Study of Round and Square Mechanical Clinching Joint Strength for SPCC Steel and Aluminium Alloy 5052 Sheet Metal

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Abstract. Round mechanical clinching is commonly used in joining sheet metals. In this research, round and square clinching joints strength were carried to study the strength of both clinching joints. SPCC steel and aluminium alloy 5052 were used for evaluation in the experiments. These materials were clinched with different punch loads by using round and square clinching dies of same geometry parameters. Shearing test and peeling test were performed to study the round and square clinched joint strength. Failure mode of the joints were examined. Optimal forming load for the clinched joint were investigated and higher forming load will lead to defects. The experimental results show that the square clinched joint is 5%–70% stronger than conventional round clinched joint but the square joint strength in peeling test for the SPCC steel is 49% weaker.

1 Introduction

The weight of automobile is preferred to be reduced in order to reduce the cost, consumption of fuel and emission of carbon dioxide. Besides welding, riveting and hemming, clinching process is commonly used in joining parts in automobile [1] and electrical devices [2]. The main tools used in the process are a punch, a die, a holder and a press. The principle of this process is by applying force to plastically deform the sheet metals and create an interlock to joint these sheet metals together. This process can join two steel of material together without adding a joining element like rivet and is able to join dissimilar materials such as joining aluminium and steel [3]. Other advantages include damage of this process to surface coating of the workpiece is relatively small and less energy required in the process when compared to spot welding and self-pierce riveting. Common clinching process are round and rectangular clinching [4]. The main parameters which will affect the joint strength are neck thickness, interlock thickness and material properties [5]. This joining method was normally applied on low density

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metal or alloy with high ductility. However, mechanical clinching can also be used on joining ultra-high strength and low ductility steel by modifying the clinching punch size and the die width and depth to control the metal flow to avoid defects during the clinching process [6]. Joint strength of two ultra-high strength steel sheets can be further increased by using a two-stage clinching process [7]. Aluminium alloy sheet of square and rectangular mechanical clinching joint strength were studied and it was found that the rectangular clinched joint is stronger than square clinched joint [8]. Even though the static joint strength of a resistance spot welding joint is higher than mechanical clinching, but mechanical clinching has a higher fatigue limit than a resistance spot welding joint [9]. In this research, the round and square clinched joints strength were investigated by experiment to serve as a reference for the design in selecting suitable clinching tools to optimize joint strength.

2 Experiment Setup and Joint Strength Evaluation

Sheet metal of aluminium alloy A5052 with 1.25 mm thickness and SPCC cold rolled steel with 1.00 mm thickness were used in this research. The mechanical properties of the materials are shown in Table 1 for comparison purpose. Figure 1 shows the shape and dimensions of upper punch and lower die used for the mechanical clinching experiment, both round and square clinching tools are having the same cross section dimensions. Forming load of 15 kN–55 kN was applied to clinch the sheet metals.

Table 1. Material properties and blank thickness

Materials	Thickness (mm)	Tensile strength (MPa)	Flow stress (MPa)	Elongation (%)
SPCC steel	1.00	309	$\bar{\sigma} = 390\ \bar{\varepsilon}^{0.17}$	25
A5052	1.25	241	$\bar{\sigma} = 354\ \bar{\varepsilon}^{0.16}$	8

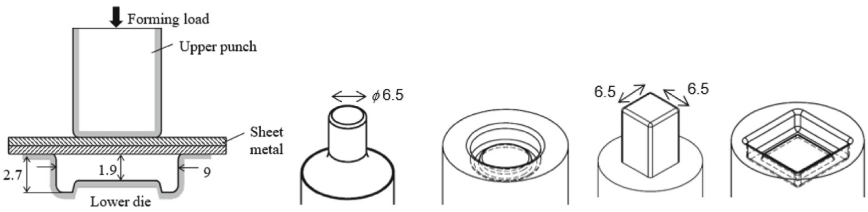


Fig. 1. Round and square clinching tools with same cross-section geometry

Tensile tests were tested on a universal testing machine at 2 mm/min and at room temperature to evaluate the round and square clinched joints strength. Based on Japanese Industrial Standard Committee, two type of loading mode (see Fig. 2), i.e., peeling test and tension-shearing test are considered for the evaluation. The maximum force in peeling test, F_o and tension-shearing test, F_s were measured until the clinched joint failed.

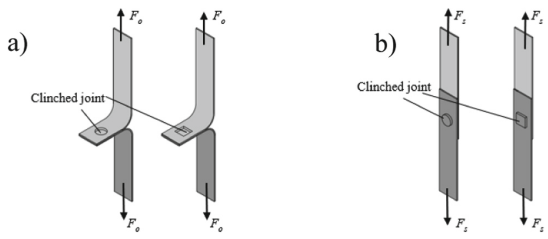


Fig. 2. Joint strength tests a) peeling test, b) shearing test

3 Results and Discussion

Figure 3 (a) and (b) show the graph of forming load vs punch stroke for round and square clinching process respectively. It was found that square clinching required higher forming load to produce the same measure of bottom thickness for both materials. This is because the cross sectioned area of a square punch has larger contact surface than a round punch. Figure. 4 (a) and (b) show the punched shape from the top and bottom view for round and a square clinched joint.

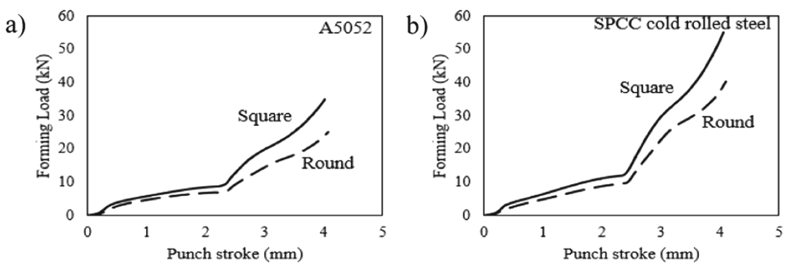


Fig. 3. Forming load vs punch stroke for round and square clinching a) A5052, b) SPCC steel

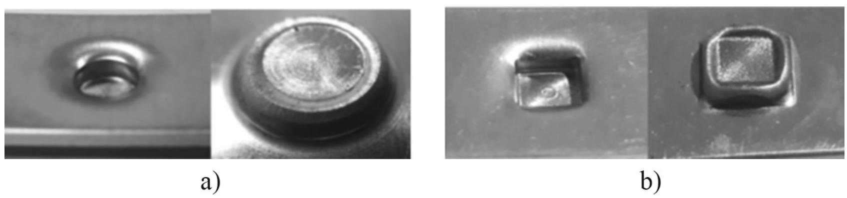


Fig. 4. Clinched joints from experiment a) round, b) square clinched joint

Figure 5 (a) and (b) show the strength for shearing and peeling test for round and square clinched joints produced by different forming load in clinching process for A5052 sheet metal respectively. Clinched joints are formed after 18 kN for round clinched joint and 25 kN for square clinched joint. When forming load increased to 30 kN on the round clinching specimen, crack can be observed on the neck of the round clinched joint because too much of plastic deformation take place at this location (see Fig. 7(a)).

As there is defect on the clinched joint, therefore the joint strength at 30 kN forming load drops drastically. However, both peeling and shearing tests show that the square clinched joint exhibits stronger than round clinched joint. This is because of the neck and interlock formed along the perimeter of a square clinched had larger areas than of a round clinched joint, therefore it can resist larger external load. In shearing test (see Fig. 5(a)), the forming load to produce maximum joint strength for square and round clinched joint is 25 kN. At this forming load, square clinched joint is stronger than round clinched joint by about 70%. Hence, the square clinch joint shows stronger joint strength to resist shear force than round clinched joint for A5052. Figure 5(b) also shows that the optimal peeling joint strength is achieved at 25 N of forming load. Square clinched joint is stronger than round clinched joint by about 42%.

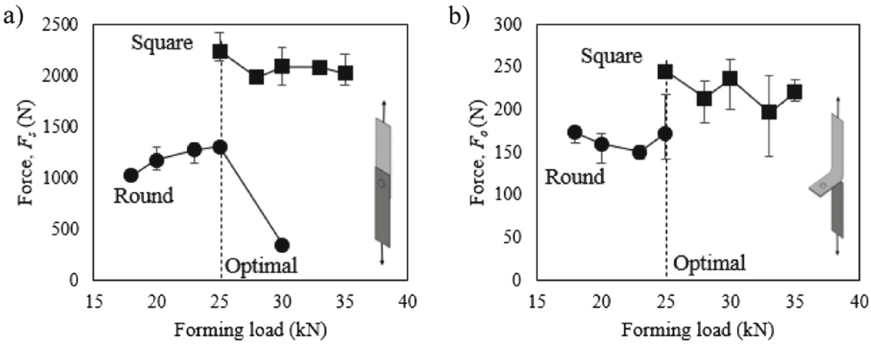


Fig. 5. Joint strength of A5052 a) shearing test, b) peeling test

Figure 6 (a) and (b) show the joint strength in shearing and peeling test for round and square clinched joint produced by different forming load in clinching process for SPCC cold rolled steel sheet metal respectively. In Fig. 6(a), round clinched joint exhibits stronger joint strength than square clinched joint at lower forming. The optimal forming load to obtain maximum shearing joint strength for round and square clinched joint is 50 kN and 55 kN respectively. Meanwhile, maximum shearing joint strength for round and square clinched joint is 1881 N and 1984 N. Square clinched joint exhibits stronger joint strength than round clinched joint by about 5% in shearing mode. From Fig. 6(b), the optimal forming load to produce maximum shearing joint strength for round and square clinched joint is 50 kN and 53 kN respectively. Square clinched joint has peeling joint strength of 378 N and round clinched joint has peeling joint strength of 565 N when the optimal forming load is applied to form the clinched joint. Hence, the round clinched joint had relatively stronger joint strength than square clinched joint for SPCC steel by about 49% in peeling mode.

From Fig. 7 (b) shows the SPCC cold rolled steel round clinched joint specimen that formed after 55 kN forming load. It was observed that material flow backward causing thinning at the bottom. This phenomenon leads to the joint strength drop after 55 kN. Therefore, further increase the forming load will not strengthen the joint but weaken it.

Figure 8 shows the types of failure mode on the peeling and shearing test for both materials were observed from the joint strength test. It was found that all the A5052

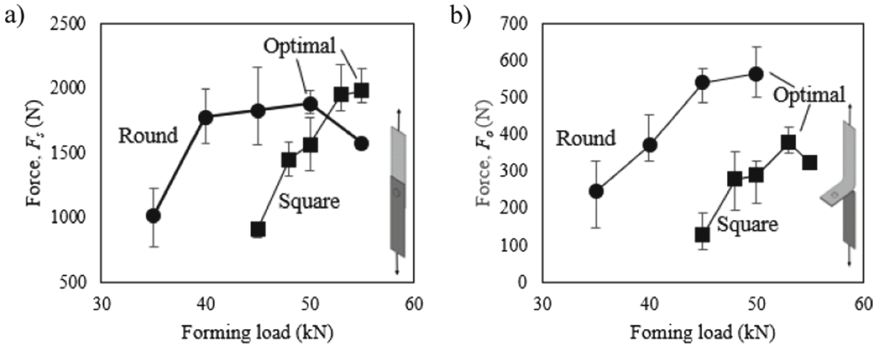


Fig. 6. Joint strength of SPCC steel a) shearing test, b) peeling test

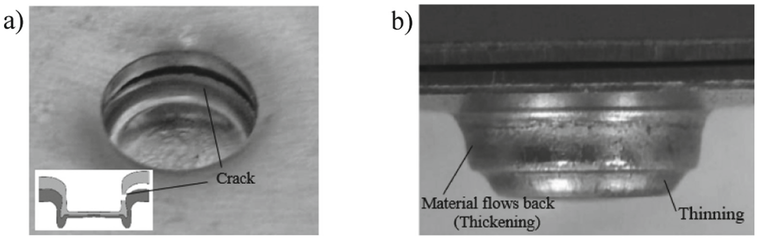
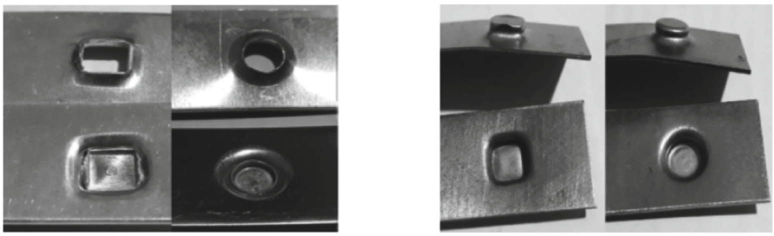


Fig. 7. Round clinched joint defects at high forming load a) A5052, b) SPCC steel

clinched joint specimens failed at the neck region due to insufficient of neck thickness and low ductility. On the other hand, button separation failure mode was found for all the SPCC cold rolled steel clinched joint specimens due to insufficient of interlock to hold the upper and lower sheet metals. Higher forming load should be applied on SPCC cold rolled steel for larger interlock formation but it was limited to 55 kN to avoid the punch from failure.



(a) Neck fracture for A5052 (b) Button separation for SPCC steel

Fig. 8. Failure mode

4 Conclusion

The present research is intended to provide a reference on the behaviour of joint strength by considering the tool shape for mechanical clinching. From the results of shearing and peeling tests, square clinched joint is 70% and 42% respectively stronger than conventional round clinched joint for A5052. For SPCC cold rolled steel, the square clinched joint is 10% stronger than round clinched joint in shearing but 49% weaker in peeling mode.

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