15th Scientific/Research Symposium with International Participation „METALLIC AND NONMETALLIC MATERIALS“, Zenica, B&H, 24th-25th April 2025

ANALYSIS OF FORMABILITY IN BENDING USING SOLIDWORKS SOFTWARE

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Keywords: formability, V-die bending, SolidWorks, material testing

ABSTRACT
Formability is the ability of a material to deform without fracturing, and the assessment of this property depends on various factors such as temperature, deformation speed, and stress state. There are two main approaches to determining formability: one is based on testing different materials under controlled stress conditions, and the other on developing failure criteria that depend on stress, deformation, deformation speed, and temperature. Bending of materials induces different stresses on the inner and outer sides of the sheet, which can lead to the Bauschinger effect during re-bending. Although the sheet formability test is outdated, it is still used to illustrate the properties of materials like high-strength steels. In this study, SolidWorks software was used to analyze the formability of the sheet during bending in a V-die, using different sheet thickness and materials.

1. INTRODUCTION

Formability is a term that is unambiguous and does not appear in any other technique or processing. It is characteristic exclusively for deformation processing. When we talk about the formability of materials, we are referring to the assessment of how a material behaves in a specific process. Due to the complexity of formability, there is no single test for determining the formability of materials; material testing methods are complex and encompass several different analyses. To define the concept of formability, information is required about the external load, deformations, material, geometric characteristics of the workpiece and tool, and boundary conditions.

The usual approach to determining the formability of a material refers to formability concerning material factors. In this case, samples of different materials are deformed under known and controlled stress conditions.

Another approach to determining formability aims to develop failure criteria in the material through stress-strain conditions as a function of strain rate and temperature. In this case, local stresses, deformations, strain rate, and temperature are known at the potential failure point of the material during deformation. By applying this method, it is possible to determine whether the material will fail or not. If failure occurs, changing the stress state, i.e., controlling the process parameters, can prevent the material from breaking/cracking.

From a scientific perspective, it is not enough to say that one material is more deformable than another; science requires that such properties be described with numbers. Therefore, one definition of formability would be the ability of a material to plastically deform without failure under specific technological conditions: temperature, degree of deformation, strain rate, and technology, or the stress state scheme. Formability can also be defined as the ratio of the maximum deformation a material can withstand (without cracking or failure) to the process parameters.

Bending differs from other deformation processes in that the deformation is not uniform across the sheet thickness but varies [1]. On the outer side of the sheet, elongation occurs, while on the inner side, compression takes place. As a result of bending, higher tensile stresses occur on the outer side of the sheet, while compressive stresses appear on the inner side. If the sheet is bent and then unrolled, it will result in a complete reversal of stresses, causing the so-called Bauschinger effect.

The deformable properties of the sheet during bending can be observed through a simple test that does not provide quantitative results. This is an outdated test and is rarely used today. In this test, the material sheet is bent twice, as shown in Figure 1, and the material is considered well deformable if there is no cracking at the edge of the double fold (Figure 1.C), where the greatest deformation occurs. It has been shown that soft steel passes this test without issues, which is likely the reason why this test has become obsolete, although it is still occasionally used for testing welded joints or illustrating the flexibility of high-strength steel. The figure also shows a cross-section at the point of the fold. Essentially, the formability of the material can be significantly improved if the material is subjected to both bending and stretching.

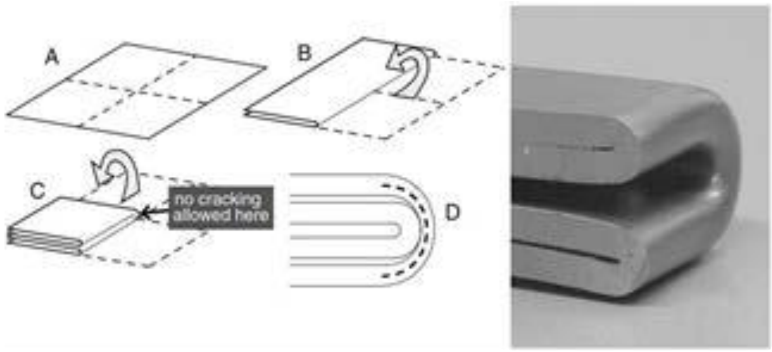

Figure 1. Bending test of sheet metal formability [2]

2. BENDING SIMULATION

The sheet formability test is an outdated method today, considering the large number of software programs that allow material formability testing. Using the SolidWorks software package, a nonlinear bending analysis in a V-die under known and controlled stress conditions was performed in this study. The material of the tool and die is carbon steel, and since the object under observation in this analysis is a sheet, the tool and die are defined as rigid bodies. The workpiece has dimensions of 40x200xs (with s = 1.5, 3, or 5 mm).

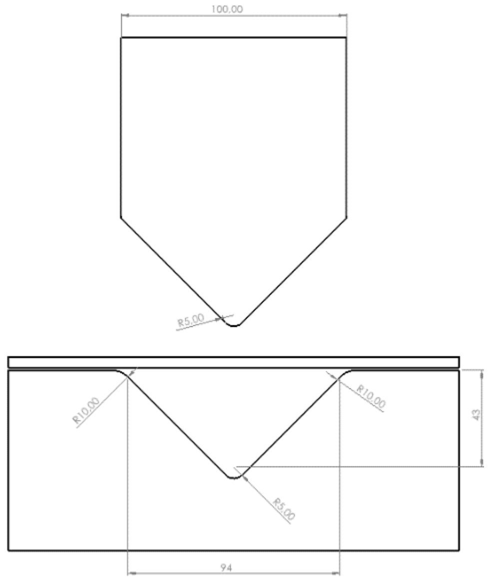

Figure 2. Tool used for simulation

Before starting the simulation, it is necessary to define the initial conditions, specifically the supports, contact surfaces, and the mesh [3]. For each simulation, the initial conditions are the same and unchangeable. The initial conditions of the analysis are shown in the following images.

When it comes to defining the supports, the bottom of the die is fixed in all directions, the sheet is fixed using a line at its center in the X and Z directions, while movement is allowed in the Y direction. Using a flat surface, the die is fixed in the X and Z directions, but movement is allowed in the Y direction. Figures 4 and 5 show the contacts between the surfaces in contact.

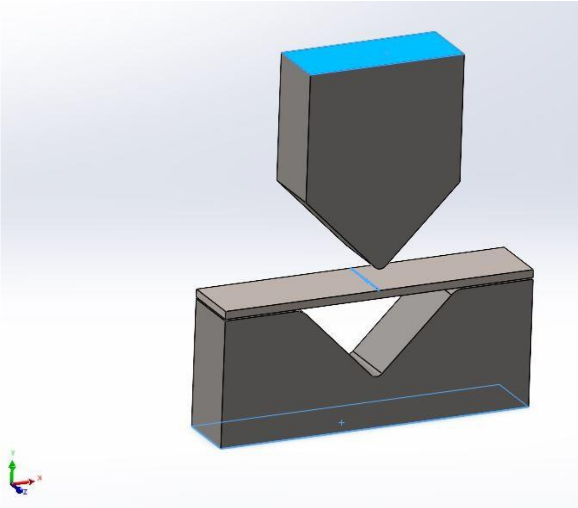

Figure 3. Surfaces defined as supports

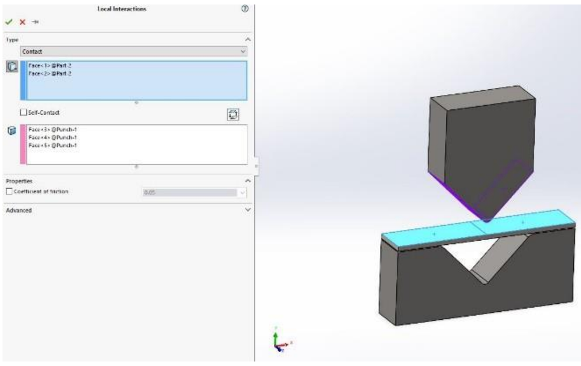

Figure 4. Set 1 of surfaces that come into contact during the simulation

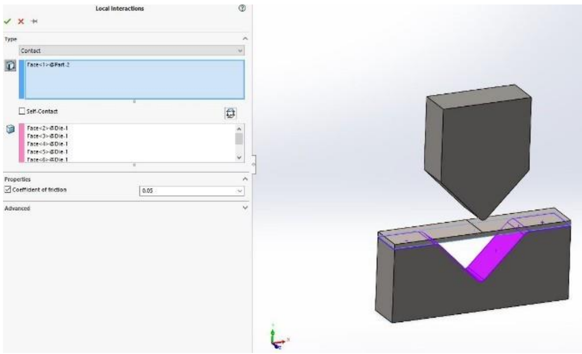

Figure 5. Set 2 of surfaces that come into contact during the simulation

In this paper, two materials of different formability and three different thicknesses of the workpiece material were analyzed. The considered cases are shown in Table 1.

Table 1. Analyzed combinations of materials and sheet thicknesses

Analysis	Material	Sheet thicknesses (mm)
I	Aluminium 1060	1,5
		3
		5
II	Brass	1,5
		3
		5

3. RESULTS

The results of this analysis will indicate the stress zones that occur in the material during bending, where the blue areas represent regions with lower stresses, while the red areas indicate high stresses. The areas of high red stress are still acceptable bending results as long as no failure occurs during the simulation. When SolidWorks indicates an error during the simulation, the bending is then considered unfeasible. In this paper, the stresses will be considered, and the formability of the material of a certain thickness will be presented using diagrams.

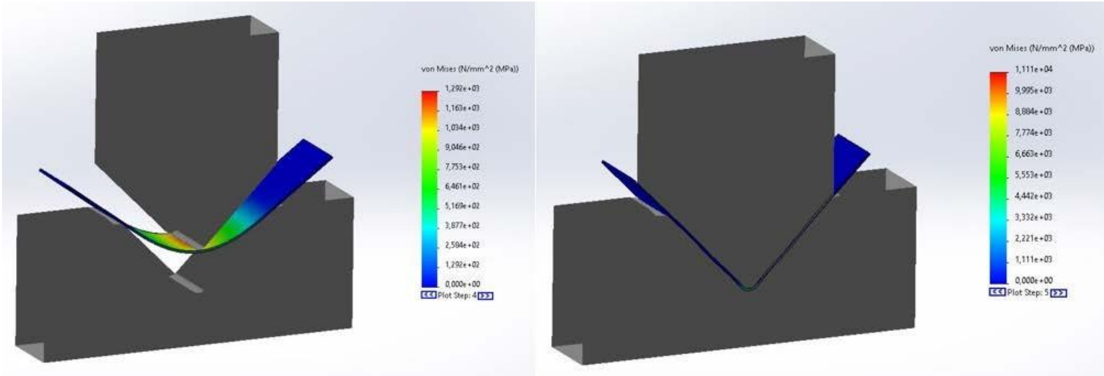

Figure 6. Bending simulation in a V-die for Aluminum 1060 s=1.5 mm

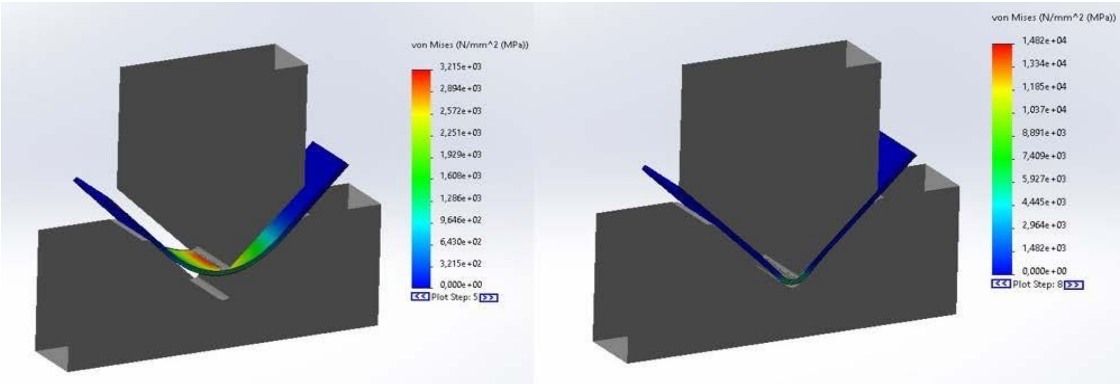

Figure 7. Bending simulation in a V-die for Aluminum 1060 s=3 mm

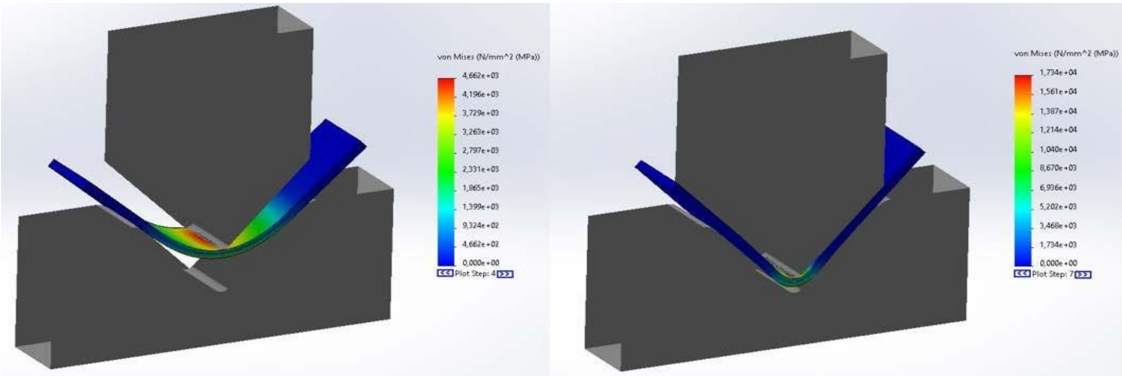

Figure 8. Bending simulation in a V-die for Aluminum 1060 s=5 mm

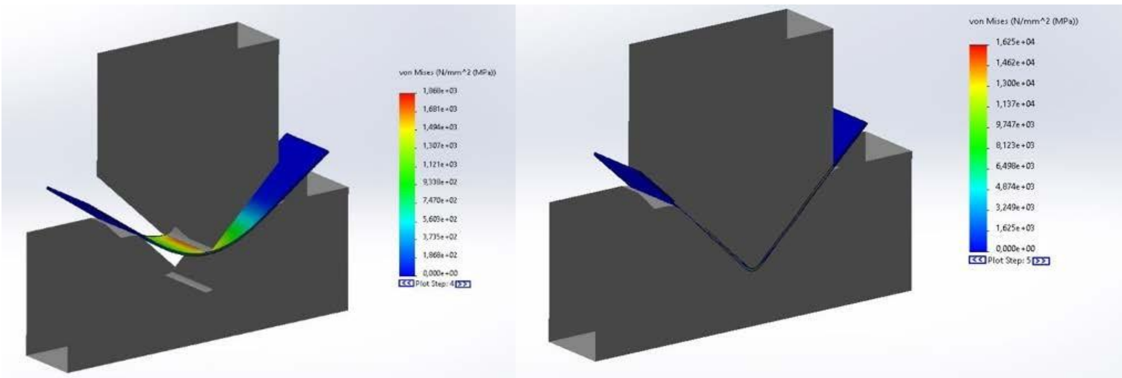

Figure 9. Bending simulation in a V-die for Brass s=1,5 mm

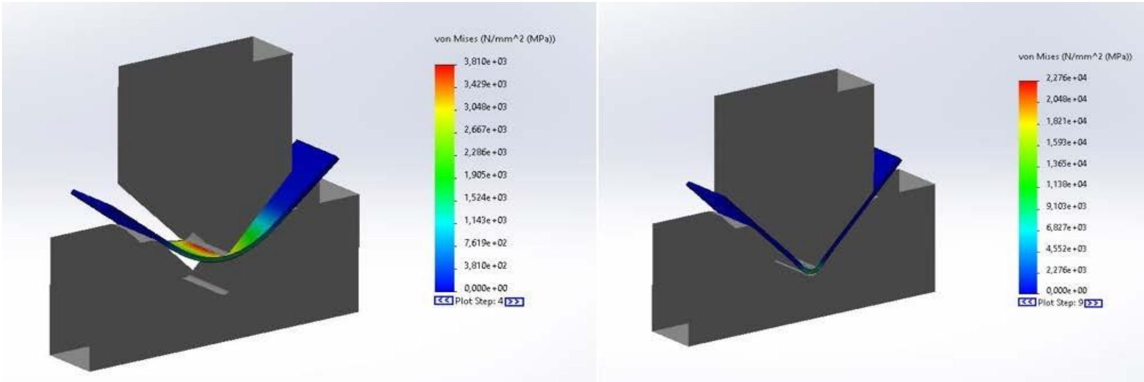

*Figure 10. Ben*ding simulation in a V-die for Brass *s=3 mm*

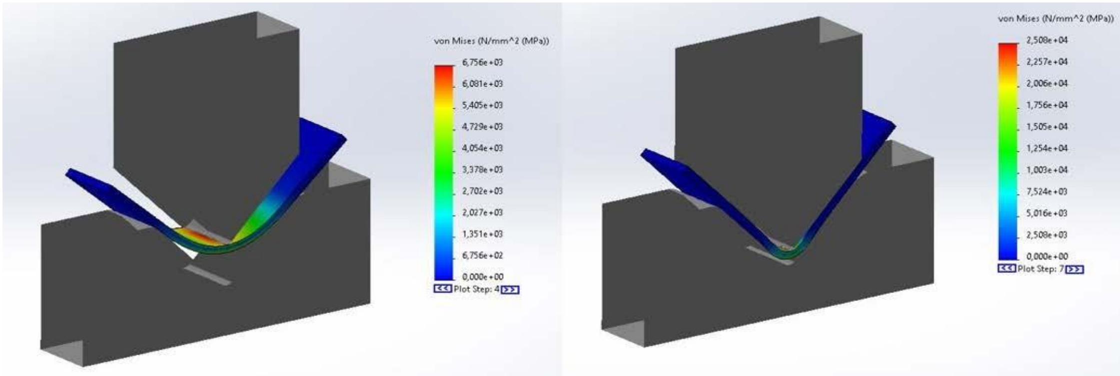

Figure 11. Bending simulation in a V-die for Brass s=5 mm

4. CONCLUSION

The resulting stresses that occurred in the materials during the final stage of bending, depending on the material and thickness of the workpiece, are presented in Diagram 1. Each material of the workpiece corresponds to a curve showing the change in stress as a function of the workpiece thickness.

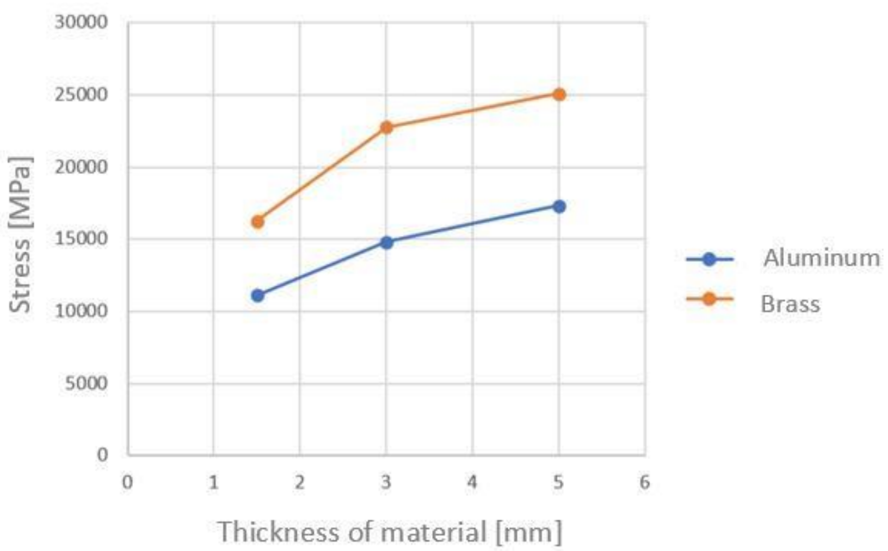

Diagram 1. Dependence of resulting stresses on the material and thickness of the workpiece

According to the material characteristics, the highest stresses will occur during the deformation of the brass workpiece. Aluminum, as a workpiece material with lower tensile strength, produced the lowest stress values in the material during deformation.

As the material thickness increases, the stress in the material also increases, meaning a higher bending force is required, which is expected.

Since the formability testing is based on material factors, and the analysis was performed under known and controlled stress conditions, we can confirm that Aluminum 1060 is a more deformable material than brass.

6. REFERENCES

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