ANALYSIS OF CLINCHING FORCE AND TIME, ON THE GEOMETRIC AND MECHANICAL SHEET METAL (AlMg3) CLINCHED JOINT PROPERTIES

Josip Cumin, Dejan Marić, Miroslav Duspara, Ivan Putnik

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Abstract:
This paper deals with force analysis necessary to form interlock in sheet metal plates during mechanical clinching. The clinching tool has to have very specific shape in order to form interlock in the joint between two sheets. The forming force has the effect on material flow inside clinching tool cavity, which subsequently has effect on the different joint bottom thickness and amount of sheet overlap. Time necessary for joint production is related with material flow curve dependent on deformation strain rate.

1 INTRODUCTION

Mechanical clinching process is used for joining similar or dissimilar materials by forming an overlap between two metal sheets (Figure 1). Although it can be used for dissimilar materials, it is required for them to be compliant with large deformations which arise during the process. The amount of overlap after joining is mostly approximated with FEM methods, since production and testing of clinching tools is extremely expensive [1-4].

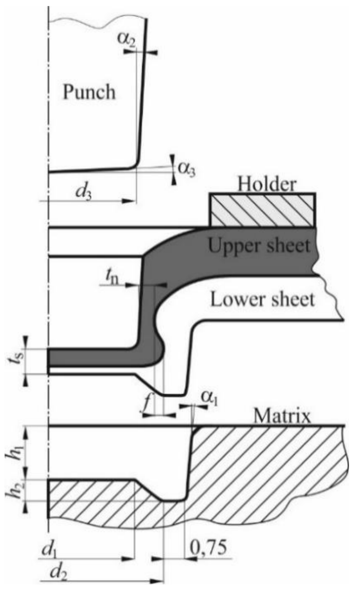

Figure 1. Clinched joint and tools.

2 MATERIAL

The material for this paper is chosen due to its excellent mechanical properties, and corrosion resistance. It is often used in automotive and maritime industries. It is designated with AlMg3 / ENAW - 5754 Alluminium alloy / EN 3.3535 [5,6].

The material flow data function is used without strain rate $\dot{\varphi}$ hardening function (1) as follows [6]:

$$k_f = 270{,}1 \cdot \varphi^{0{,}11837} \cdot e^{\frac{-0{,}0038}{\varphi}}$$

For the input in program MSC.MARC it is necessary to exclude linear behavior of material, thus leaving only plastic material properties as an input. The conversion expression was used for the material input [7]:

$$\varphi_{pl} = \varphi - \frac{k_f}{E} \tag{2}$$

3 FEM MODEL

The matrix, punch, sheet, and sheet holder were modeled as axisymmetric geometries as shown in Figure 2. Both metal sheets were 1 mm thick. For the simulation purposes, the outer diameter was 20 mm in order to ensure that the ends of the sheet in FEM model were long enough from the clinched joint itself. This was done to create computationally undemanding model, while maintaining sheet joint properties in the model. The punch diameter was set as $d_3 = 6{,}5$ mm, with angle $\alpha_2 = 6°$, angle $\alpha_3 = 5°$, punch edge radii of 0,4 mm. Matrix was machined from specifications shown in Figure 3.

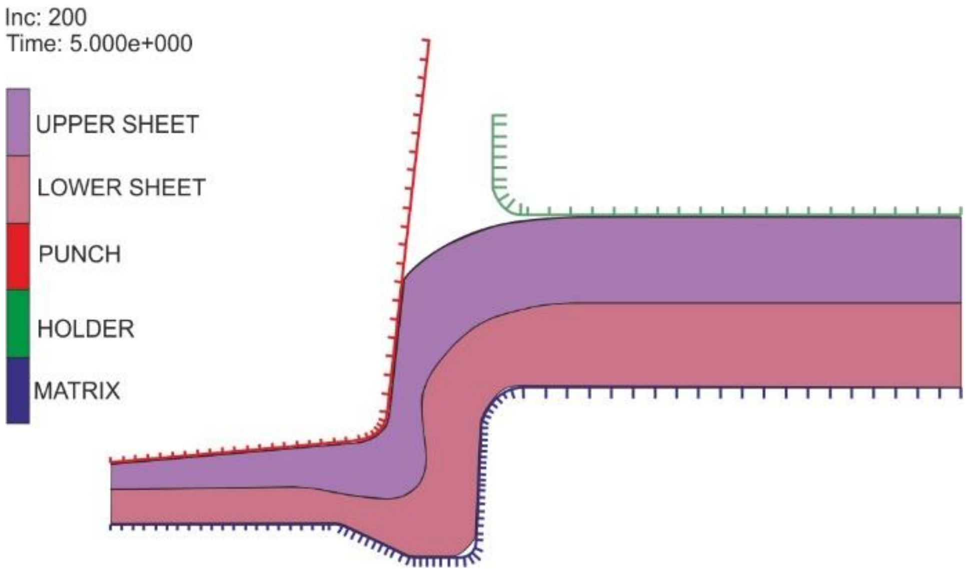

Figure 2. FEM model with deformable and rigid bodies modeled

In the FEM setup (Figure 2), model was axisymmetrical with the use of assumed strain and constant dilatation functions, which are to be used in the large strain deformation cases along with the lower order quadrilateral elements, in order to avoid possible problems with element locking due to overconstraints for nearly incompressible behavior [7]. The sheets were meshed with the lower order quadrilateral elements type 10 [8], with the size of $0,08 \cdot 0,08$ mm. Subsequent fine remeshing with the element edge length goal size of 0,05 mm was used with advanced grid regeneration algorithms. The "Advancing front quad" internal mesher, was activated when logarithmic strain was larger than and when the quadrilateral element was distorted (internal angle larger than 120°) was activated. The numerical simulation was set as large strain plasticity with large strain updated Lagrange option, where additive decomposition method was used for matrix solving.

Contact control was done internally through the software with CTABLE option, where it was necessary to define possible deformable contact bodies (two sheets), and rigid bodies with prescribed motion (matrix was set as stationary, and punch had linear z-axis motion).
Friction factor of $\mu = 0,2$ between punch /upper sheet, $\mu = 0,3$ between aluminium sheets, $\mu = 0,12$ between lower sheet/matrix with respect to research of [4]. Coulomb friction model with arctangent approach was used.

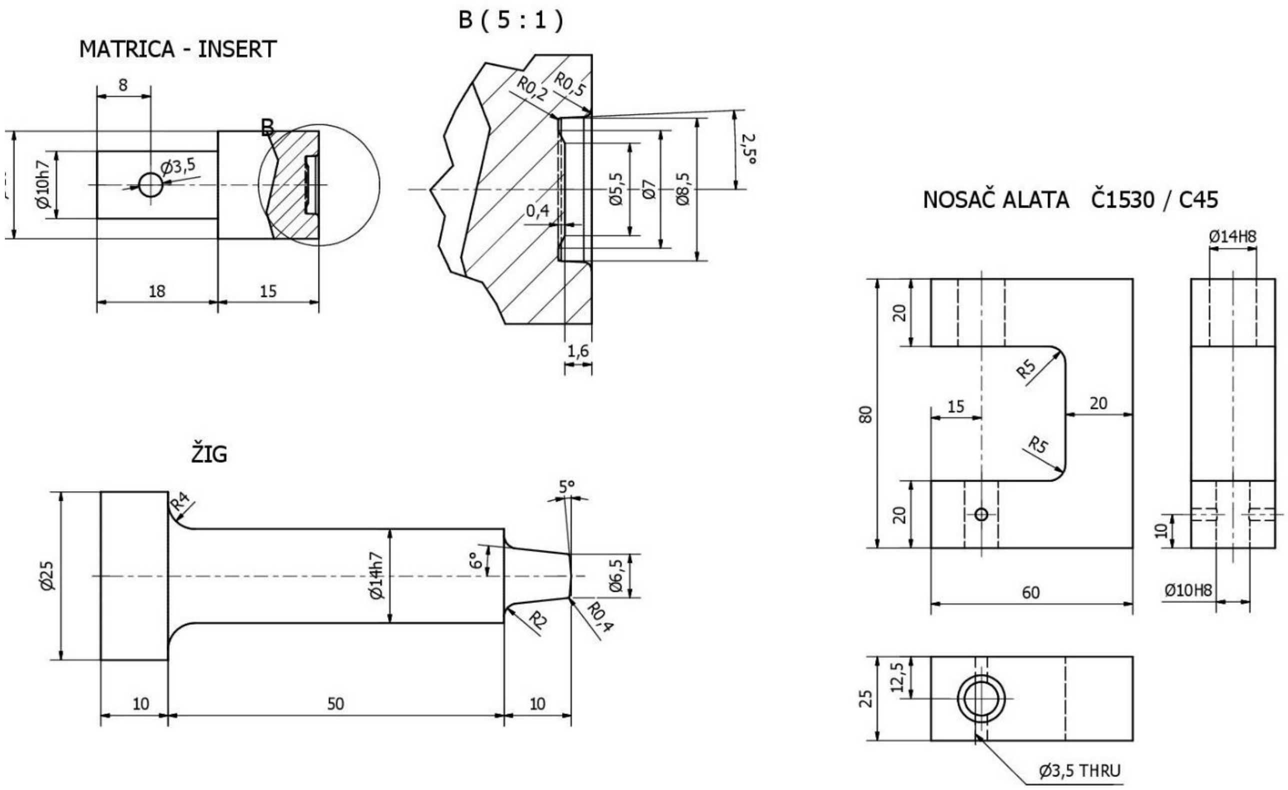

Figure 3. Technical drawing for tool production

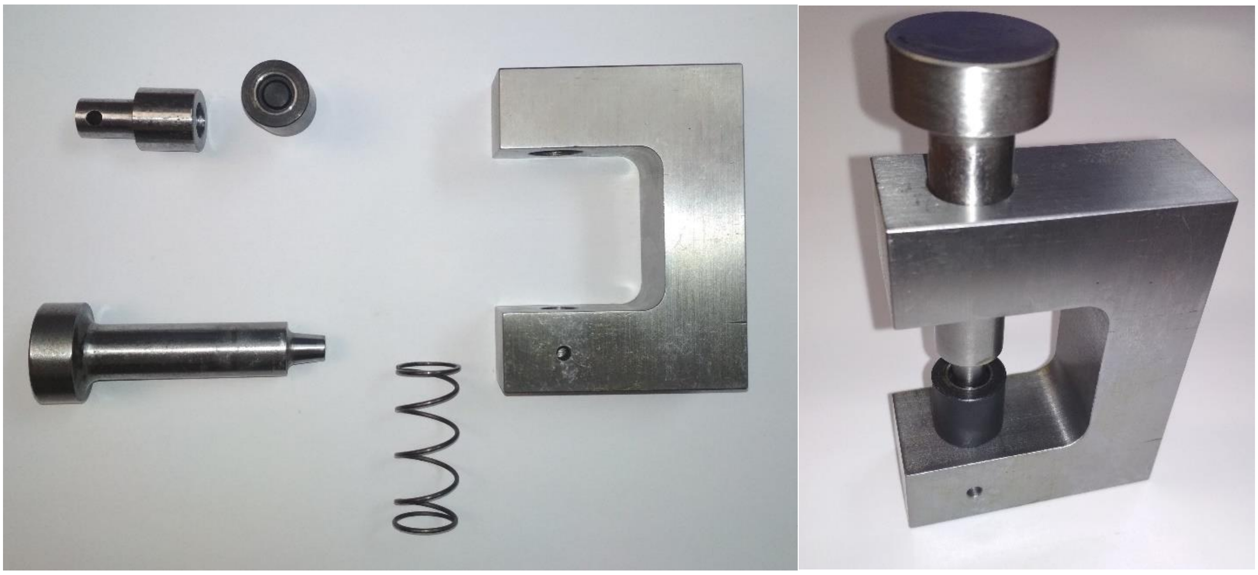

Figure 4. *Clinching tool*

4 RESULTS

Figure 4 shows history data plot of punch position vs. punch force for the clinching process. There are three sections shown in this diagram.

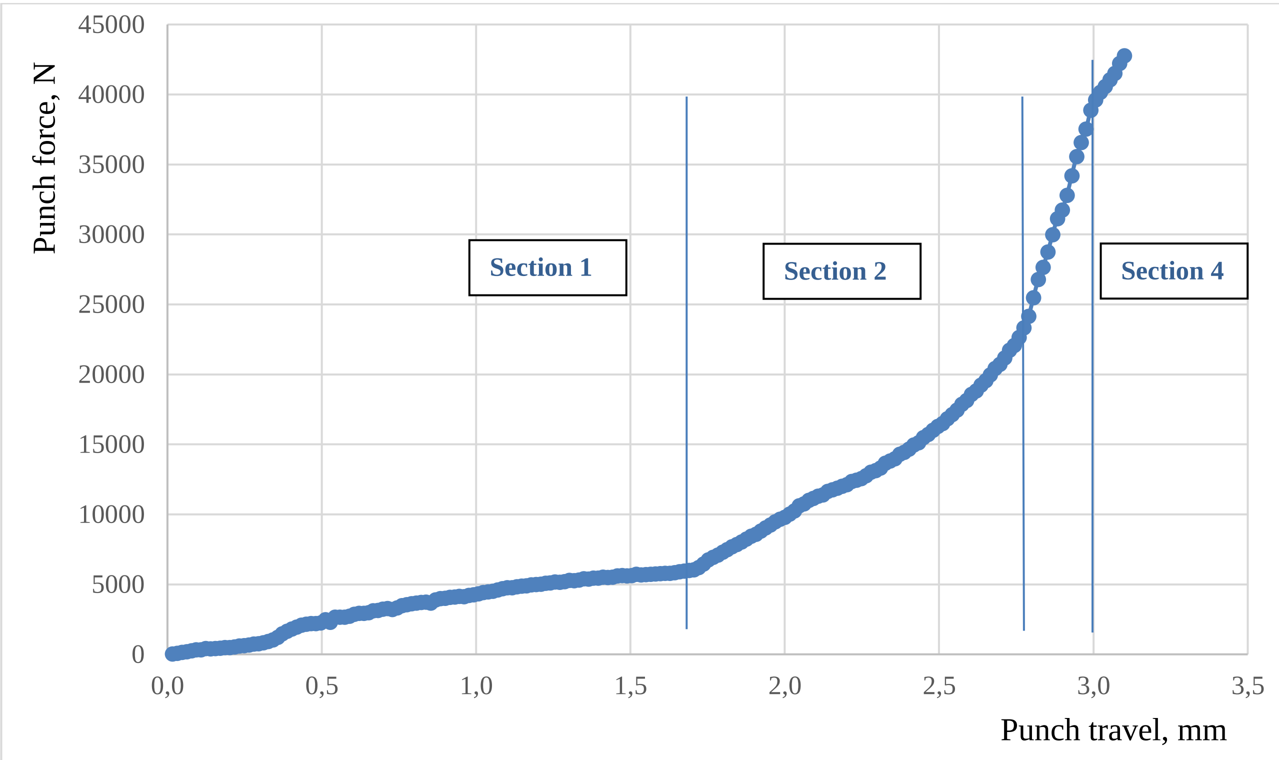

Figure 5. *Punch travel*

The first section shown is force needed for punch indentation in the upper sheet, and both sheet bending as is shown in Figure 6. When the lower sheet touches bottom tool (die), the section 2 of the diagram in Figure 4 begins. In this section the material flows in tool cavity until flow resistance begins to increase due to the tool walls geometry shown in figure 7. From this point on (section 3), the material fills whole tool cavity and then coining process begins where the largest forces can be observed.

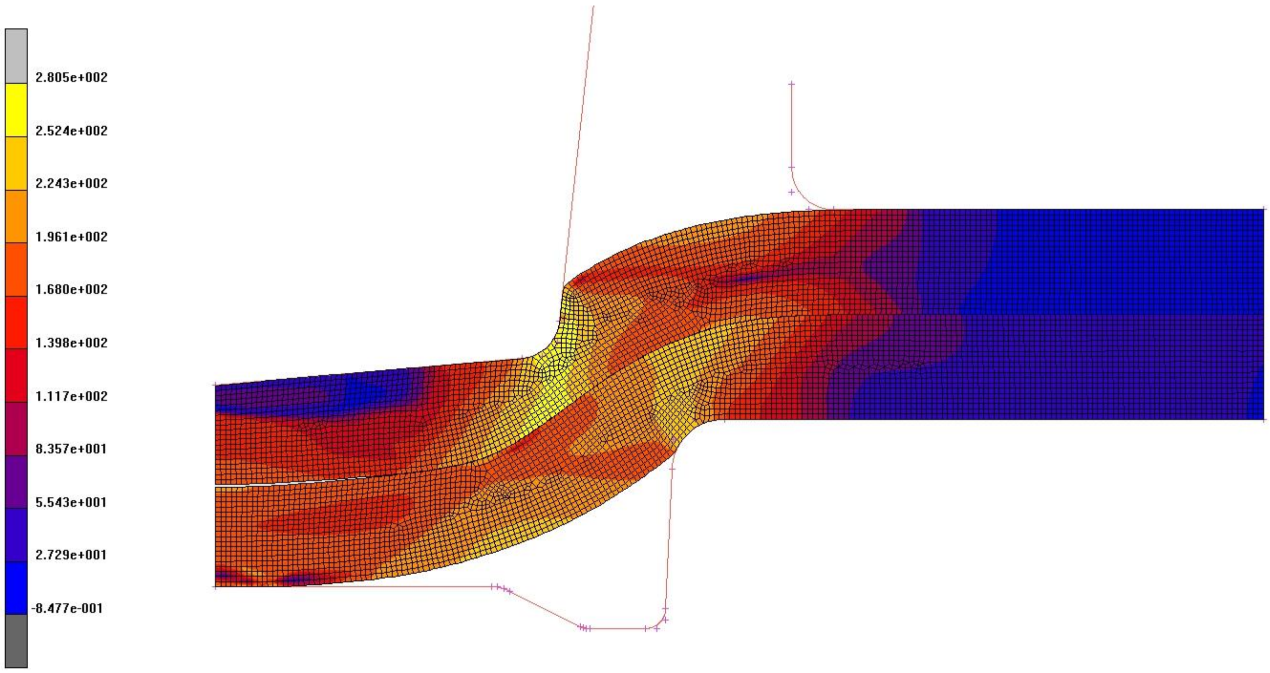

Figure 6. Sheet bending and punch indentation

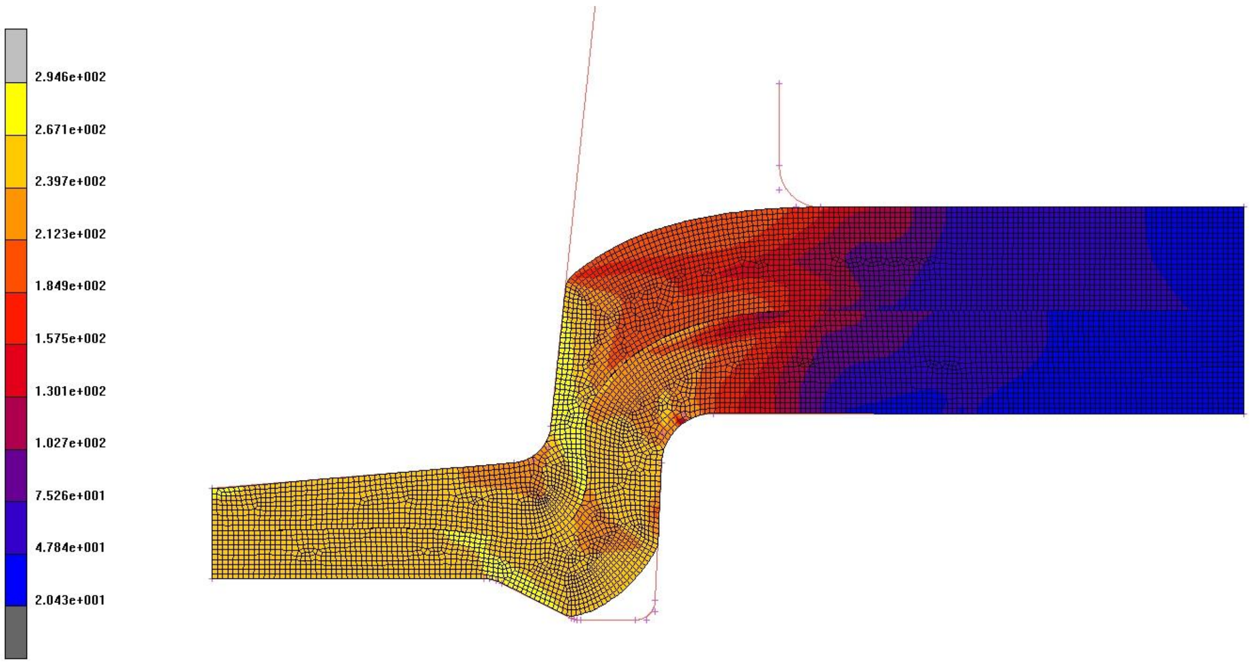

Figure 7. Material flow (filling of the die cavity)

Figure 8 shows the last section 4 (coining). Here the clinched joint is formed, and the forming forces are largest. Further punch movement causes abrupt rise in punch force, the thinning of joint bottom (ts from Figure 1), and flow of material upwards from the tool cavity. This is where the clinching process should be stopped.

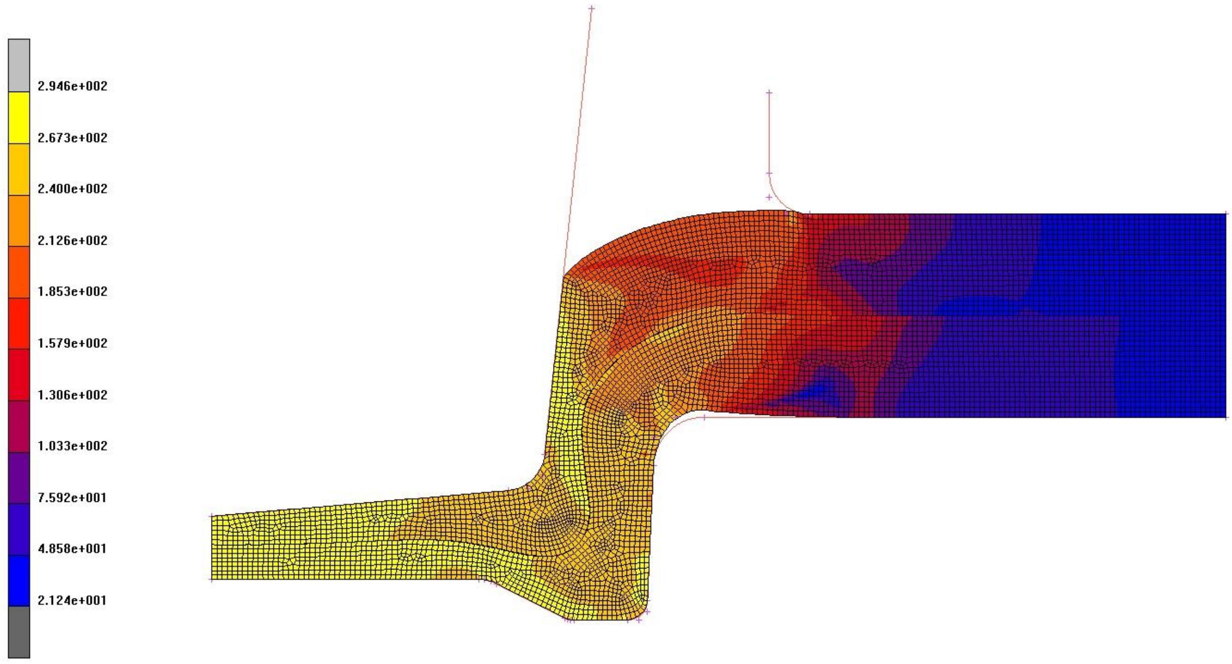

Figure 8. Formed joint

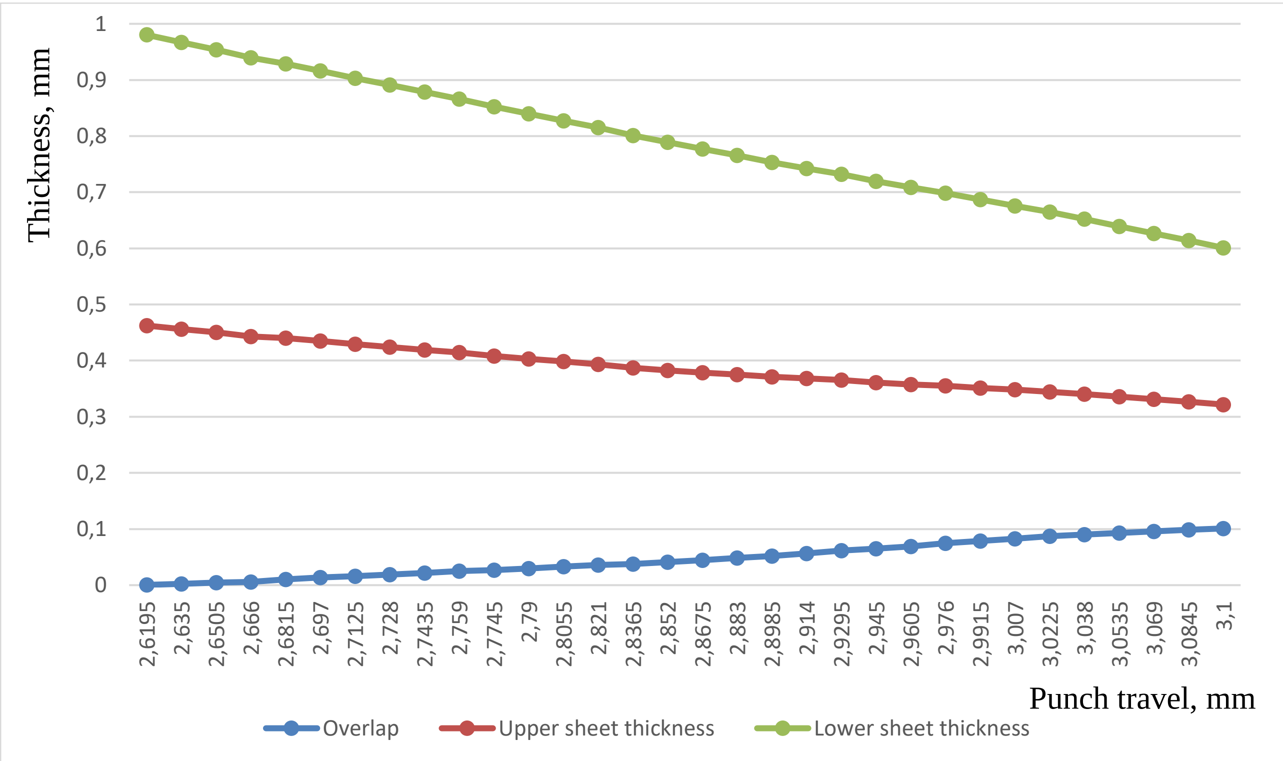

Figure 9. Overlap and sheet thicknesses during clinched joint forming

Figure 9 shows development of overlap f, mm (from figure 1), upper sheet thickness tcu, mm and lower sheet thickness tcl, mm. Bottomed sheet thickness is represented in Figure 1 as tc, mm and consists of $t_c = t_{cu} + t_{cl}$, mm.

From the technological standpoint the overlap f is of the most interest. The overlap occurs at 169 time increment (out of 200 increments) or at punch travel of 2,6195 mm from the starting point (upper sheet in undeformed state).

Gradually, from this point on the overlap f is increasing, while bottom of the clinched joint becomes thinner. Here stresses are compressive, and material flows under the punch cone into the tool cavity.

Punch angles α_1, α_2 help material flow inside tool cavity.

It can also be seen that the upper sheet is thinner in the clinching process than the lower sheet is. It is also observed in [8,9,10].

Further punch travel than 3,1 mm would be futile since material would flow outside of the tool cavity, thus creating protrusions of the joint. Too large punch travel would also cause excessive thinning of the upper sheet and with that possible fractures due to the large stresses occurring due to the strain hardening curve.

5 CONCLUSION

In this paper FEM analysis of the mechanical clinching process of AlMg3 sheets of 1 mm thickness is shown. Mechanical clinching is often used oft the joining of materials which are hard to weld by Electric Resistance Welding (ERW), or for joining of dissimilar materials such as steel/aluminium, or copper/aluminium and similar materials.

For the joint creation during clinching process, the tool geometry is very important, since the material flow is determined by the same tool geometry parameters shown in Figure 1.

There are two approaches to clinching process joining, one is by trial and error, and the other is utilization of FEM methods for approximation of material flow in the tool cavity.

In this work the FEM simulations were made for the produced tool shown in Figure 4, in order to track the necessary amount of force required to make the joint (Figure 5), and to find optimal punch travel (Figure 9).

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