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Numerical Modelling and Simulation of Sheet Metal Forming Process

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Introduction

Sheet metal forming processes are widely used and common in our days from the automotive industries to the aerospace and home appliance application regarding the huge benefits and income of its application. Hence, we need forming parts with high complexity forms, less energy, then these kind of forming processes is highly recommended [1].

Whereas there are a lot of advanced research and methods was elaborated to deal with field of sheet metal forming process. There are always new techniques and optimization strategies needed to optimize some input parameters during the initial configuration in order to overcome the unusual results both on our final product and increase the durability of tools and equipment, and the efficiency of the process design as well.

Whereas this research is focused on modelling of stamping process of stainless steel AISI 304 to investigate to formability of the material, and studying the influence of the friction factor on the quality of the product as well the energy required. Some an overview about the optimization techniques in this field of research will be given in the first part.

1. Sheet metal forming processes optimization techniques

Optimization of sheet metal forming processes are evolving faster and longer in our days. For instance, the numerical simulation is well known for several purpose, there is missing gaps related to optimization using others methods based on artificial intelligence algorithm such Neural Network Algorithm.

1.1. Numerical simulation

As one of basic method for metal plastic processing, with the development of finite element technology, using numerical simulation we can accurately predict the results of forming process virtually, but in the optimization of forming process parameters, still mainly use the numerical method combined with trial

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and error technique to do so. But in order to select the optimal set configuration possible involved more combinations of design variables, it is so difficult and time, tests consumed by experience. So, it is mandatory to use artificial neural network, orthogonal experiment, and others methods for the sheet metal forming parameters optimization [2].

1.2. Artificial Neural Network

Artificial Neural Network (ANN) is a complex network system, which is composed of a large number of simultaneous and very simple processing units (or neurons). This method is especially suitable for processing need to consider many factors and conditions, inaccurate and fuzzy information problems [3].

2. Numerical modelling of stamping process of stainless steel AISI 304

This research is focused on modelling of stamping process of stainless steel AISI 304 to investigate the formability of the material, and to study the influence of the friction factor on the quality of the product as well the energy required for each set configuration. The problems contain three main parts during the process which are the blank which the deformable body, upper die (Punch), and the lower die. The of these tools is steel X45 Ni Cr Mo 04 (EN DIN 1.2767) which considered as rigid body during the process regarding their high hardness which equal to 56 HRC.

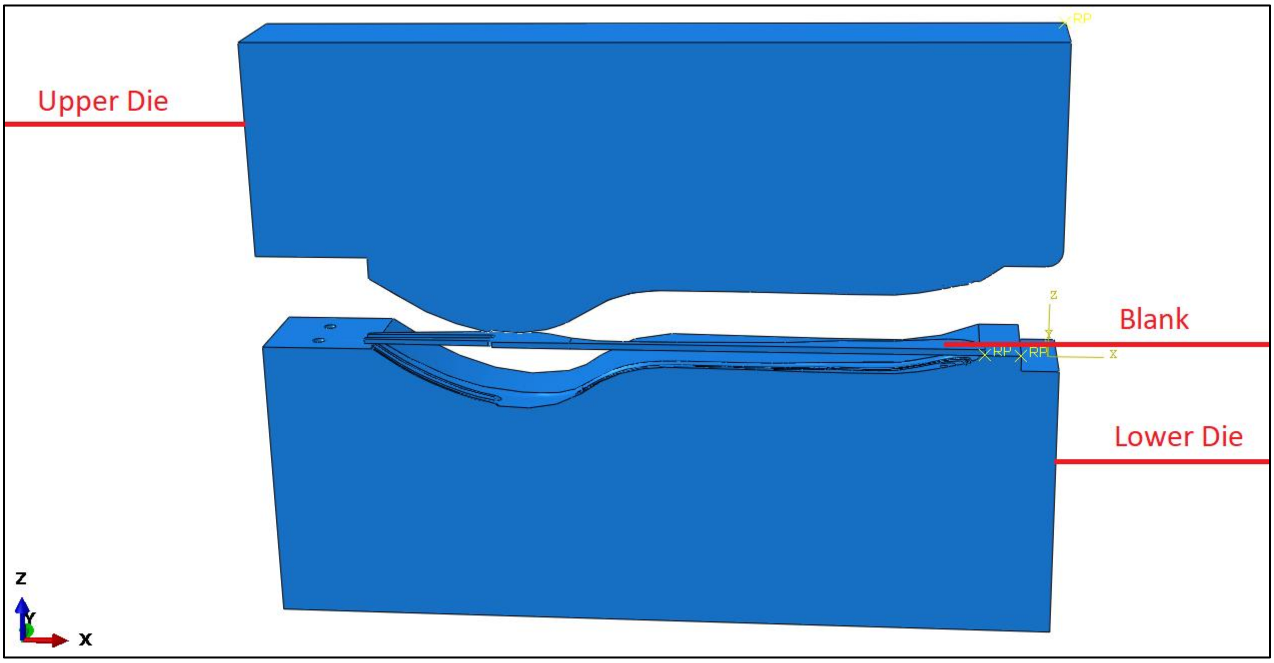

Figure 1: Symmetric modelling of stamping process of stainless steel AISI 304

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2.1. Material behaviour

The blank is made of stainless steel AISI 304. It is an austenitic stainless steel composed of at least 18% chromium and 8% of nickel. It has the properties of being weldable and ductile. Its Young's modulus is $E = 200$ GPa and its Poisson's ratio is $\nu = 0.29$

Several hardening models have been tested and Ludwick's hardening law seems the best suited to describe the behaviour of AISI 304 by linking the flow stress σ_y to the plastic deformation ε_p [4]. This law is written in the form:

$$\sigma_y = \sigma_e + K.\varepsilon_p^n$$

Where σ_e , K and n are intrinsic characteristic related to material, they have the values defined in the table 1.

Table 1: Hardening Parameters of AISI 304

Parameters	σ_e	K	n
Value	197.3 (MPa)	1340.6 (MPa)	0.64

In the figure 2, it presented the flow curve of material behaviour under conventional tensile test

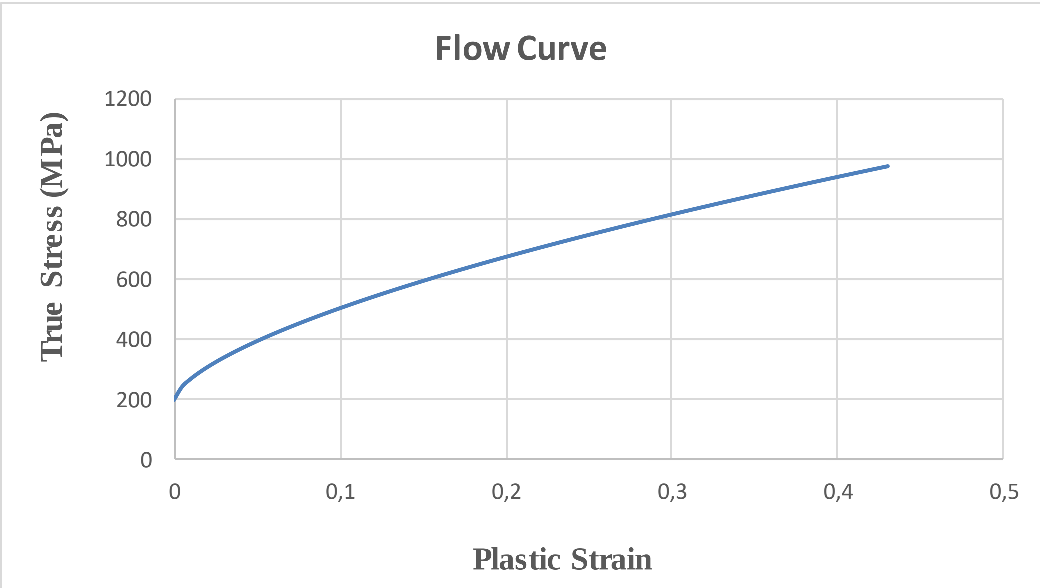

Figure 2: Flow Curve of AISI 304

- The calculation and simulation were done using Abaqus Software Standard [5]
- Since our model is symmetric, the half of the model was carried out in the simulation in order to decrease the time of calculation.
- The ration of between the thickness n and the length L of the blank is:

$$\lambda = \frac{e}{L} = \frac{2}{202} = \frac{1}{101} << \frac{1}{10}$$

So, it is recommended to mesh the deformable body with shell element.

- Whereas the tools are meshed as discrete rigid body, the blank is meshed with triangular thin shell element.
- The interaction between the dies and the deformable with friction, using the value $f = 0.15$

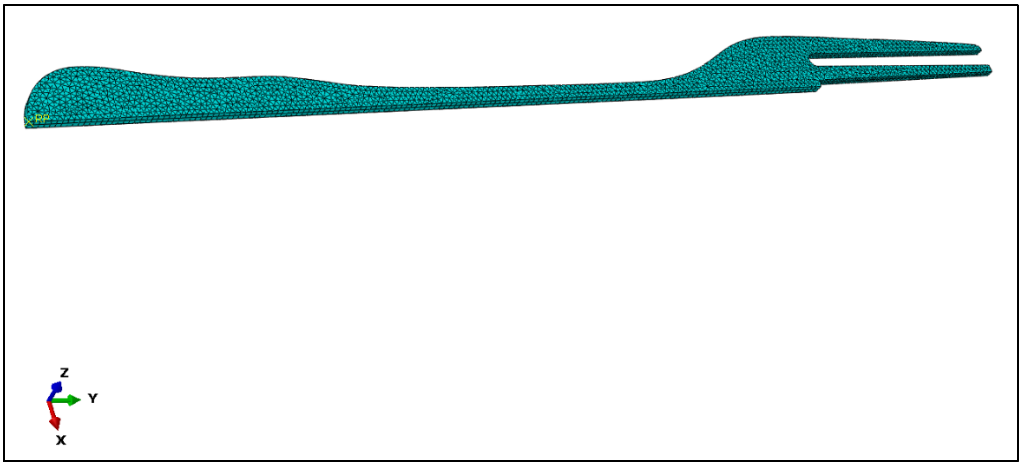

Figure 3: Meshing of the blank

2.2. Results and analysis

- Stress Distribution

There are a lot of results can be useful for any purpose, and this depends with the requested properties for the specific application. For our model, we need to visualize to stress distribution in the sample part as shown here in the Figure 4

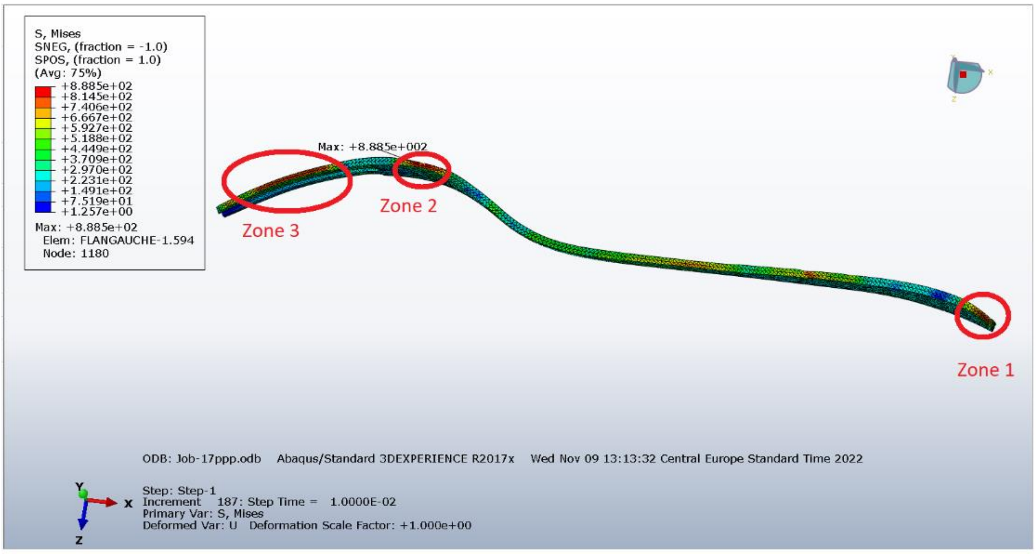

Figure 4: Stress distribution in whole deformed body

- Interpretation 1:

The stress is high in the three main regions in the deformed body denoted by Zone 1, Zone 2, and Zone 3. However, the maximum value is located in zone 2 ($\sigma_{max} = 888.5$ MPa).

- Thickness distribution

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One of the main useful curves and results is to plot the thickness in the deformed body and make comparison with some predefined equation and experimental tests with the real thickness change. In the Figure 5 has shown the value of the thickness taken at in symmetry plane.

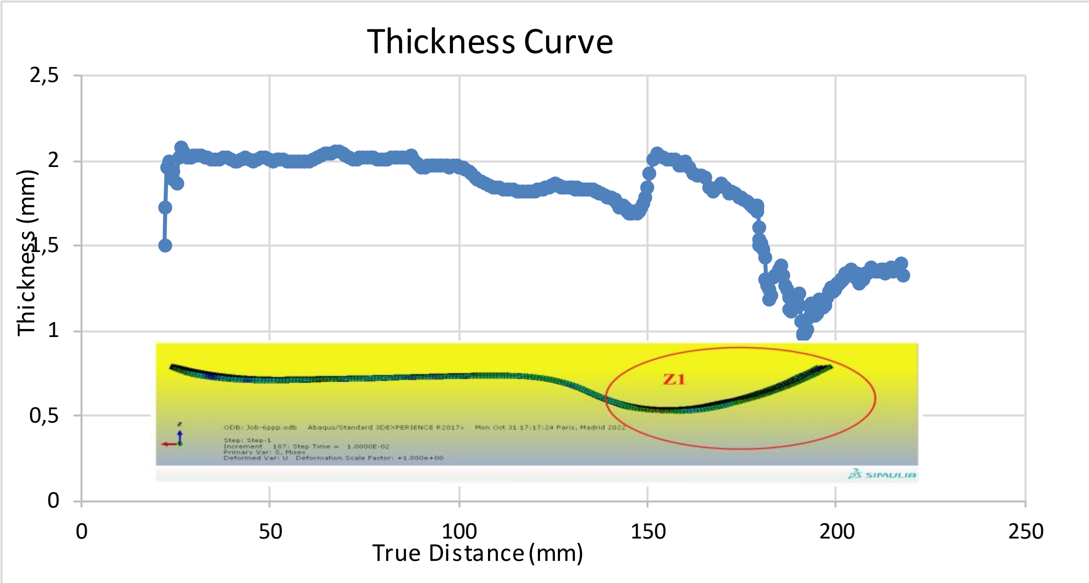

Figure 5: Thickness distribution on the deformed body

- Interpretation 2:

The range of thickness between 1.5 to 2.07 mm in the fork. However, the minimum value is reached in Z1 with e_{min}= 1.06 mm

- Energy required

In order to identify la force nominal required to form this hardening material is to plot la reaction force as function of displacement in the punch as shown in the Figure 6 illustrated below.

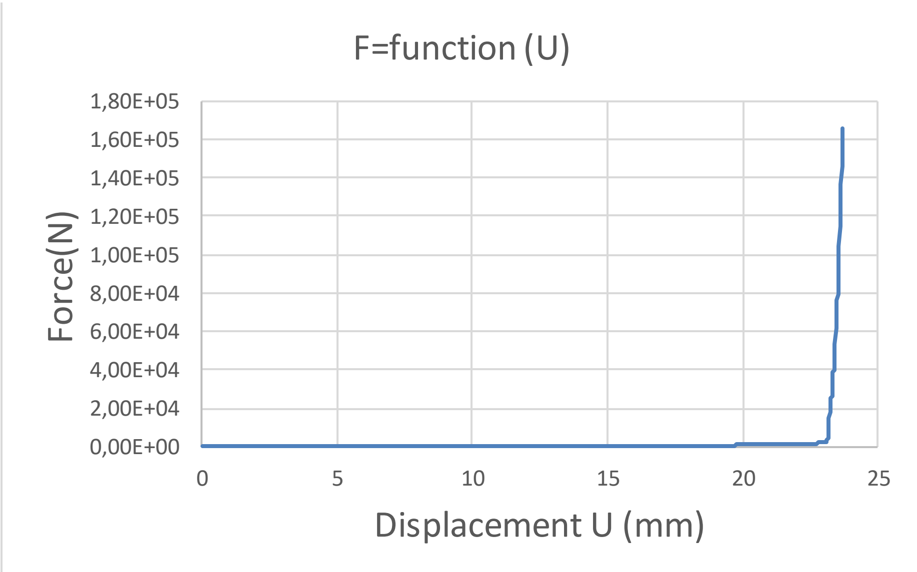

Figure 6: The reaction force in the punch

- Interpretation:

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The force required to stamp this blank is $Fmax = 1.66.10^4$ N

3. Conclusion and further research

Numerical modelling using finite element method in our days has an impact and influence for developing forming processes, to design a successful sheet metal forming process virtually which requires expensive and time-consuming prototype testing to obtain the best set of initial configurations.

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