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EFFECT OF SPOT WELD POSITION VARIATION ON QUALITY OF AUTOMOBILE SHEET METAL PARTS

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Abstract- Resistance spot welding is the most preferred and widely used method for joining metal sheets in automotive and many other industrial assembly operations. The body of a car is typically joined by thousands of spot welds. One of the many geometrical factors affecting the final geometrical outcome of the metal part assemblies is the welding process considering welding sequence used when the parts are welded together. The spot welds guarantee the strength of the car, but their positions also affect the geometrical quality of subassemblies and the final product. In practice, the positions of the weld points often deviate from nominal position. By analyzing industrial scanning data, deviations of spot weld positions are found to be of magnitudes up to 19 mm. In this paper, the influence of variation in position of spot welds is investigated with respect to geometrical quality, by simulating and analyzing the geometrical variation of an A-pillar assembly.

Keywords- *Tolerance, Spot Welding, Simulation.*

I. INTRODUCTION

A typical automotive car body consists of about 300 sheet metal parts, joined by about 4000 spot welds. In body-in-white production plants, the welds are distributed between several hundred industrial robots, organized in up to 100 stations. The number and position of spot welds, as well as the order in which they are executed, also affect the geometrical quality of an assembly. Geometrical variation propagates from parts through the assembly systems and may lead to products not fulfilling requirements, with high costs and reduced competitiveness as a consequence [1]. Geometrical variation in the final subassembly is mainly a result of:

- Variation in size and shape of single parts due to previous manufacturing steps, such as the metal forming process.
-Variation in the positioning of parts in the assembly fixture.
-Variation due to the joining process. In this category, effects of variation in spot weld position belong.

As spot weld joints provide localized connection, and thus lead to high stress concentration in the joined plates, any improper design may result in excessively high stresses and premature failure [2]. Dimensional variation affects fit quality and functionality. For example, variations in a body-

in-white (BIW) can ultimately cause poor sealing, undue effort required for door closing, water leaks, excessive wind noise, prolonged time-to-market and added manufacturing costs. Each step in the process is capable of contributing a degree of variation. Those variations in turn act on one another to compound distortion in the final BIW (body in white) [3]. One of many factors affecting the final geometrical outcome of a sheet metal assembly is the spot welding sequence, used when the parts are welded together. 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 [4]. It is of course desirable to choose a welding sequence that minimizes both variation and deviation in critical dimensions of the final assembly [5]. As dimensional integrity of the automotive body (body-in-white), has a great effect on the quality and functionality of the vehicle [6].

II. GEOMETRY ASSURANCE AND VARIATION SIMULATION

Geometry assurance is a term used to describe different kinds of activities aimed at reducing geometrical variation and its effects. Such activities take place in all three phases of the product realization loop, see Fig. 1. [1]. Several authors have proposed methodologies to predict variation in sheet metal assemblies.

They identified three sources of variation in such assemblies: component variation, fixture variation, and joining tool variation. Considering the compliant nature of sheet metal parts, Liu and Hu presented a model to analyze the effect of component deviations and assembly springback on assembly variation by applying linear mechanics and statistics.

The model considered the process at a station level. Using finite element methods (FEM), they constructed a sensitivity matrix for compliant parts of complex shapes.

The sensitivity matrix established a linear relationship between the incoming part deviation and the output assembly deviation [7].

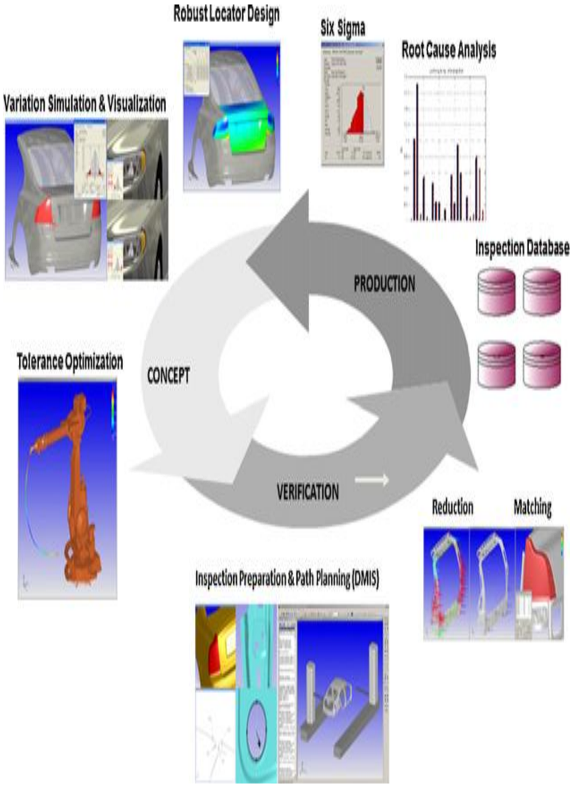

Fig. 1. The product realization loop [1].

However, since a large number of runs are required to achieve satisfactory accuracy, the method is very time-consuming if a new Finite Element Analysis (FEA) calculation is executed in each run. . Liu and Hu presented a technique called Method of Influence Coefficients (MIC) to overcome this drawback. The main idea of their method is to find a linear relationship between part deviations and assembly spring-back deviations. A sensitivity matrix, constructed using FEA, describes that linear relationship. This sensitivity matrix is then used in the simulations, and a large number of FEA calculations can be avoided [1].

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. In Fig. 2 such factors are listed. Statistical parameters concern things like number of samples and inspection errors when inspection data on part level are used as input to the simulation. If predicted data, i.e. tolerances on parts, are used, it is important to choose correct distributions and a sufficiently large number of iterations (Monte Carlo runs). The model should include some material-related information, such as elasticity and Poisson ratio. It is also important that information about the assembly and joining processes is included in the simulation. Assembly and joining sequences as well as methods for contact modeling significantly affect the simulation accuracy [1].

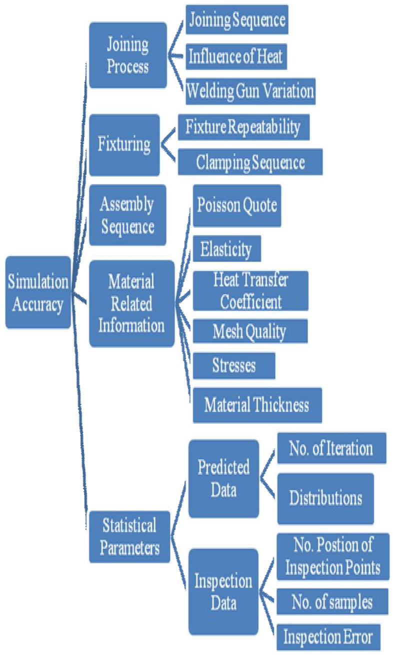

Fig. 2. Factors affecting the accuracy of a non-rigid variation simulation [1].

III. SPOT WELDING IN AUTOMOTIVE INDUSTRY

Spot welds are the dominant joining method in the automotive assembly process [5]. A spot weld is materialized by clamping the sheets with two pincers while applying force and transmitting current as depicted in Fig. 3.
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 [2]. A spot welding gun has two electrodes, which are applied from either side of the sheet metal parts. 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 [1].

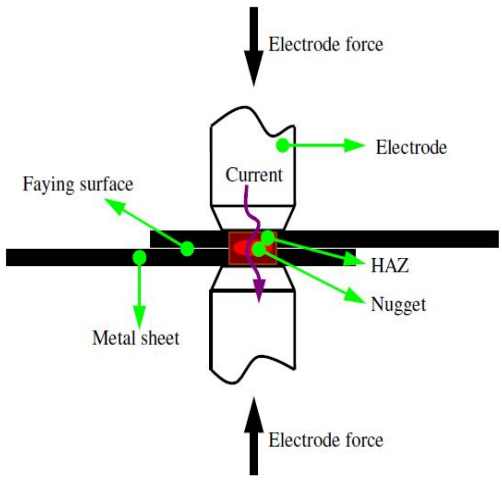

Fig. 3. A schematic representation of the resistance spot welding process [2].

In this work, a balanced welding gun is used. Using this gun, the electrode are applied simultaneously from each side of the metal sheets in order to connect the parts and equal forces are applied to the welding pins. Therefore, the sheet metal parts will meet in a position of equilibrium. 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

- geometrical variation on part level in areas where spot welds are located;
- variation in the positioning of the parts to be assembled;
- wearing of electrodes on the welding gun;
- lack of repeatability in the robot and the welding gun.

To investigate the magnitude of this variation, spot-welded assemblies were scanned. The instrument used was a 3D scanner with phase-based distance sensor. Data were captured on 1–2 m distance with accuracy of 1 mm and resolution of 0.5 mm. The complete door area was scanned within 10 s. The use of this kind of scanner allows for quick and easy in-line inspection of geometries; it can also be used for other industrial applications, such as scanning of environments and facilities.

In Fig. 4, a scanning of a spot-welded assembly from a Swedish automotive manufacturer is shown. The deviation between nominal and actual positions of the spot welds is in many cases quite large. For a number of more closely analyzed spot welds, the maximum deviation from nominal position amounted to 19 mm. The mean deviation was 9 mm [1].

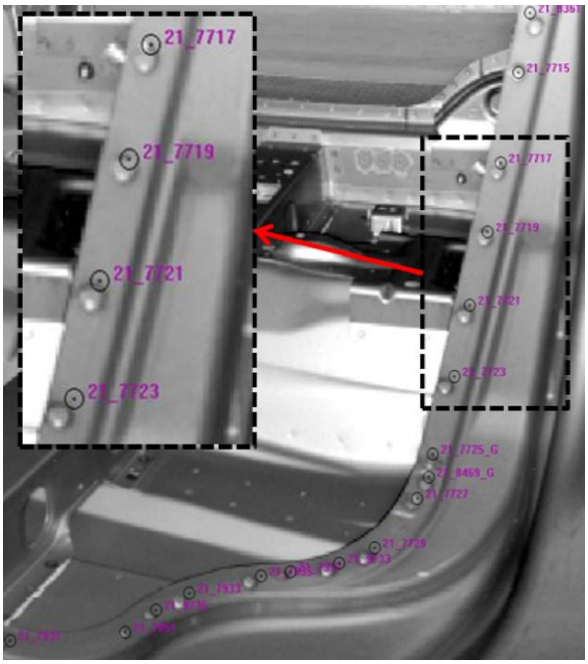

Fig. 4. The actual spot weld position compared to nominal spot weld position (indicated with black circles) [1].

IV. SIMULATION OF THE INFLUENCE OF VARIATION IN

SPOT WELD POSTIONING ON GEOMETRICAL VARIATION

In order to investigate how the variation in spot weld position, revealed in the previous section, influences geometrical variation in the final assembly, a variation simulation of an industrial case study is conducted. The case study consists of an A-pillar assembly, shown in Fig. 5. The complete A-pillar assembly is evaluated in a number of inspection points, illustrated with small squares in the figure. The inputs to the simulation consist of:

- scan data, represented by Finite Element meshes, of geometries included in the assembly on part level;
- tolerances for spot weld position.

Validation of the simulation model for this case study (with nominal spot weld position) has previously been conducted. The results were validated against industrial scanning data of the complete assembly . The correlation between simulated results and scanning data of a complete assembly amounted to 0.94 for inspection points located on the A-pillar and 0.87 for inspection points on the extension. The simulation is conducted in the software RD&T and is based on Monte Carlo simulations and a FEA-based simulation model describing all mating conditions, kinematic relations and non-rigid behavior [1].

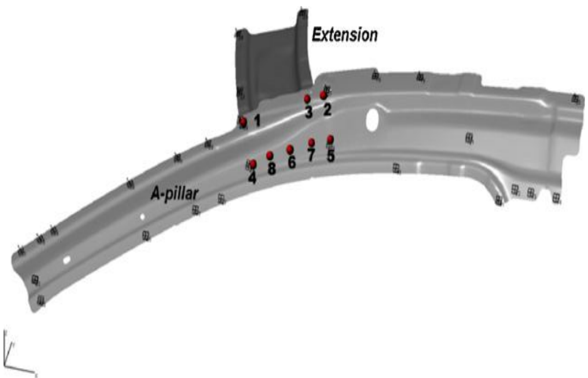

Fig. 5. A-pillar and its extension. The spot welding points and their welding sequence are illustrated by spheres and numbers, while the inspection points are illustrated by squares [1].

Carlo simulation is based on repeated sampling and is a standard technique in variation simulation. It is used to approximate the distribution for a number of user-defined

Critical measures in the final assembly. Spot welding sequence is taken into consideration in the simulation model and in a normal non-rigid (FEA based) variation simulation; the following steps in the assembly procedure are simulated in order to predict variation and deviations in critical dimensions of the final assembly:

1. The parts are positioned in their fixtures and over-constrained locating systems (i.e. clamps) are applied. Forces are applied to clamp non-nominal parts.
2. The parts are joined together in a pre-defined joining order. The gaps in the joining points are closed, one by one.
3. After the last joint is set, the assembly is unclamped and is allowed to springback.

The mathematical details of the procedure described above are described in [8]. The outcome from the scanning shown in Fig. 4 is used to estimate a reasonable tolerance for the spot weld position. To each spot weld position, a circular tolerance consisting of an angle and a radius is allocated. For the radius, two different tolerances are used in order to illustrate the significance of tolerance size. The angle is uniformly distributed between 0 and 2p and the radius is uniformly distributed on [0, 17.5] mm (blue solid line) and [0, 7.5] mm (red dotted line), respectively. A Monte Carlo simulation with 2000 iterations is run for both choices of tolerance. In each iteration, a disturbance for every spot weld position is randomly generated and the node pair closest to the new position is chosen as the new position of the spot weld. The element length of the meshes is approximately 3 mm, so in practice the radius of the circular tolerance might be up to 19 mm (corresponding to the maximum deviation found in the case study) for the blue solid line and up to 9 mm (corresponding to the mean deviation found in the case study) for the red dotted line. No other sources of variation in the final assembly, but the variation in spot weld position, are added. As already mentioned, the meshes for the individual parts are, however,

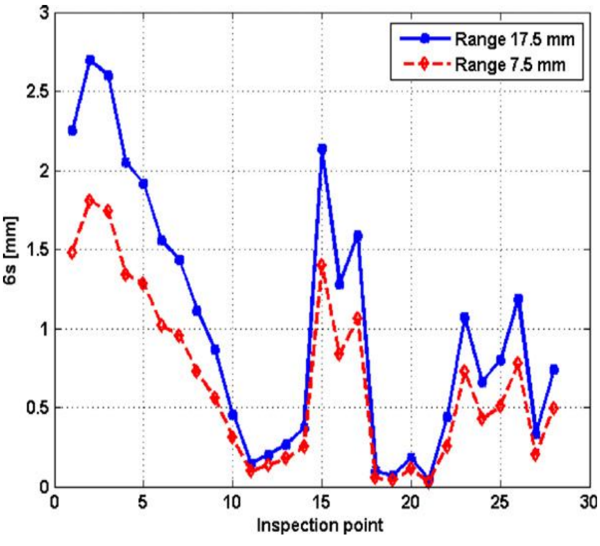

Fig. 6. 6s due to variation in the position of the spot welds in 28 different inspection points on the final assembly [1].

based on non-nominal scanning data. The result of the variation simulation of the A-pillar assembly is shown in Fig. 6.

The variation in the 28 inspection points is represented by 6s, where s is the standard deviation. As can Be seen, the level of 6s is very high in some of the inspection points. Using the larger tolerance illustrated by the blue solid line, 6s is about 2.8 mm for the second inspection point, which is quite a large variation for this kind of assembly. Also when using the smaller tolerance (red dotted line) the amount of variation is quite large. The resulting variation can also be illustrated using color coding. In Fig. 7 the simulated outcome of the complete A-pillar assembly is shown. The color coding shows the levels of 6s for each node. The second inspection point in Fig. 6 is located in the orange area in the left part of the assembly [1].

V. DISCUSSION

The conclusion from the case study is that the variation in positions of spot welds strongly affects the geometrical variation in the final assembly. Therefore, the variation in spot weld position needs to be reduced. This is not an easy task, but a first step is to find the origin of the variation. The magnitudes of the different variation sources need also to be estimated. In Section 3 possible causes of variation in spot weld position were listed. Part variation is normally in focus in automotive industry and reducing this source of variation is usually a balance between cost and quality.

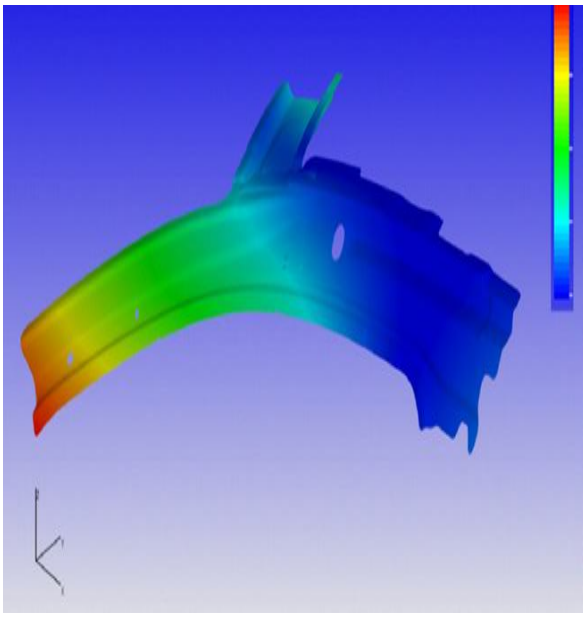

Fig. 7. Color coding showing 6s for the final A-pillar assembly. The color coding goes from 0.1 mm (blue areas) to 3.25 mm (red areas) [1].

The chosen concept is also affecting how sensitive an assembly is to part variation. The variation in positioning of parts during assembly should be investigated using repeatability studies. That is also the case with the lack of repeatability in robot and welding gun. Knowing the contribution from different variation sources should be a good start when searching an approach to reduce the variation in spot weld position [1].

VI. CONCLUSIONS

The objective of this paper is twofold. The first is to investigate the magnitudes of variation in spot weld position in automotive industry. The second is to analyze how this variation in spot welds position affects the geometrical variation of the final assembly. By scanning spot-welded assemblies from a Swedish automotive manufacturer it was found that the deviation between nominal and actual spot positions amounted to up to 19 mm. The mean deviation was 9 mm. The figures in themselves are less important than the fact that there really is a non-negligible deviation from nominal for the main part of the spot welds. To investigate how this variation in spot weld position affects the final assembly with respect to geometrical quality, a variation simulation was conducted. In the simulation, a case study

which previously has been validated using industrial inspection data was used. The results showed that the variation in spot weld position actually has quite a large influence on variation of the final assembly. For the inspection points most sensitive to this kind of variation, 6s amounted to 2.8 mm, showing that the variations in spot weld positions contribute greatly to the degree of geometrical quality of the final assembly [1].

REFERENCES

[1] G. So derberg, Kristina Warmefjord, Lars Lindkvist, Rolf Berlin, “The influence of spot weld position variation on geometrical quality,” CIRP Annals. Manufacturing Technology, vol. 61, 2012, pp. 13–16.

[2] AhmetH.Ertas, FazılO.Sonmez, “Design optimization of spot-welded plates for maximum fatigue life,” Finite Elements in Analysis and Design, vol. 47, 2011, pp.413–423.

[3] Min Hu a, Zhongqin Lin a, Xinmin Lai a, Jun Ni, “Simulation and analysis of assembly processes considering,” International Journal of Machine Tools & Manufacture, vol. 41, 2001, pp. 2233–2243.

[4] Kristina War0mefjord, Rikard Soderberg and Lars Lindkvist, “Variation Simulation of Spot Welding Sequence for Sheet Metal Assemblies,” Nord Design 2010.

[5] Stijn Donders, Marc Brughmans, Luc Hermans, Nick Tzannetakis, “The Effect of Spot Weld Failure on Dynamic Vehicle Performance,” 2001.

[6] Dariusz Ceglarek, Jianjun Shi, “Dimmensional Variation Reduction for Automotive Body Assembly,” Manufacturing Review, vol. 8, june 1995, pp. 2.

[7] Jaime A. Camelio and S. Jack Hu Dariusz Ceglarek, “Impact of Fixture Design on Sheet Metal Assembly Variation,” journal of Manufacturing Systems, Vol. 23/No. 3, 2004.

[8] K. D. Hardikar, D.J.Nidgalkar, Dr. K.H. Inamdar, “Techniques to ensure minimum distortion of an assembly of metal parts induced due to the process of welding used for an assembly,” International Journal of Scientific & Engineering Research Volume 3, Issue 2, February-2012.

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