Mechanical Clinching Technology of the Lightweight Sheets

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Abstract: Aluminum alloy, magnesium alloy and other lightweight materials have been widely used in the lightweight body. The mechanical clinching does not require additional parts and is a kind of green connection technology, which has a broad development prospect in connecting lightweight materials. The scholars have studied the process about this technology and have put forward some reliable connection methods. In this paper, these methods are classified into two types according to the movement forms of the punch is vertical or composite in the clinching process. The working principle and characteristics of the typical methods of each type are mainly described in detail.

1 INTRODUCTION

In recent years, various kinds light materials (such as aluminum alloy, magnesium alloy, composite material and plastic) have been widely used in automobile manufacturing with the development of automobile light weight technology. There are many ways to connect these different materials, such as self-pierce riveting, mechanical clinching and friction stir welding. The mechanical clinching technology is very suitable for connection sheets of dissimilar materials by the plastic deformation of the sheet to create mechanical interlock to realize the connection without pre-treatment, with high production efficiency, simple operation and good forming effect of the joints. It has broad development prospects in the manufacture of lightweight car body. For improving the strength and quality of the joint, some researchers have carried out correlative studies on this technology and many connection methods are proposed.

These methods are classified into two types: single-action clinching and multi-action clinching, according to the movement forms of the punch during the clinching process. The working principle and characteristics of the typical connect methods of each type are mainly described in detail.

2 SINGLE-ACTION CLINCHING

Single-action clinching is that the movement of punch is single direction during the clinching process, it mainly includes dieless clinching, flat clinching, hole clinching etc.

2.1 Dieless Clinching

The principle of dieless joining by forming should be explained in detail in Figure 1 (Neugebauer, 2007). The components required for joining are the punch, clamp, the upper sheet, the lower sheet and the flat anvil. Firstly, these two sheets to be joined are lying partially overlapped on the flat counter tool. After that, for forming the clamp and the punch move towards the sheets, the clamp gets into contact to the upper sheet and a limited pressure is applied without deforming. Then the punch is pressed into the sheets with a high force. The material of the sheets is displaced partially and flows in the opposite direction to the movement of the punch, thereby pushing the clamp upwards. Thus an elevation is formed on the downside of the bottom sheet. The size of this elevation is increasing the further the punch is pressed into the sheets. As soon as the material of the upper sheet has come into contact with the shoulder of the punch, the material flow against the movement of the punch is stopped. Finally, when the punch is pressed even further, the elevation at the downside of the bottom sheet is flattened and the material displaced by the punch is

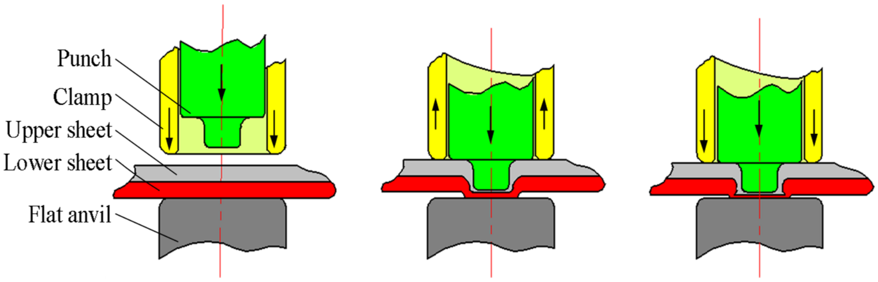

Figure 1: Principle of dieless clinching.

forced to flow in radial direction, thus forming an interlock between the sheets. Compared to joining by forming processes with a contoured die, dieless joining has the following features (Neugebauer, 2005): the wear of mold is low, the accuracy of the joining equipment is less, and don't require alignment, the process reliability is high, but the joining force is higher and the combined thickness of the connected sheets is limited.

2.2 Flat Clinching

Figure 2 shows the process of flat clinching (Neugebauer, 2007). The flat clinching is based on the same principle as dieless clinching. The components required for joining are the punch 1 , blank holder 2 , joint sheets 3and 4, the flat anvil 5. Firstly, the two joined sheets are placed up on a flat anvil. Afterwards, the blank holder moves down and fixes the sheets in place. Subsequently, the punch moves down and forms the material to establish the characteristic interlocking within the total material thickness.

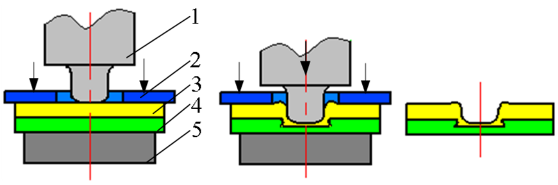

Figure 2: Principle of flat clinching.

In contrast to other clinch connections, the material flow is opposite to the punch movement during the process, a one sided planar connection is created that does not show the die-sided protrusion reaching out of the material plane, so the flat clinching can be used for the connection of metal sheets to nonmetal sheets.

2.3 Hole Clinching

Schematic diagram of hole-clinching as shown in Figure 3 (Chan-Joo, 2014), it is similar with the process of flat clinching. The parts for the connection are the punch 1, the holder 2, the upper sheet 3, the lower sheet 4 and the die 5 with the circular groove. In the hole-clinching process, the ductile material is positioned uppermost and the brittle material-into which a hole is formed is positioned below that. At first, the holder presses the upper sheet, and the upper sheet is squeezed into the gap between the punch and the lower sheet. when the upper sheet contacts the die bottom, it is indented into a die cavity through the hole in the lower sheet and spread out to fill the cavity in the die to form geometrical interlocking.

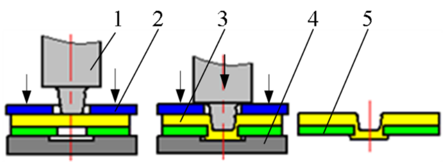

Figure 3: Schematic diagram of hole-clinching process.

The hole-clinching is suitable for joining different sheet in mechanical properties, but the material with reduced formability on the die-side must be pre-punched and the costs would increase; there are protrusions at the joints and joints cannot be created if the lower sheet is too thick.

2.4 Flat Hole-Clinching (FHC)

The principle of flat hole-clinching as shown in Figure 4 (Tong, 2016). The flat is based on the same principle as hole-clinching. It is different from the hole-clinching, the hole of the flat hole-clinching is stepped or inverted conical, there are not protrusions at the joints too. This technique is fit for connecting two layers of metallic sheets with dissimilar materials and thicknesses by adding additional parts to adjust the depth of the hole.

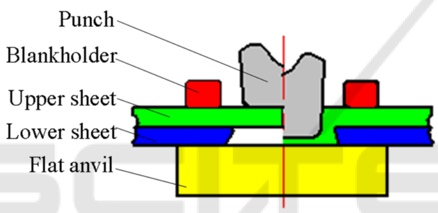

Figure 4: The principle of flat hole-clinching.

2.5 Injection Clinching

A detailed illustration of the injection clinching process is shown in Figure 5 (Abibe, 2011). For the material flowing during the process, there is a round cavity at the bottom of the blank holder, a gap between the hole and the stud that the lower plate with a deformation element (normally a cylindrical or cone stud). firstly, the joined sheets are assembled together, inserted into the hole of the upper sheet, the blank holder moves down and clamps the joined plates with designed pressure; Afterwards, the punch moves down to the plates and applies forming pressure on the stud, to force it into the cavity in the blank holder and the upper plate's hole; then the forming pressure is maintained to fully fill the round cavity and gap; finally, the punch retracts and the joint is formed.

In This technology creates a rivet by using part of the structure itself, resulting in weight savings and improved mechanical reliability. It is suitable for the connection between metal to metal, metal to non-metallic material (e.g. metal and thermoplastic material).

2.6 Hydro-Clinching

Figure 6 shows the forming process of hydro-clinching (Neugebauer, 2008), it is made up of the punch 1, hydroforming tool 2, jointed sheet 3, hydroformed sheet 4 and fluid 5. Firstly, the hydroformed sheet and the jointed sheet are brought in contact to the hydroforming tool by the fluid. During calibration the fluid works as a punch to press the hydroformed sheet through a hole in the jointed order to avoid bursting and to ensure a higher forming level at the produced protrusion, the punch is withdrawn. Subsequently, the punch is set towards the high pressure fluid. Because the back forming is prevented by the high pressure fluid, the material that has been pressed through the hole is spread and formed an interlock at the chamfering of the connected sheet. During joining process, the punch is not moving, the interlock forms automatically at the hole chamfering of the joined sheet when the hydroformed sheet is pushed through the hole.

The hydro-joining process decreases the number of processing steps and can join in complex hydroformed units and inaccessible places, but the device needs to be sealed and higher pressure when connecting thick sheets.

2.7 Roller Clinching

The schematic setup for rolling clinching is depicted in Figure 7 (Daniel, 2014).

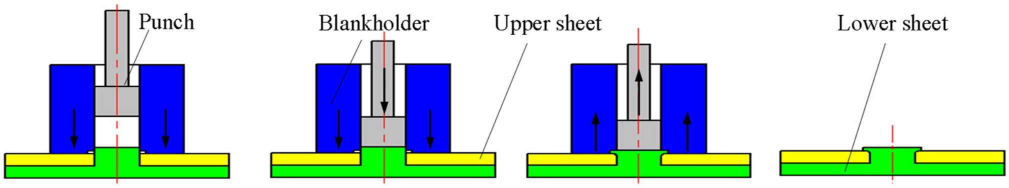

Figure 5: The stages of the injection clinching process.

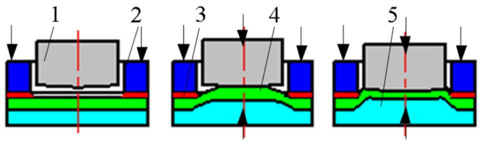

Figure 6: The forming process of hydro-clinching.

The movement of punch is only rolling. Punches and dies are mounted on contrariwise rotating rolls. During clinching, the punch roll and die roll rotate contrariwise, with the angular velocity and the sheet is continuously fed through the rollers. A spring-suspended blank holder prevents the material from an extrusion out of the die cavity. It ensures a proper separation of the obtained clinching point from the tools. This process can be divided into four distinct phases: initial contact, drawing phase, forming the undercut and retraction.

The rolling radius have significant influence on the joint formation and therefore on the joint's mechanical properties for the employed material combinations, and the variation of the rolling radius will result in an symmetry of the neck or the undercut.

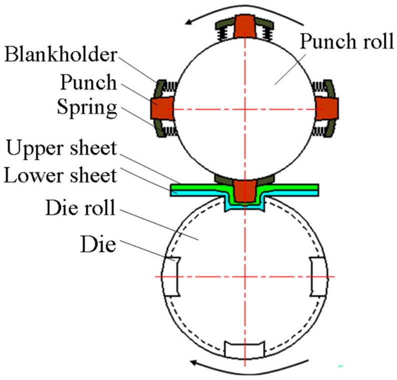

Figure 7: The schematic setup for roller clinching.

3 MULTI-ACTION CLINCHING

The multi-action clinching is that the movement of punch is multy during the clinching, there are rotational motion and vertical motion and so on. It mainly cludes friction clinching and spinning clinching.

3.1 Friction Clinching

The friction clinching is that the punch rotates at a given speed and plunges the material (under load control) up to reaching a given depth; then, the punch is retracted up to the initial position to finish the clinching, as shown in the Figure 8 (Lambiase, 2017). Due to the rotation of the punch, so the friction between the punch and the connected sheet material is produced, that the connecting plate is heated and the join-ability is greatly improved.

The friction clinching can be used on highly reflective materials (such as aluminum and copper alloys), the heating is confined in the joint position so the plunging force is dramatically reduced, and the development of cracks in the aluminum alloy was delayed or even avoided.

3.2 Spinning Clinching

The principle of spinning clinching is shown in Figure 9 (Zhi-chao, 2011). It is composed of the punch 1, blankholder 2, upper sheet 3, lower sheet 4 and die 5. The punch turns around the axis in an acute angle continuously and vertically downward to exert pressure on the sheet to form interlock during the clinching process. Compared with the ordinary clinching, the spinning clinching has the advantages of larger interlock value, smaller forming load and higher efficiency, but the joint exists an asymmetry.

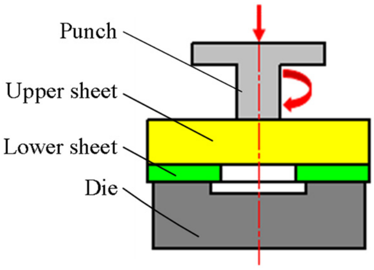

Figure 8: The principle of friction clinching.

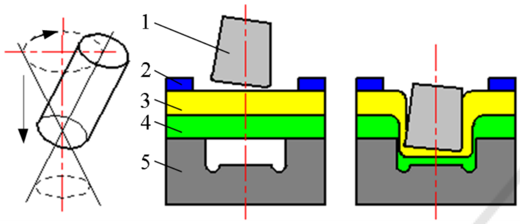

Figure 9: The principle of spinning clinching.

4 CONCLUSIONS

In addition to the above the mechanical clinching technology of the sheet, there are some other auxiliary connection technology, such as ultrasonic assisted clinching , laser clinching, vibration assisted clinching, etc. The main purpose of these methods are to increase the strength of joint, to improve the connection quality and decrease the forming force and to join the different sheets. No matter what kind of methods, the strength of joint has a great relationship with the geometry of clinched joint, while the technological parameters, geometric parameters and material flow have important effects on the joint shape and size, therefore, it is necessary to find some new connection methods to further research by using numerical simulation calculation and experimental method.

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REFERENCES

1. Neugebauer R., Reimund Neugebauer, Dietrich S., Kraus C., 2007. Dieless clinching and dieless rivet-clinching of magnesium. Key Engineering Materials.
2. Neugebauer R., Mauermann R., Dietrich S., 2005. Chances and challenges in joining by forming with flat a counter tool. Advanced Materials Research.
3. Neugebauer R., Reimund Neugebauer, Dietrich S., Kraus C., 2007. Joining by Forming With a Flat Counter Tool – a New Way of Joining Magnesium Components. Materials Science Forum.
4. Chan-Joo L., Jung-Min L., Ho-Yeon R., et al, 2014. Design of hole-clinching process for joining of dissimilar materials Al6061-T4 alloy with DP780 steel, hot-pressed 22MnB5 steel, and carbon fiber reinforced plastic. Journal of Materials Processing Technology.
5. Tong W., Qian H., Qing L., et.al, 2016. Joining different metallic sheets without protrusion by flat hole clinching process.Internationa Journal Advanced Manuf acutoryTechnology.
6. Abibe AB, Amancio-Filho ST, Dos Santos JF, et al, 2011. Development and analysis of a new joining method for polymer-metal hybrid structures. Journal Thermoplast Composite Mater.
7. Neugebauer R., Mauermann R., Grützner R., 2008. Hydrojoining. International Journal of Material Forming.
8. Lambiase F., Paoletti A., Di Ilio A., 2017. Advances in Mechanical Clinching Employment of a rotating tool. SHEMET17, 17th International Conference on Sheet Metal, Procedia Engineering.
9. Zhi-chao H., Zu-feng Q., Lian-hong P., Jia-mei L., 2011. Comparison of Numerical Simulations Between Spin Clinching and Ordinary Clinching. Coal Mine Machinery. (In Chinese)
10. Daniel R., Maria W., Hartmut H., 2014. Simulation Assisted Analysis of Material Flow in Roller Clinched Joints. Advanced Materials Research.