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Optimization of a reshaping rivet to reduce the protrusion height and increase the strength of clinched joints

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ABSTRACT

Conventional mechanical clinching attracted more and more attentions in recent years, but the application of mechanical clinching might be restricted because of the exterior protrusion above the sheets which could affect the performance of clinched joint. In order to reduce the protrusion height and increase the strength of clinched joints, a new method using a reshaping rivet to reshape the clinched joint was proposed in this paper. In the reshaping process, the reshaping rivet was embedded in the clinched joint, then the protrusion was compressed in a single stroke with a pair of flat dies. Finite element simulation and orthogonal design were used to optimize the geometrical parameters of the reshaping rivet in terms of cross-tension strength. The best combination of geometrical parameters of the reshaping rivet was gotten by simulating 25 groups of different combinations. Static strengths of the joints before and after reshaping were compared experimentally to validate the performance of the reshaping method. In the experiment, the protrusion height of the joints was reduced to 1.0 mm. The average cross-tension strength and tension-shearing strength were increased from 957.9 to 1154.9 N and from 1229.4 to 2757.3 N respectively.

1. Introduction

In order to reduce the weight of automobile body, many lightweight materials like aluminum alloys and magnesium alloys are adopted. The use of aluminum alloy and magnesium alloy is more and more because of their low density, anticorrosion and excellent machining performance. As these new materials cannot be joined effectively by traditional connecting techniques like spot welding, one of alternative joining technologies is mechanical clinching which can be used to join sheets firmly by generating an undercut (Varis, 2006). It can be used to join aluminum alloys, magnesium alloys, coated and different material sheets.

Some methods for optimizing the clinching tools and investigating the influence of process parameters were proposed in recent years. Roux and Bouchard (2013) optimized a clinched component using the efficient global optimization (EGO) algorithm based on Kriging meta-model. Oudjene and Ben-Ayed (2008) used Taguchi method to investigate the influence of clinching tool geometry on the clinched joint characteristics: maximum separation force, neck thickness and undercut. Abe et al. (2012) discussed the method of mechanical joining of high strength steel and aluminum alloy sheets by optimizing the shapes of clinching tools to control material flow.

Conventional mechanical clinching technology has many advantages, e.g., no damage on surface, no light and smoke, no pre-punching, energy saving and environmental protection. However, the most obvious disadvantage of conventional clinched joint is the exterior protrusion above the sheets which could affect the wide use of mechanical clinching technology. Because of the protrusion which results in a bump jutting out of the sheet, conventional clinching technology cannot be used for visible areas where relatively flat surface is needed. In order to reduce the protrusion height, some improved clinching technologies were proposed.

Neugebauer et al. (2007) investigated a new technology named dieless clinching which can form lower protrusion using a flat anvil. Nevertheless, the movement and force of the punch must be precisely controlled during the joining process which increases the complexity and cost of the devices. Gerstmann and Awiszus (2014) introduced a new method named flat-clinching to create a one-sided planar material plane which does not show the obvious protrusion. The tension-shearing strength of the flat-clinching is higher than the conventional clinching. However, a higher blank-holder force is needed in the process of flat-clinching. Wen et al. (2014) proposed a new method to reduce the protrusion height of

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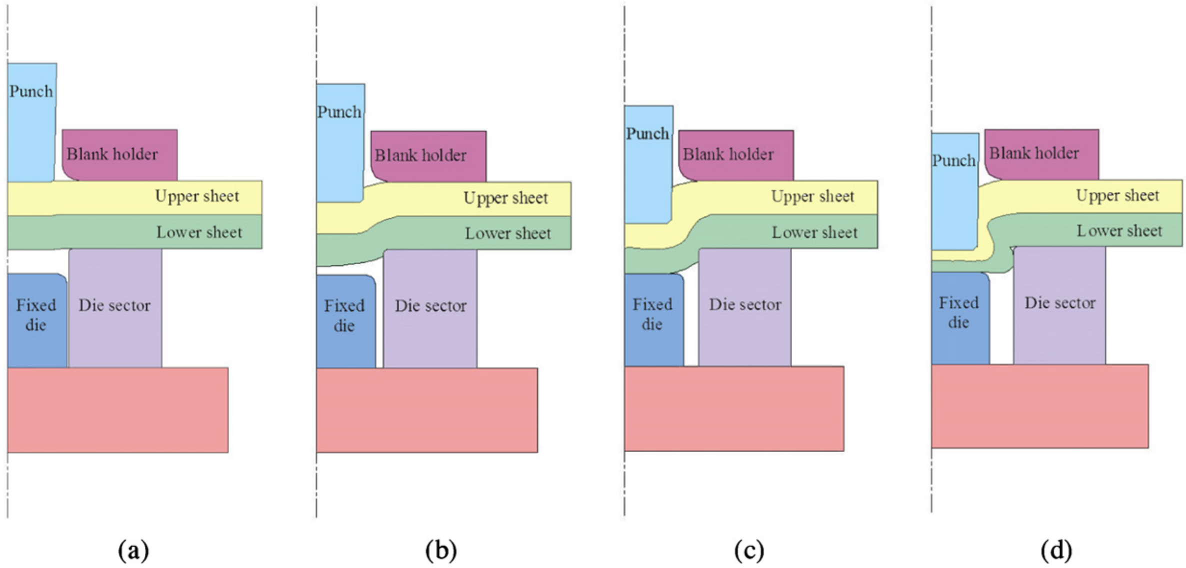

Fig. 1. Mechanical clinching process with extensible dies.

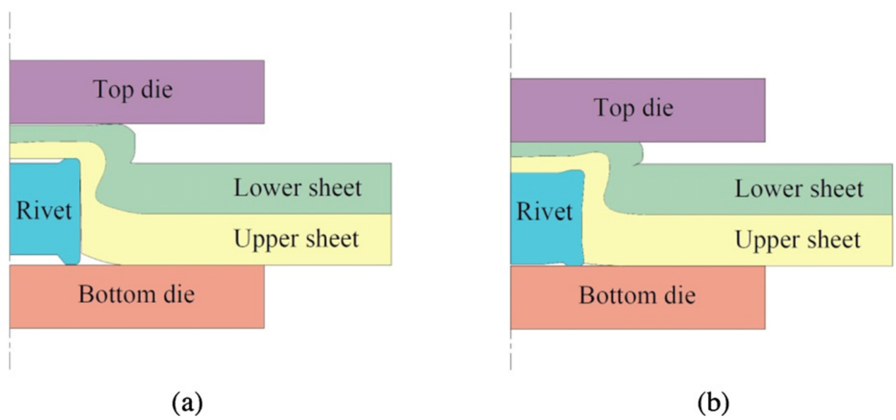

Fig. 2. Reshaping process.

clinched joint with a pair of reshaping tools on CMT6305 testing machine. In his study, the protrusion height was reduced from 1.7 to 0.68 mm, while the cross-tension strength was increased from 230.8 to 331.4 N, and the tension-shearing strength was increased from 559.7 to 657.5 N. Even so, special reshaping tools which may increase the cost of production are required in the reshaping process.

In the current study, a new method to reduce the protrusion height and increase the strength of clinched joints was presented by simply utilizing a reshaping rivet to control plastic deformation of the clinched joint. This new reshaping method will be used in the automobile body. There is an outer packing outside the car frame. The distance between them is no more than 1.0 mm. So the protrusion height is reduced to 1.0 mm in this study. The reshaping method can be a helpful supplement of conventional mechanical clinching. Geometrical parameters of the reshaping rivet were optimized using the commercial finite element analysis software Deform-2D and then validated by the experiment. The reshaping method using a rivet can be used in the place where a higher strength and a lower height of the joint are needed.

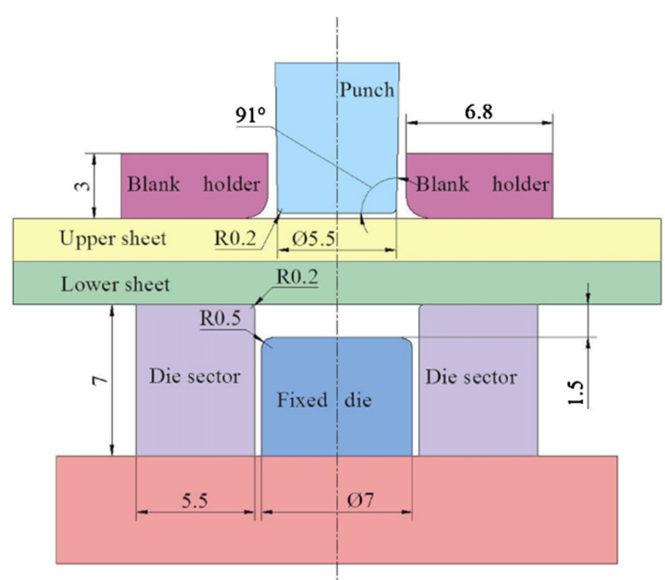

Fig. 3. Basic geometry of the extensible dies.