Simulative analysis of surface accuracy control for spot welding assembly part

Huanyang Xie†, Jianqiang Jiang, Wu Cao and Jisong Zhao
Kunshan Daya Automotive Parts Co., Ltd, Suzhou, Jiangsu, China
†E-mail: huanyang.xie@ks.shdlgroup.com

This paper investigates the influence of spot-welding process on surface accuracy of cold and hot stamping assembly part. In order to control surface accuracy after spot welding, simulative work was carried out. In simulative work, welding sequence under given clamping position was considered. The results show that under the same clamping positions, the welding sequence has an impact on welding deformation. Welding residual stress derived from continuous spot welding is considered the main reason that contributes to welding deformation. For assembly part which possesses multiple welding spots, enough time gap between welding spots can be helpful for welding residual stress release. Additionally, more clamping positions also favour reducing welding deformation. By using relevant welding process for specific welding assembly, surface accuracy of the assembly part can be well controlled within ± 0.5mm. Spot welding simulation plays a crucial role for welding surface accuracy control of assembly part, thereby reducing the number of trial and error attempts.

Keywords: Welding deformation; Cold and hot stamping; Simulative; Clamping position; Welding residual stress.

1. Introduction

The safety factor of a vehicle in its service life is very crucial for drivers and passengers. In order to improve the active and passive collision performance, more and more hot stamped parts are used in car body structures due to their high strength and lightweight effect [1]. For example, hot stamped middle channel is spot welded with cold formed floor panel to enhance the rigidity of the vehicle floor which therefore increases the safety of member cabins. However, the deformation induced by spot welding influences the dimensional accuracy of the cold and hot assembly part leading the inability to install any other parts. Hence, how to control welding deformation has become a hot issue in car floor frame as well as other frame structures. It is known that there are usually two methods to control welding deformation: One way is to apply external force to correct the deformed parts after welding [2]. This is a time-consuming task because you don't know how much adjustment is needed each time and how many times it needs to be repeated to achieve your goal; The second way is to use the anti-deformation method to control welding deformation [3]. The anti-deformation amount also needs to be adjusted multiple times which affects production efficiency. The above mentioned two methods are currently commonly used to handle welding deformation, but their production efficiency is relatively low and they can no longer adapt to the fast-paced production rhythm. There is an urgent need to seek an efficient way to handle welding deformation. As it is known that the root cause of welding

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deformation is the residual stress generated during the welding process, and its nonhomogeneous distribution and the uncertainty magnitude of stress release devotes to welding deformation. As an input parameter, welding sequence is considered one of the most important factors that influence welding residual stress [4], therefore welding deformation control may be realized by varying welding sequence. Similar work has been conducted when connecting two cold forming blanks [5] and shows the effectiveness of simulative method. Nevertheless, there are not many literatures on welding deformation simulation of cold and hot stamping materials.

In this study, welding deformation simulation technology was carried out to reduce the frequency of welding deformation debugging. In simulative work, welding sequence under the same clamping position was well considered. For conditions with relatively small welding deformation, the influence of added clamping positions on welding deformation was also simulated. The reasons for welding deformation were also discussed.

2. Simulative procedure

2.1. *Parts and materials*

In this paper, a hot stamped middle channel is connected with cold stamped floor panel by 12 welding spots. The assembly part is shown in Figure 1. The middle channel is a hot stamped part with 22MnB5 as shown in Figure 2.

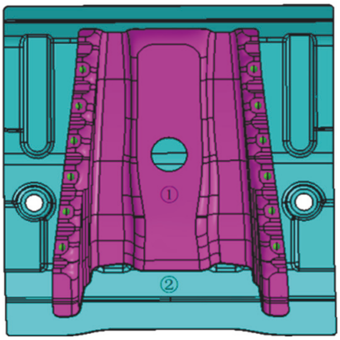


Fig. 1 Assembly part：① Middle channel；② Floor panel

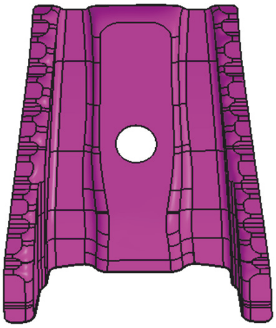


Fig. 2 Middle channel

The chemical composition of the raw material is listed in Table 1. The corresponding yield stress and the ultimate tensile stress of the raw material are 426MPa and 619MPa respectively. Its fracture elongation is 26.5%. The cold stamped floor panel is shown in Figure 3.

Table 1. Chemical composition of the as received steel (wt. %）

C	**Si**	**Mn**	**P**	**S**	**Cr**	**Al**	**B**	**Fe**
0.21	0.22	1.2	0.012	0.0023	0.15-0.28	0.035	0.0022-0.0077	balance

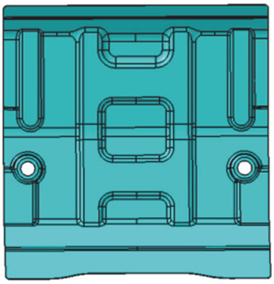


Fig.3 Floor panel

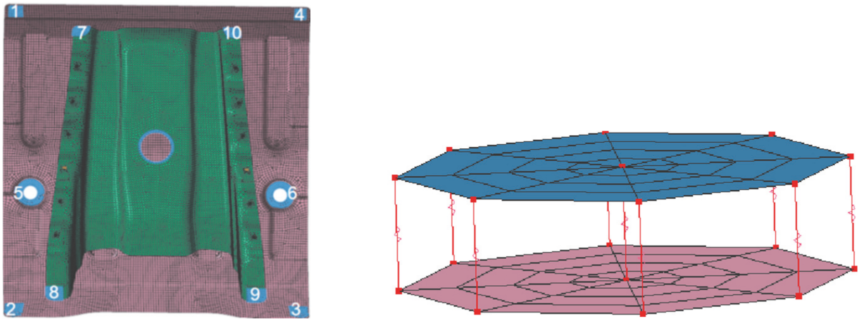
The material grade is L340/590DP. Its chemical composition of is listed in Table 2.

Table 2. Chemical composition of the as received steel (wt. %)

C	**Si**	**Mn**	**P**	**S**	**Al**	**Fe**
0.071	0.493	1.818	0.026	0.0075	0.027	balance

2.2. *Finite element model*

The clamping position as the boundary condition that fix the middle channel and the floor panel. No. 1 to 6 clamping points fix the floor panel to the welding fixture and No. 7 to 10 clamping points fix the middle channel to the floor panel. The element type for both the floor panel and the middle channel as well as the welding points is 2D shell element. Figure 4(a) shows the clamping positions and finite element mesh division. The welding spots and two sheet metals are connected through common nodes as shown in Figure 4(b).

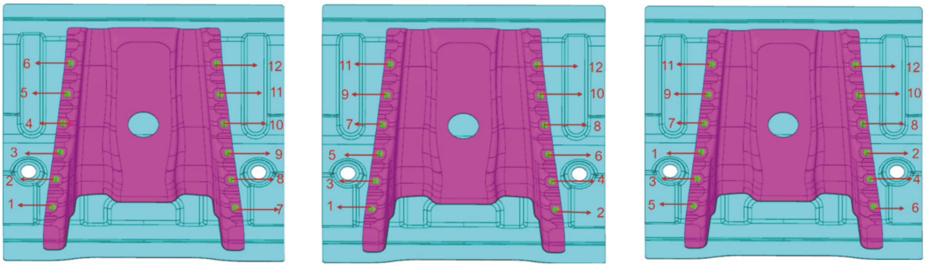


(a) (b)

Fig. 4 Finite element model: (a)Boundary conditions and mesh; (b) Welding spot model.

2.3. *Welding sequence*

Targeting to distinguish welding induced deformation under different welding sequence, this paper displays three different welding sequence that may be used in actual production process. Figure 5 shows the concrete welding sequence according to the numerical order. Sequence A represents welding sequence from one side to the other. While sequence B adopts welding sequence similar to a button order. Sequence C starts from middle to the end.

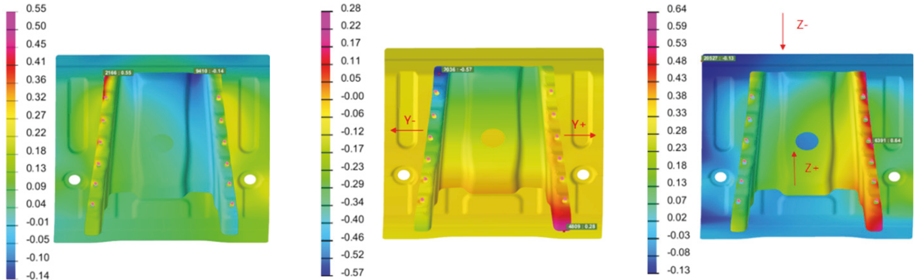


(a) sequence A (b) sequence B (c) sequence C

Fig. 5 Welding sequence

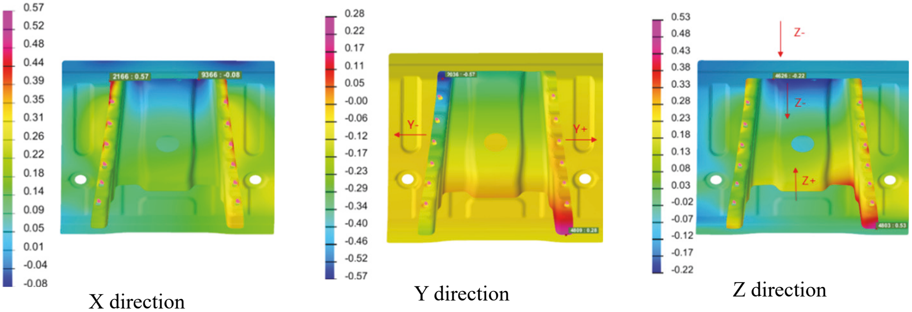
3. Results and discussion

Displacement distribution according to sequence A/B/C is shown in Figure 6.



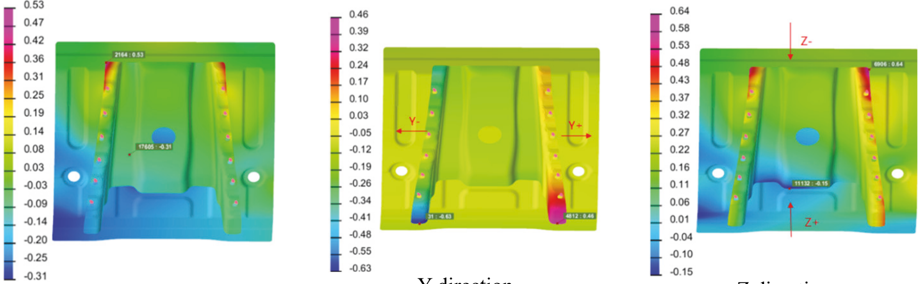
X direction Y direction Z direction

(a) Displacement distribution: sequence A



X direction Y direction Z direction

(b) Displacement distribution: sequence B



X direction Y direction Z direction

(c) Displacement distribution: sequence C

Fig.6 Deformation distribution under sequence A/B/C

The maximal deformation in X/Y/Z directions under sequence A/B/C is shown in Table 3.

Table 3. Maximal deformation in X/Y/Z directions under sequence A/B/C (mm）

Welding sequence	**X**	**Y**	**Z**
A	0.55	0.57	0.64
B	0.57	0.57	0.53
C	0.53	0.63	0.64

It can be seen from Table 3 that deformation under sequence B is better than the other two sequences. Deformation in Z direction is larger than sequence B when Compared sequence A with sequence B. Because welding residual stress derived from continuous spot welding in one side then another side leads to large deformation. When taking into account for this welding residual stress accumulation effect, deformation under sequence C displays a little bending phenomenon. Previous researchers utilized several approaches to release the welding residual stress, e.g. ultrasonic, post heat treatment [6, 7]. Nevertheless, welding residual stress under sequence B can be well released due to enough time gap between two welding spots. From a mechanical perspective, stress relaxation can partially explain this phenomenon. In addition, the significant strength difference between hot formed parts with super higher strength and cold stamped parts with lower strength may also be a factor leading to welding deformation.

In order to decrease the deformation value, more clamping positions were added under sequence B as shown in Figure 7. The maximal deformation in X/Y/Z directions as shown in Figure 8 is 0.44mm/0.35mm/0.49mm respectively. It means that by increasing the clamping positions, welding deformation can be reduced.

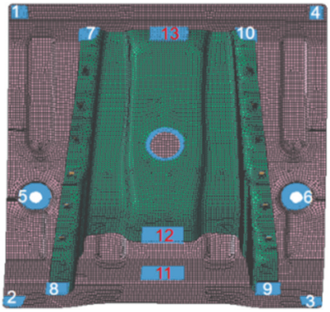


Fig.7 Additional clamping positions

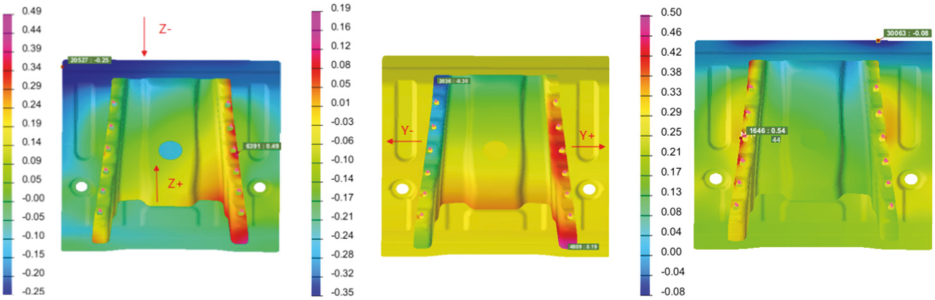


Fig.8 Deformation distribution under additional clamping positions

4. Conclusions

This article investigates the influence of welding sequence on welding deformation through numerical simulation. The results indicate that under the same clamping positions, the welding sequence impacts the welding deformation. Residual stress derived from continuous spot welding is considered the main reason that contributes to welding deformation. Enough time gap between welding spots can be helpful for stress release. Additionally, more clamping positions also favour reducing welding deformation.

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