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Assessment of Clinching as an Alternative to Riveting and Spot Welding

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Abstract

The riveting and resistance spot welding are the most common methods for joining the steels of structures. However, these methods require some specific time-consuming pretreatment of joined materials such as cleaning surface before welding or drilling the holes before riveting. In addition, when galvanized steel sheets are joined, the protective layer is destroyed which lead to decreasing of corrosion resistance of structures. It is necessary to utilize the other joining methods. The paper deals with the assessment of the possibilities of mechanical joining as an alternative method to resistance spot welding and riveting. All the mentioned joints such as riveted joints, resistance spot welded joints and clinched joints are permanent joints. Those joints cannot be disassembled without damaging the assembled parts. Hot-dip galvanized structural steel sheet S250GD with the thickness of 1.5 mm and 2.5 mm were used for the experiments. Mechanical clinching is a combination of drawing and forming. The research is focused on the evaluation of joints' properties using shear tensile test and metallographic observation.

Keywords

Clinching, Riveting, Spot Welding, Shearing Load, Metallographic

1. Introduction

Methods of joining in the industry are predominantly driven by advances in materials, working with dissimilar materials and the call for increased automation. Riveting machines apply rivets to materials in a wide variety of configurations, from manually operated riveting guns to multi-head automated electrical, hydraulic or pneumatic riveting tools. There are three main types of riveting machinery - compression riveting, non-impact riveting and impact riveting [1].

During the last few decades, the rapid development of welding technology has considerably reduced the sphere of application of riveted joints. Today, riveted joints have almost been replaced by welded joints [2].

Resistance spot welding is one of the oldest of the electric welding processes in use by industry today. This joining method is accomplished by passing an electrical current through joined sheets via electrodes. The heat induced by the electrical current creates a molten nugget.

The molten nugget then solidifies to create a bond between the sheets [3, 4] After spot welding, important changes occur in mechanical and metallurgical properties of the spot welded areas and heat affected zones. The investigation of these changes is very important for the strength of welded joints [5, 6]. When welding galvanized steel sheets, it is required to use greater welding current and electrode pressure as well as longer welding time due to the shunting effect of zinc coating compared to welding of uncoated steel sheets of the same thickness and quality [7, 8]. The wear of welding electrode tips becomes large because of the lower electricity resistance and melting temperature of protective layer [9].

Both riveting, as well as resistance spot welding, destroyed protective coating (zinc coating) on the joined steel sheets, which causes the decreasing of corrosion resistance. Another disadvantage is the need of drilling holes in the steel sheets (riveting) and consistent surface cleaning of steel sheets before joining (resistance spot welding). Therefore, it is important to utilize other joining methods such as mechanical joining – clinching. Clinching can overcome the disadvantages of resistance spot welding and riveting.

Clinching as a most used method of mechanical joining is a metalworking process which can connect steel sheets effectively without any splashes, flashes or harmful light. Moreover, this joining method can be used for joining the coated sheets with no damage to the surface. The sheets are joined by local hemming with a punch and die. It can be used in automotive, building or electrical industry [10, 11].

2. Material and Experiment

2.1. Principle of Clinching

Clinching is a high-speed joining technique, which uses a special punch and die. The joined sheets are formed by the punch and die to create the mechanical interlock between the lower and the upper sheets. The strength of the joined sheets is determined by the amount of the formed interlock. These sheets are joined by way being hooked on the interlock, which is created around the punch corners, whereas the thickness of upper sheet decreases. It is necessary to obtain the critical wall thickness of the upper sheet around the punch corner without any fracture. The fracture of the joined sheets can lead to corrosion of the parts [12-14].

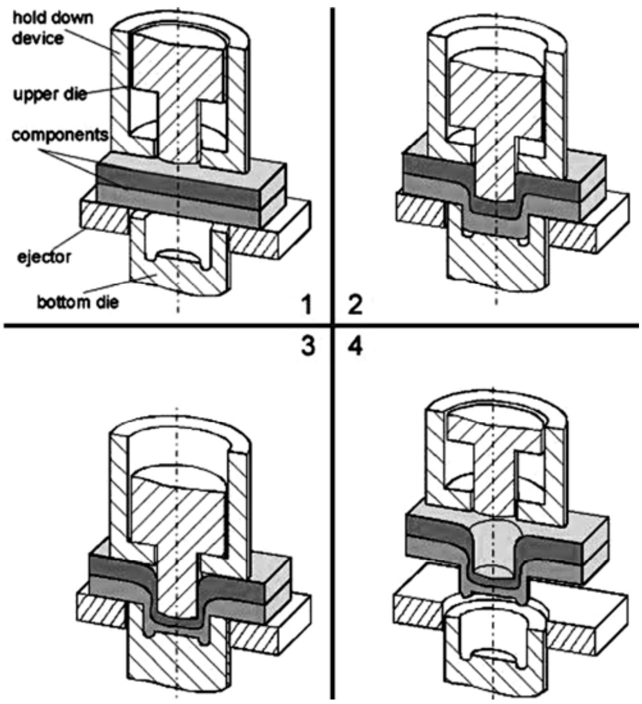


Fig. 1. *Principle of clinching [4].*

Single-step clinching process (Figure 1) can be described as:

Part 1: The punch and blank holder move downward, the workpieces are clamped and fixed by the spring force of blank holder.

Part 2: By action of the punch the material flows into the bottom die cavity forming a cup. The process parameters and dimensions of the punch and die are finely tuned to the sheet thicknesses of the workpieces. This ensures that no material is laterally drawn into the joint from surrounding area.

Part 3: Finally, the thickness of the cup's bottom is reduced by upsetting and the material forced into the die groove and in the lateral direction, forming the necessary undercut.

Part 4: After reaching a preset maximum force (force control) or a preset displacement (stroke controlled), the punch is retracted and the clamping force relieved. The joint connection requires no finishing.

2.2. Materials for Experiments

The material for the joining was the hot-dip galvanized construction steel sheet S250GD with the thickness of a_0 = 1.5 mm and 2.5 mm, produced by U.S. Steel Košice, Ltd. The basic mechanical properties (Re – yield strength, Rm – ultimate tensile strength, A_{80} – elongation) and chemical composition of the steel sheet is shown in Table 1 and Table 2.

Table 1. *Mechanical properties of joined materials.*

R_e [Mpa]	R_m [Mpa]	A_{80} [%]
248	337	19

Table 2. *Chemical composition of joined materials [in %wt].*

C	Mn	P	S	Si
0,18	1,54	0,06	0,002	0,51

The typical ferrite-pearlite structure of the S250GD steel sheet is shown in Figure 2.

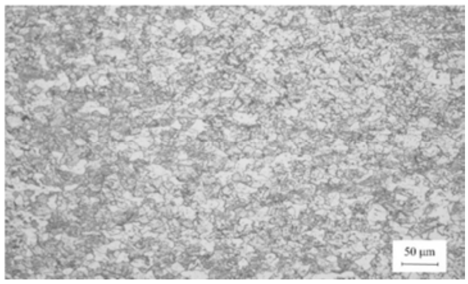


Fig. 2. *Structure of S250GD steel sheet.*

2.3. Methods of Experiments

Tubular rivets of ø4.8 mm were used for riveting of both thicknesses of steel sheets – Figure 3.

Fig. 3. *Sample joined with tubular rivet.*

Resistance spot welding was performed with the samples (Figure 4) on the pneumatic spot welding machine BPK20. The welding electrode tips from CuCr with the ø8 mm diameter of working area were used. The values of welding current were monitored during welding process by welding monitor Miyachi MG3 Digital.

Fig. 4. *Spot welded samples with steel sheets of (a) 1.5 mm and (b) 2.5 mm.*

The parameters of resistance spot welding used for joining of both steel sheets are shown in Table 3. The welding parameters were determined according to the recommended welding parameters by IIW - International Institute of Welding, adapted to the used welding machines.

Table 3. *Welding parameters.*

Welding Parameters	**Sheet thickness a_0 [mm]**	
	1.5	**2.5**
Pressing force *Fz* [kN]	4	6
Welding time *T* [per.]	13	17
Welding current *I* [kA]	7	9

The mechanical clinching was realized by two types of the tool with the active parts punch and die (Figure 5). The tool including the punch with a diameter of ø5 mm and the die with a diameter of ø8 mm was used for joining of 1.5 mm sheets thickness and the tool with the punch of ø7 mm and the with ø10 mm was used for joining of 2.5 mm sheet thickness.

Eleven samples were prepared for joining by all the observed methods. Ten of them for shearing test and one for metallographic observation.

The surfaces of the joined materials were not cleaned before riveting and clinching. The surfaces of the sheet for resistance spot welding were degreased in concentrated CH3COCH3.

Fig. 5. *Clinching tool with punch and die.*

The samples with clinched joints after mechanical joining are shown in Figure 6.

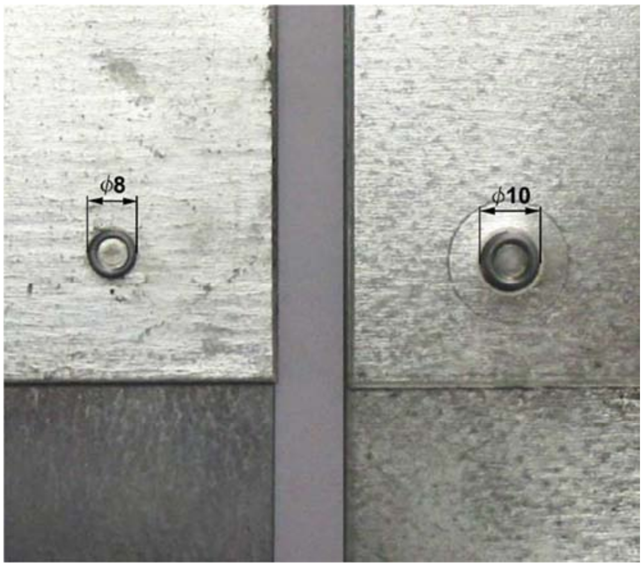


Fig. 6. *Clinched joints.*

The load-bearing capacity of the joint was evaluated according to STN 05 1122 standard – Welding: Tensile test on the spot - and complete penetration welds. The dimensions of the samples for the tensile test are shown in Figure 7. The static tensile test was carried out on the testing machine with the loading speed of 8 mm/min.

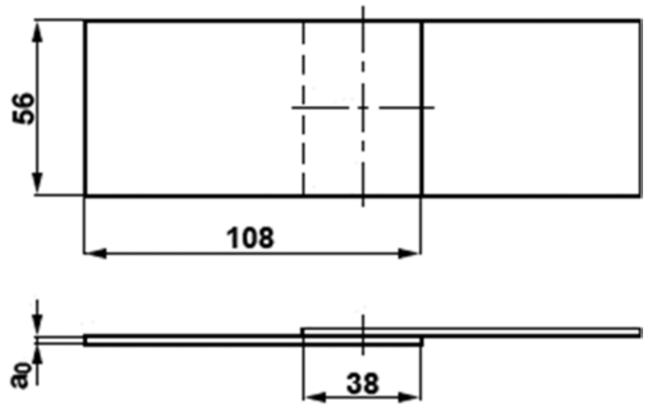


Fig. 7. *Dimension of samples for joining.*

A further test for quality evaluation of the joints included the metallographic observation. The quality of joints was evaluated by light digital microscopy on metallographical scratch patterns prepared according to ISO 6507-1 and ISO 6507-2 standards on Olympus TH 4-200 microscope.

3. Results

The tensile test was executed under displacement control conditions on the specimen configurations in order to characterize the static behavior of the joints and the ultimate tensile strength. The maximum shearing load was the most significant value obtained from this test. The values of maximum shearing load Fmax of all types of the joints are shown in Table 4 and Table 5 for the observed sheet thicknesses 1.5 mm and 2.5 mm, respectively.

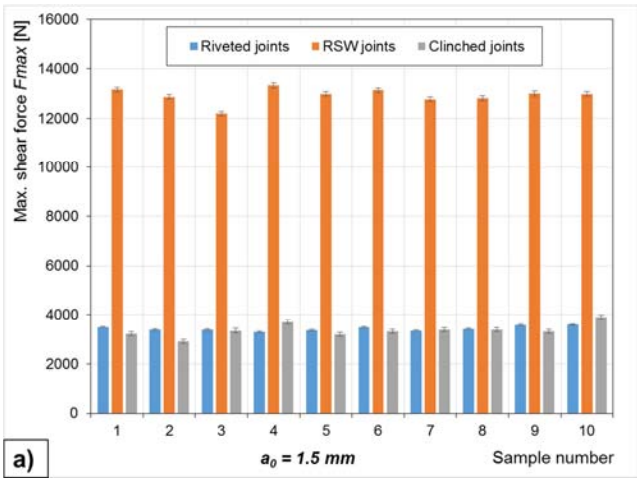
Table 4. *Values of load-bearing capacity of the joints for samples with the sheet thickness of 1.5 mm.*

Sample number (a_0=1.5mm)	Fmax [N]		
	Riveted joints	**RSW joints**	**Clinched joints**
1	3505	13175	3235
2	3404	12877	2909
3	3393	12195	3361
4	3295	13331	3706
5	3369	12990	3215
6	3495	13150	3321
7	3359	12780	3406
8	3432	12820	3402
9	3589	13010	3317
10	3601	12990	3891

Table 5. *Values of load-bearing capacity of the joints for samples with the sheet thickness of 2.5 mm.*

Sample number (a_0=2.5mm)	Fmax [N]		
	Riveted joints	**RSW joints**	**Clinched joints**
1	3404	13399	5674
2	3511	13695	6113
3	3470	12959	5020
4	3419	13471	5990
5	3386	13225	5076
6	3567	13110	5194
7	3514	12980	4982
8	3380	13470	5921
9	3496	13550	6053
10	3706	13215	6045

The highest values of Fmax were measured in resistances spot welded joints, in both joined thicknesses of steel sheets. The values of Fmax of the riveted and clinched joints were approximately at the same level in materials of 1.5 mm thickness (Figure 8a). On the other hand, when steel sheets of 2.5 mm thickness were joined, the significantly higher values were measured in clinched joints in comparison with the riveted joints (Figure 8b).



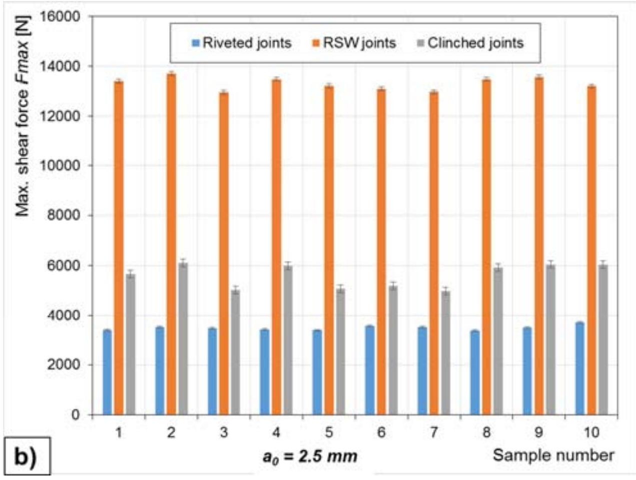


Fig. 8. *Maximum shear force Fmax of the joints.*

The typical riveted sample after tensile is shown in Figure 9. The tubular rivet was deformed during load until the failure occurred.

Fig. 9. *Riveted joints after tensile test.*

When the samples were joined by resistance spot welding, two types of failure occurred during a tensile test, depending on the thickness of joined materials. Welding the steel sheet S250GD with the thickness of 1.5 mm led to the failure mode, where weld nugget was pulled out from the one of the joined steel sheet Figure 10a. The welding of the same material but with the thickness of 2.5 mm lead to the failure mode through the weld nugget (Figure 10b).

The failure mode of the clinched joints was the same for both thicknesses of joined steel sheets, as shown in Figure 11. Joints made by clinching failed at the neck of the joint. There is insufficient material in the neck of the joint and loading will result in failure in the neck; excessive elongation in the region of the joint neck, causing crack formation.

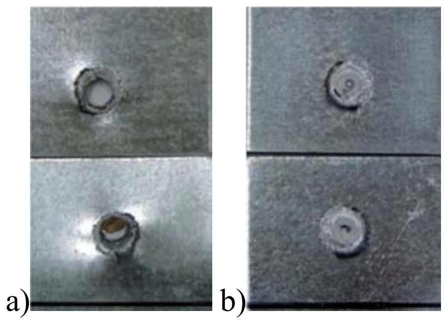


Fig. 10. *Spot welded joints after tensile test: (a) sheet thickness of 1.5 mm and (b) sheet thickness of 2.5 mm.*

a) b)

Fig. 11. *Dimension of the joined sample with sheet thickness of 1.5 mm (a) and 2.5 mm (b).*

The metallographic analysis confirmed the formation of only fusion welded joints with characteristic areas of weld metal (WM), heat affected zone (HAZ) and base material (BM) of both thicknesses of welded materials, as shown in Figure 12 and Figure 13. Grains in the HAZ are oriented in the direction of the cooling of the weld.

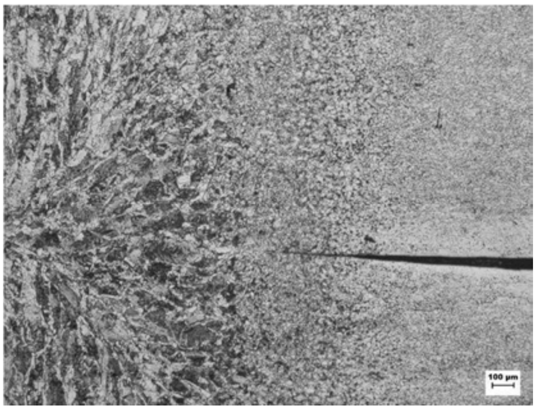


Fig 12. *Microstructure of welded joint with characteristic areas of WM, HAZ and BM with the sheets of thickness 1.5 mm.*

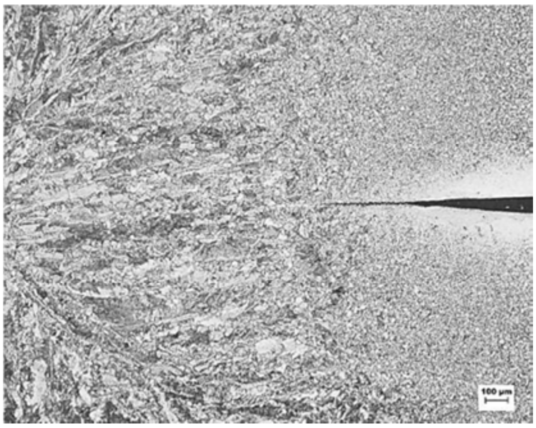


Fig. 13. *Microstructure of welded joint with characteristic areas of WM, HAZ and BM with the sheets of thickness 2.5 mm.*

The microscopic observation of macrostructure of the weld made on steel sheets of 1.5 mm thickness shows no pores or cavities occurring in the weld metal – Figure 14. The microstructure of weld metal consists of mostly fine-grained martensite arranged in typical lamellar formations.

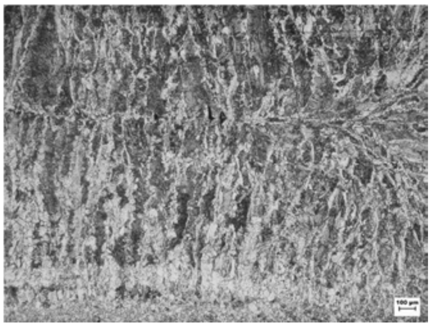


Fig. 14. *Microstructure of weld nugget; steel sheet of thickness 1.5 mm.*

Figure 15 shows cavities in the weld nugget of sample with the steel sheets of 2.5 mm thickness. The cavities occurred due to shrinkage of weld metal during the solidification process. These defects led to the failure mode through weld nugget in a tensile test.

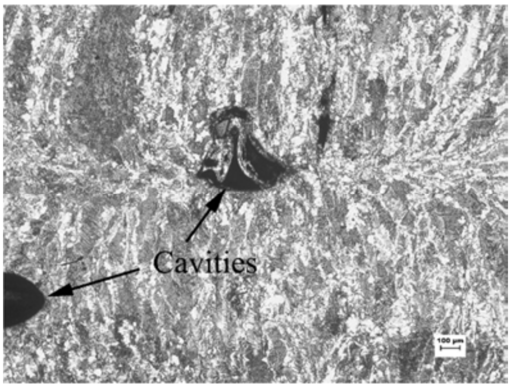


Fig. 15. *Cavities in microstructure of weld nugget; steel sheet of thickness 2.5 mm.*

The metallographic observation of clinched joints confirmed the creation of the high-quality clinched joint with the characteristic mechanical interlocking area (Figure 16). Characteristic deformation structure of joined materials in the interlocking area and the bottom of the clinched joint was observed as well. No internal defects occurred in the clinched joint.

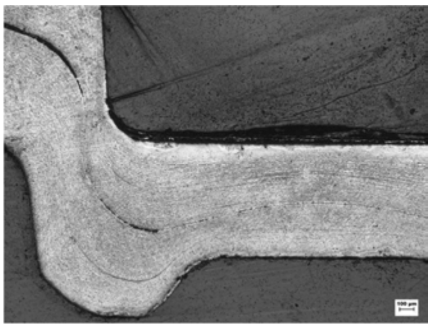


Fig. 16. *Interlocking are of clinched joint with sheet of thickness 1.5mm.*

4. Conclusion

Clinching as a relatively new method of joining have become more and more popular during the last decades as the plastic press joining method in sheet metal construction assembly. Clinching does not use any kind of appending joining components.

On the basis of the conducted experiment, the following conclusions can be formed:

a) The clinching is suitable method for joining the tested materials S250GD (1.5 mm as well as 2.5 mm).
b) The maximum values of load-bearing capacity were measured in the spot welded samples, in both thicknesses of the joined steel sheets.
c) The values of load-bearing capacity of riveted joints and clinched joints were approximately at the same level in joining the materials of thickness 1.5 mm.
d) In joining materials of thickness 2.5 mm, clinched joint reached higher load-bearing capacity values than riveted joints. The riveted joints reached about 58% of the load-bearing capacity of clinched joints.

The resistance spot welding appears to be the best method of joining of observed steel sheets. Unlike clinching and riveting, it is necessary to clean the surfaces of the joined materials before spot welding. In comparison to resistance spot welding, utilizing the clinching as cold joining method significantly reduces the time required for joining process, consumes less power and doesn't destroy surface protective layer. The utilizing of the clinching in comparison to riveting reduces the time required for the joining of the steel sheets, since it is unnecessary to drill holes for rivets.

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References

[1] A. Chrysanthou and X. Sun, Self-piercing riveting, Woodhead Publishing: Cambridge, 2014.

[2] V. B. Bhandari, Design of Machine Elements, 3rd ed. Tata McGraw-Hill: New Delhi, 2010.

[3] P. S. Wei and T. H. Wu, "Electrical contact resistance effect on resistance spot welding", International Journal of Heat and Mass Transfer, vol. 55, 2012, pp. 3316-3324.

[4] Ľ. Kaščák, J. Mucha, J. Slota and E. Spišák, Application of modern joining methods in car production, Oficyna Wydawnicza Politechniki Rzeszowskiej: Rzeszów, 2013.

[5] Ľ. Kaščák and E. Spišák, "Effect of welding parameters on the quality of spot welds combining AHSS steel and HSLA steel", Key engineering Materials, vol. 586, 2014, pp. 162-165.

[6] I. Sevim, "Effect of hardness to fracture toughness for spot welded steel sheets", Materials and Design, vol. 27, 2006, pp. 21-30.

[7] M. Lifang, et al., "Comparative study on CO_2 laser overlap welding and resistance spot welding for galvanized steel", Materials and Design, vol. 40, 2012, pp. 433-442.

[8] H. Zhang and J. Senkara, Resistance welding: Fundamentals and Applications, Taylor and Francis: New York, 2006.

[9] X. Q. Zhang, G. L. Chen, Y. S. Zhang, "Characteristics of electrode wear in resis-tance spot welding dual-phase steels", Materials and Design, vol. 29, 2008, pp. 279–283.

[10] T. Jiang, Z. X. Liu, and P. C. Wang, "Effect of aluminum pre-straining on strength ofclinched galvanized SAE1004 steel-to-AA6111-T4 aluminum", Journal of Materials *Processing Technology*, vol. 215, 2015, pp. 193–204.

[11] C. Chen, et al., "Mechanical properties of the two-steps clinched joints with a clinch-rivet", Journal of Materials *Processing Technology*, vol. 237, 2016, pp. 361–370.

[12] J. Mucha, Ľ. Kaščák and E. Spišák, "Joining the car-body sheets using clinching process with various thickness and mechanical property arrangements", Archives of civil and mechanical engineering, vol. 11, 2011, pp. 135-148.

[13] Y. Abe, T. Kato, K. M and S. Nishino, "Mechanical clinching of ultra-high strength steel sheets and strength of joints", Journal of Materials *Processing Technology*, vol. 214, 2014, pp. 2112–2118.

[14] C. J. Lee, J. Y. Kim, S. K. Lee, D. C. Ko and B. M. Kim, "Parametric study on mechanical clinching process for joining aluminum alloy and high-strength steel sheets", Journal of Mechanical Science and Technology, vol. 24, 2010, pp. 123-126.