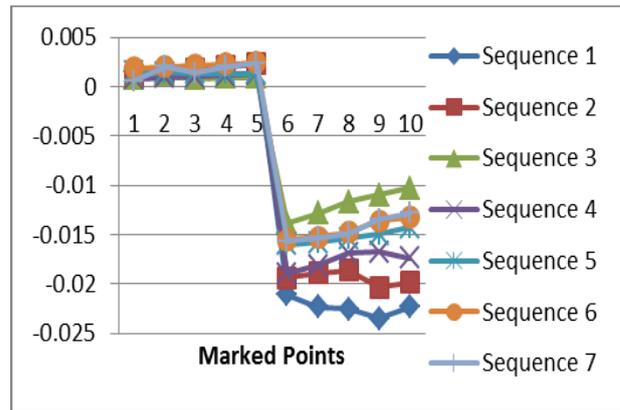


Fig. 6 Graph for physical ΔY deflection

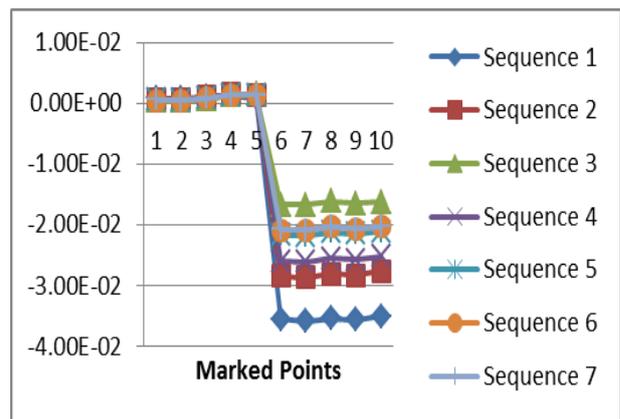


Fig. 7 Graph for Software ΔY deflection

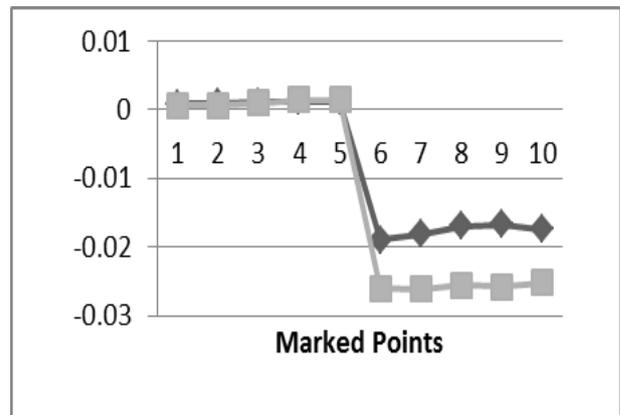


Fig. 8 : Graph for comparison of physical and software ΔY deflection

The comparison graph is also plotted to compare the results obtained from physical measurements and the software measurements of distortions as shown in the Fig. 8.

B. Bending in a vertical plane:

For this ΔZ of points 6-11 is measured from a ref. plane. The measurements for bending in Vertical plane i.e. ΔZ for points 6-11 is done by using CMM. From these measurement readings the graphs are then plotted for prediction of the optimum sequence of welding and compared with the software results.

(a) Analysis of Actual Results:

The graph is plotted with actual measurements of points 6-11 for the comparison purpose as follows in the Fig.9.

(b) Analysis of Software Results:

The graph is plotted with software measurements for the comparison purpose as follows in Fig.10.

(c) Comparison between Physical and Software Distortions at marked points:

(for optimum Sequence of welding Sequence No.03) is as shown in the Fig. 11.

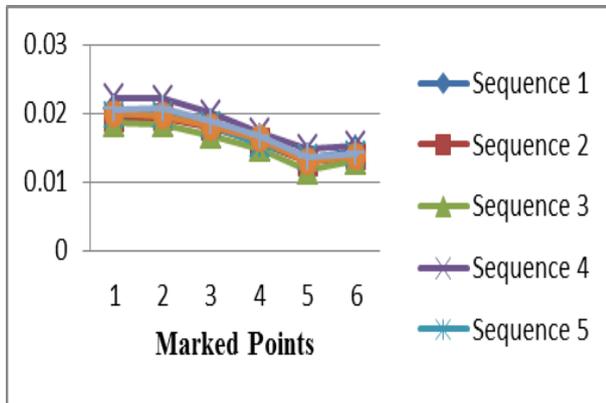


Fig. 9 : Graph for physical ΔZ deflection (Points 6-11)

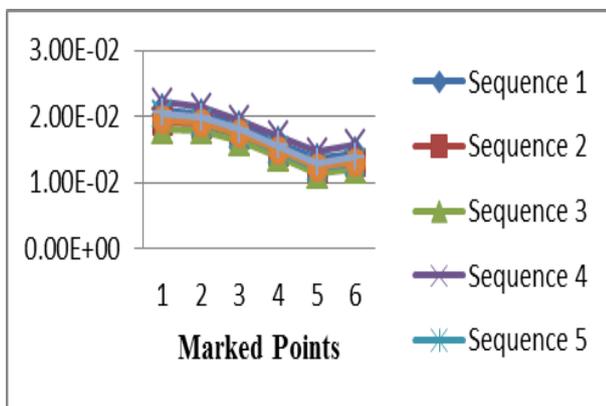


Fig. 10 : Graph for software ΔZ deflection (Points 6-11)

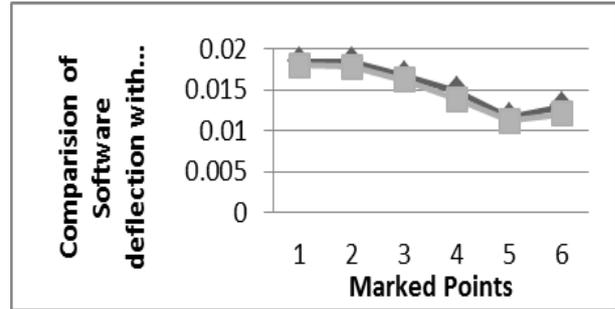


Fig. 11 : Graph for comparison of physical and software ΔZ deflection (Points 6-11)

V. TORSIONAL DISTORTIONS OR TWIST

For torsional distortions or twist the methodology used is change of C/S B at one end of the pillar with respect to C/S A at another end of a pillar. To do this 2 points C, D are marked and measured for ΔZ on edge of C/S A and points I, J are marked and measured for ΔZ on edge of C/S B as shown in the Fig.8.1. The measurements for torsion i.e. ΔZ for points C, D, I, J is done by using CMM. From these measurement readings the graphs are then plotted for prediction of the optimum sequence of welding and compared with the software results.

The line is considered for joining points C and D on C/S A, i.e. line CD and points J and I on C/S B, i.e. line IJ. The slopes for the lines CD and IJ are calculated as

$M1 = (Z2 - Z1) / (Y2 - Y1)$ for line CD and $M2 = (Z2 - Z1) / (Y2 - Y1)$ for line IJ. From slopes M1 and M2 the angular deviation for torsion is calculated as $\theta_1 = \tan^{-1}(M1)$ and $\theta_2 = \tan^{-1}(M2)$. The difference $(\theta_2 - \theta_1)$ gives the angular deviation between two lines i.e. Angular Deviation of C/S B with respect to C/S A of a B-Pillar and hence gives the torsional deviation also.

(a) Analysis of Actual Results:

The graph is plotted for angular deviation $(\theta_2 - \theta_1)$ for physical measurements and for the comparison purpose, which is as follows in the Fig.12.

(b) Analysis of Software Results:

The graph is plotted for angular deviation $(\theta_2 - \theta_1)$ for software measurements and for the comparison purpose, which is as follows in the Fig.13.

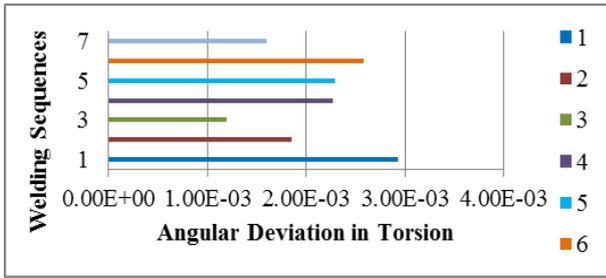


Fig. 12 : Graph for physical torsional deflection

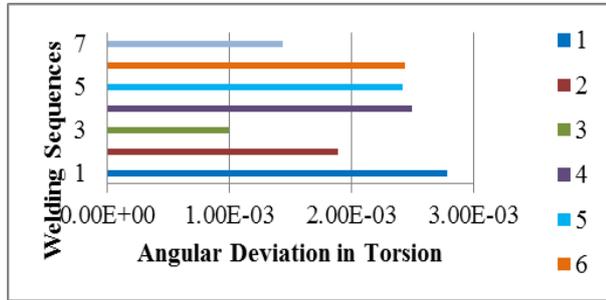


Fig.13 Graph for software torsional deflection

(c) Comparison between Physical and Software measurements for Angular Deviation of C/S B with respect to C/S A, is as follows:

(for optimum Sequence of welding Sequence No.03) is as shown in the Fig. 14.

VI. CONCLUSION:

1. From various field visits with car shops it is found that selecting the proper welding methodology and welding sequence is of prime importance. Also the distortion of assembly will reduced drastically by choosing proper sequence.
2. Sample B-Pillar length is taken 500mm purposefully accommodating 5 spots on one flange and 6 spots on another flange (exactly as Maruti omni cargo car has) just to prove the technique of sequence welding. Once the technique is established it can be extended to any B-Pillar.
3. From Fig.7 to 14 it is concluded that sequence no. 3 i.e. firstly welding the centre spot on left flange i.e. 4th, then welding spots alternately and centre spot on right flange i.e.9th, then welding alternately. i.e. (Sequence as 4-3-5-2-6-1-9-8-10-7-11) is the best possible minimum possible solution for welding the B-Pillar assembly and is validated by both physical as well as software analysis.
4. By welding the B-pillar components by using sequence No. 3 yields minimum torsional deviation, Bending in a horizontal plane and Bending in a vertical plane too.

5. Welding the centre spot on the flange first yields the even distribution of heat induced due to welding, which gives the best thermal distribution plot along the B-pillar and hence reduced overall distortions.
6. The deviation in the physical and software analysis results is due to following reasons:
 - a. The welding and cooling cycle timings for the software analysis are taken by doing time study of physical welding. Calculating the time in seconds and mili-seconds introduced an error in the software measurements.

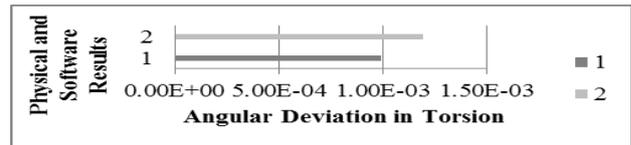


Fig. 14 Graph for comparison of physical and software torsional deflection

- b. The manufacturing constraints deviates the physical analysis results from the software analysis.
- c. Convection film coefficient required for the software analysis is taken uniformly as a 10W/m⁰K as a thumb rule which may not be the case while welding physically.
- d. Tongs pressure while welding is not considered for software analysis which exits in case of welding physically.

REFERENCES:

- [1] F.W. Brust, Paul Scott, “Weld distortion control methods and applications of weld modeling,” Transactions, SMiRT, Toronto, August 2007, paper #B05/1.
- [2] Lin, Echele, Shi, “Effect of welding sequence on welding induced alignment distortion in butterfly laser diode module,” University of California, eScholarship, 02-01-2005.
- [3] Scott E. Zilincik and Wm. Jeffrey DeFrank, Ernie Monroe and Salman Khan, “A new approach to evaluating spot welds for automotive durability,” Society of Automotive Engineers, Inc., 982277.
- [4] Dr.R.M.Warkhedkar, M.S.Mukhedkar, “Optimization of spot welding using taguchi method,” International Conference on Sunrise Technologies, 13th – 15th Jan 2011.
- [5] Dongyul Lee, Ki Eak Kwon, Jaeyool Lee, Haeseong Jee, Seong Wook Cho, Jong-Gye Shin, Gyubong Lee, “Tolerance analysis considering

- weld distortion by use of pre-generated database,” Journal of Manufacturing Sciences and Engineering, August 2009, Volume131/041012-1.
- [6] C.L.Tsai, S.C. Park, W.T.Cheng, “Welding distortion of a thin plate panel structure,” Welding Research Supplement, 156-s/May1999.
- [7] Kathleen Hoffman, Fadil Santosa, “A simple model of sheet metal assembly,” Society for Industrial and Applied Mechanics, 2003, Vol.45, No.3, pp. 558-573.

