# Mechanical Description of The Clinched Joint

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**Abstract:** There is a mechanical description of a clinched joint loaded in the perpendicular direction to the joint axis (shear strength) in this text. The description is based on the simplified mechanical scheme considering different components of load, such as shear, tensile load, bending or friction in the contact surfaces. The resulting stress state in the place of fracture is compared with the ultimate strength of the material considering also the material strain hardening that occurs during the creation of the joint.

**Keywords:** clinched joint; mechanical model; force analysis; shear loading; fracture.

## 1 Introduction

Nowadays, the need of connecting different components to create a final assembly is crucial in the industry production. Clinching represents one of the modern methods for the joining of the sheet metal plates. This method uses the plastic deformation of the basic material when the joint is created using special tool set (punch and die) – see figure 1. This technology is suitable for connecting components in many branches of production, primarily where the fast, cheap and reliable connection of thin sheet-metal plates in needed. Automotive industry, HVAC, appliance manufacturing etc. are typical examples of clinching application.

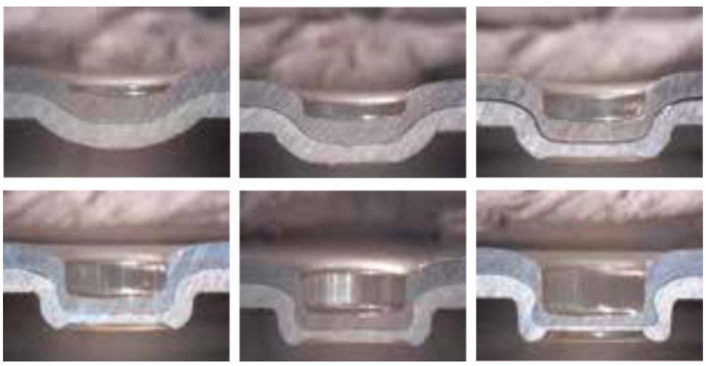

Fig. 1: TOX®-Round Joint formation, [1]

Although there are many articles describing the clinching method, process and properties that are based mainly on the FEM analysis, the new modern technologies often lack the fundamental theoretical background, therefore this article presents first insight into the basic theoretical description of the clinched joint that can be applied in a practical design of complex components and assemblies.

## 2 Joint and material description

The clinched joint may be loaded in two basic directions: in the direction of the axis (pull-out strength), or in the perpendicular direction to the axis of the joint (shear strength). This text focuses on the clinched joint under the shear load when the parameters were obtained for this state of loading by a single lap shear test.

There are different failure mechanisms of the clinched joint that depend firstly on the type of loading, used material or geometry of the joint. The two basic failure modes are unbuttoning of the joint and the fracture in the neck of the joint.

The shear strength of the joint (TOX®-joint with outer diameter of 10 mm) is approximately 3900 N. The clinched joint with the loading is shown in the figure 2, the joint after the fracture located in the joint neck is shown in figure 3. It is obvious from the figure that the fracture is characterized with very small accompanying plastic deformation therefore it can be supposed that the material in the joint was significantly plastically deformed during the creation of the joint.

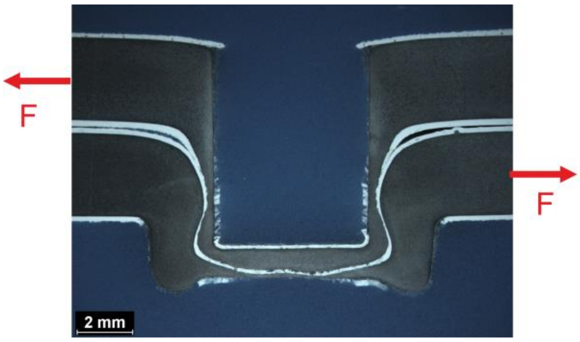


Fig. 2: Macrosection of the clinched joint

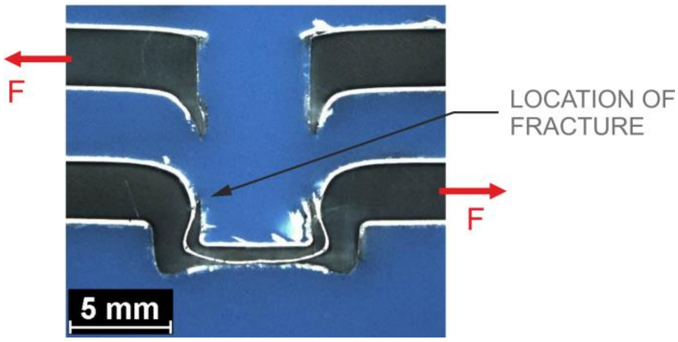


Fig. 3: Clinched joint – fracture after the single lap shear test in the joint neck

## 2.1 Scheme of the joint

The simplified scheme of the joint used for the mechanical description is shown in figure 4. The interlock of upper and lower sheet-metal plates is simplified by two cones and the neck. The geometry is characterized with the dimensions: outer and inner diameter of the joint neck (d, D) and the angle $\alpha$. Specific dimensions were measured with usage of the stereomicroscope and are listed in the table 1.

This simplified scheme is used for the calculation of the total reduced stress in the location of the fracture. Different load components were considered for calculation of the reduced stress, so e.g. the shear load, tensile load, bending moment, friction and their combination can be used to find the optimal model of the joint.

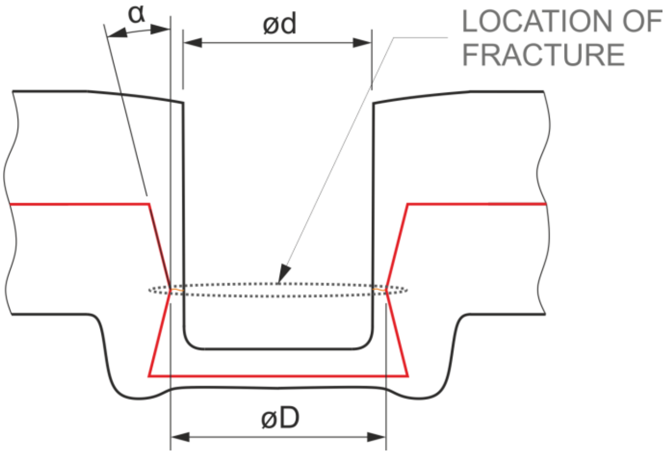


Fig. 4: Simplified scheme of the joint

Tab. 1: Dimensions of the joint.

| d [mm] | D [mm] | $\alpha$ [deg] |
|---|---|---|
| 5.54 | 6.09 | ~20 |

## 2.2 Material properties

The calculated reduced stress is compared with the ultimate strength of the material. The set of testing specimens was made of coated sheet-metal plates from low carbon steel DX51D (material No. 1.0226) with the tensile strength in the range of 270 to 500 $N/mm^2$. The detailed parameters of the used material are listed in the table 2.

Tab. 2: Material properties.

| Grade | | Material no. | | Tensile strength $R_m$ [$N/mm^2$] | Minimum elongation $A_{80}$ [%] |
|---|---|---|---|---|---|
| DX51D | | 1.0226 | | 270 - 500 | 22 |
| Chemical composition (max. %) | | | | | |
| C | Si | Mn | P | S | Ti |
| 0.18 | 0.5 | 1.20 | 0.12 | 0.045 | 0.30 |

Furthermore, the microhardness in the specific places of the joint was measured. The average value of hardness HV0.2 in the place of the fracture, i.e. in the joint neck of the upper sheet-metal plate, is approximately 286HV0.2.

The creation of the joint is accompanied by the plastic deformation of the base material thus the strain hardening of the material occurs. The increased tensile strength of hardened material in the joint neck was determined using hardness conversion table, e.g. CSN EN ISO 18265 Metallic materials – Conversion of hardness values. The tensile strength of plain carbon or low-alloy steels is 915 $N/mm^2$ for the hardness of 286HV0.2.

# 3 Mechanical description of the joint

The simplified mechanical description and fracture of the joint can be characterized by the stresses assumed in the location of fracture in the joint, i.e. tensile and bending stress are the stress components used for determination of the total stress that is in the material during the fracture. The shear stress in the fracture is omitted in this mechanical description of the joint because there is a contact between two sheet-metal plates in the joint during the loading.

The force components that cause the stress components during the loading of the joint in shear strength direction are shown in the figure 4.

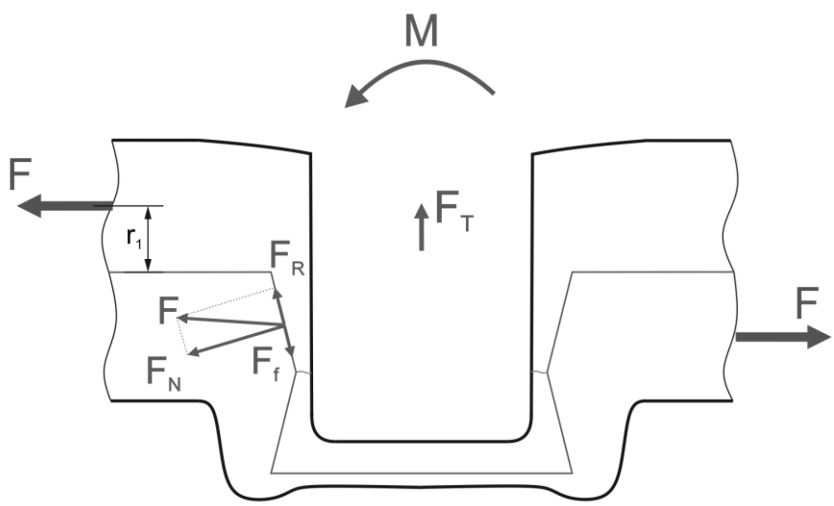


Fig. 4: Computational scheme of the joint

Force components $F_N$ and $F_R$ arise when considering force resolution of loading force $F$ on the inclined surface of the cone in the joint. The normal force $F_N$ causes the friction force $F_f$ between upper and lower sheets in the joint that can be expressed by the static friction law ($F_f = f \cdot F_N$). The static friction coefficient $f$ can be considered for steel-steel combination 0.05 – 0.11 for greased surfaces or 0.5 – 0.8 for dry surfaces. The total force $F_T$ in the direction of the joint axis is then expressed by the eq. 1 and the bending moment is for simplification expressed by the eq. 2.

$$F_T = \left(F_R - F_f\right) \cdot \cos\alpha = F \cdot \sin\alpha \cdot \cos\alpha - F \cdot f \cdot \cos^2\alpha \qquad (1)$$

$$M = F \cdot r_1 \qquad (2)$$

The stress components, i.e. tensile and bending stress, can be calculated using the load components and cross-section characteristics (area and section modulus). The reduced stress in the location of fracture in the joint neck is calculated with help of suitable material strength theory. For this case, the maximum stress during the fracture is the sum of two above specified stress components. The resultant reduced stress can be compared with the tensile strength of the hardened material in the joint neck.

When the parameters of the joint (dimensions etc.) and experimentally obtained shear strength (force $F$) are used in the model, the maximum reduced stress in the joint is in the range between 800 till approximately 950 N/mm2, depending on other parameters (e.g. coefficient of friction). It is obvious that the maximum reduced stress is near the tensile strength of the material in the joint neck.

# 4 Conclusion

The mechanical description of the clinched joint can be used for the design and calculation of complex connection of two sheet-metal plates with more single joints, or for the computational assessment of the approximate shear strength without need of usage of the methods that can be more time consuming. This mechanical model is further subjected to the detailed specification, detailing of force analysis and verification with the help of experimental testing or FEM.

# Acknowledgement

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