Experimental Testing of Clinched Joint

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Abstract: This work concerns with the shear testing of clinched joint used for connection of two painted sheet metal parts. The set of six specimens was used to obtain the force-displacement characteristic and to identify properties of the joint that are used for the following work including usage of advanced calculation and simulation methods.

Keywords: Clinched Joint; TOX-Joining System; Tensile Test; Strength of the Joint.

1 Introduction

Nowadays many products in a variety of industries are made of sheet metal plates using different forming operations. Many products have final shape after the forming process. However, many semi-finished thin-walled products need to be assembled or integrated into final complex assembly. Therefore suitable joining methods for thin-walled metal are needed. The joining technologies may be divided into four major categories: welding, joining with aid of consumables, adhesive bonding and joining by forming. The last mentioned category relies on forming of the base material to establish the connection and clinching represents one of these technologies. TOX-Joining System is possible industrial application of such joints (see Fig. 1). This joining method is used in many branches of production, especially where the fast, cheap and reliable connection of thin sheet-metal plates is needed. Automotive industry, HVAC, appliance manufacturing or electrical enclosures represent some main examples of clinched joints applications.

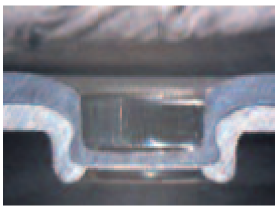


Fig. 1: TOX-Round Joint, [1].

2 Properties of the Clinched Joint

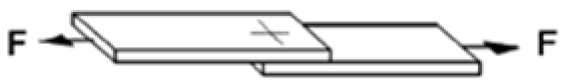
The clinching joining technology is based on local plastic deformation of the base material, so no additional consumables such rivets are needed. The principle of the connection is to create interlock between the thin sheet-metal parts using relatively simple tools comprising from a punch and a die (see Fig. 1). The punch draws the material into the die and the material is pressed resulting the creation of the mechanical interlock.

Many advantages of the clinched joint technology may be mentioned, for example:

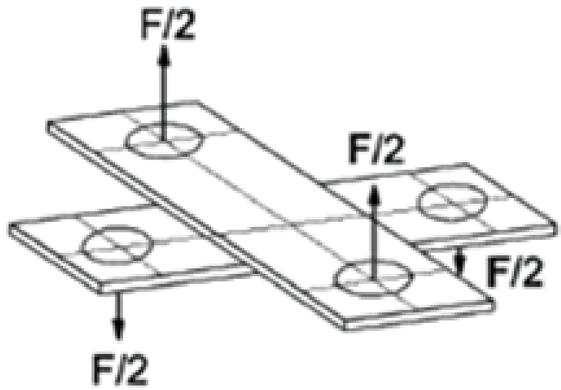
- no additional binding material is needed,
- clean technology (no harmful fumes, burrs, sparks, or dirt),
- fast, economic technology,
- possibility to connect dissimilar materials, pre-painted, coated, or multiple layers of material.

3 Testing and Measurement

The properties of the clinched joints are obtained using simulation methods or experimental testing. The quasi-static mechanical behaviour of the clinched joints may be tested by a single lap shear test (Fig. 2a) when the shear strength of the joint is obtained. Another often used experimental identification of the properties is by cross-tension test for measuring the pull-out strength (Fig. 2b). The pull-out strength is the maximum force in the axial direction of the clinched joint. In general, the shear strength of the clinched joint is stronger than pull-out strength.



(a) determination of Shear Strength



(b) determination of Pull-out Strength

Fig. 2: Test samples and test configuration for experimental testing of clinched joint.

3.1 Failure Modes of the Clinched Joints

When the clinched joint is pull-out loaded three general failure mechanisms may be distinguished [4]: failure by deformation, failure by fraction in the neck of the joint, combination of deformation and fracture. There are different failure mechanisms during the single lap shear test, depending mainly on the geometry of the test specimen, the combined materials and the geometry of the joint [4]. The first failure mode is characterized by plastic deformation without any visible fracture (unbuttoning of the joint). The local fracture in the neck of the joint occurs in the second failure mode.

3.2 Experimental Testing

The set of six specimens was loaded by quasi-static tension according to the Fig. 3. As the controlled variable, the deformation with constant velocity was used, the reaction force was detected.

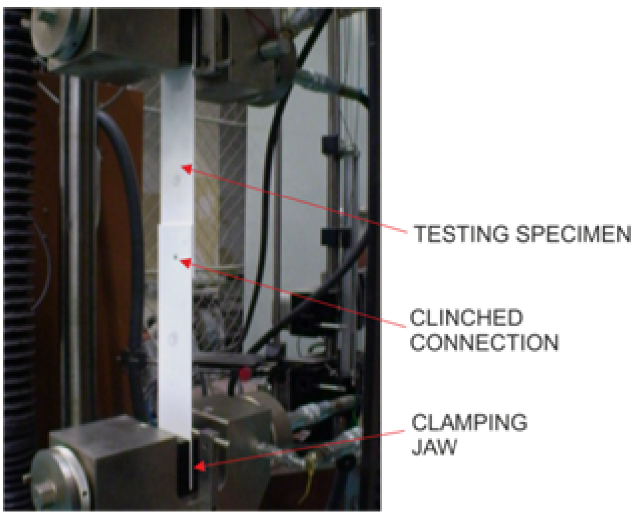


Fig. 3: Test configuration.

The specimens were made of coated sheet-metal plates with a cross-section 60 × 3 mm that were clinched by TOX-joint with outer diameter of 10 mm (Fig. 4).

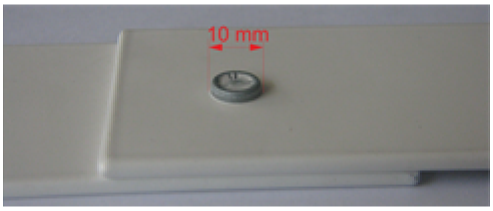


Fig. 4: Tested specimen (clinched joint).

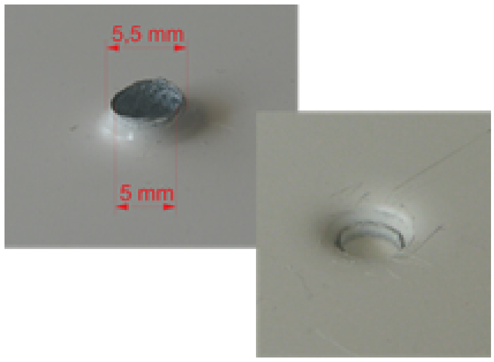


Fig. 5: Fracture of the clinched joint.

4 Measured Data Interpretation and Processing

Graphical interpretation of measured data, i. e. force-displacement curve, is shown in Fig. 6. The first part of the curve (I) can be described as elimination of clearances (e.g. in the clinched joint or other mechanical clearances). The following part of the curve (II) that has linear character shows the main behaviour of the clinched joint. Using linear regression we get parameters of the straight line and the slope of the line gives information about the rigidity of the joint. The correlation coefficient of such linear regression R^2 is approximately 0.99. The last part of the curve (III) is characterized by creep followed by plastic deformation of the material and final fracture of the clinched joint.

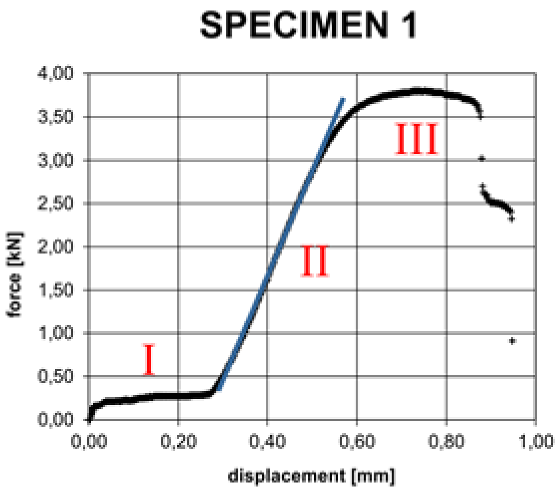


Fig. 6: Force-Displacement characteristic.

The result maximum force (shear strength of the joint) was obtained and was used for the computation model of "real" shear stress in the joint in the moment of the fracture. For the reason of simplification and basic stress analysis in the initial calculation model, only the pure max. shear stress in the joint was calculated according to the following formula:

$$\tau = \frac{F_{max}}{S_F} \tag{1}$$

where S_F [mm^2] is calculated from dimensions of the joint (see Fig. 5) and F_{max} [N] is the maximal measured value of the force.

The results of the calculated "real" shear stress are summarized in the Tab. 1.

Tab. 1: Result data.

Specimen	Force [N]	Shear Stress [N/mm^2]	Rigidity of the joint [N/mm]
1	3800	880	12.25
2	3910	905	12.4
3	4270	988	13.5
4	3760	870	12.5
5	3940	912	12.4
6	3880	898	12.0
Average	3927	909	12.51
Standard deviation	165	38	0,47
Variation coefficient	4.21 %	4.21 %	3.77 %

5 Conclusion

Based on the measured data and low variation coefficient of tracked variables, it can be proven that the mechanical properties of the tested clinched joints are characterized by very good stability.

Since the calculated "real" shear stress in the clinched joint exceeds significantly the ultimate strength of the base material (steel, 270 - 500 N/mm^2), it can be concluded that hardening of the material in the clinched joint is very significant. This conclusion can be proven by the fact that the failure mode of all tested specimen was characterized by dominant local fracture of the joint neck accompanied by the negligible plastic deformation.

From this point of view it is also interesting to compare above mentioned "real" shear stress with the fictive shear stress that can be determined assuming the undistorted area of the joint at the beginning of the loading and the maximal force. The value of the fictive shear stress is approximately 650 N/mm^2 and compared with the average value of shear stress from Tab. 1 it is obvious that "real" shear stress is approximately 1.4 greater than the fictive shear stress.

It is also obvious from the results that the analysis of real stress in the joint is much more complicated. Therefore the work will continue focusing on the detailed study of material deformation in the clinched joint and its vicinity.

Acknowledgement

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