IJAME

Int. J. of Applied Mechanics and Engineering, 2025, vol.30, No.3, pp.11-25
DOI: 10.59441/ijame/205460

EFFECT OF THE CHOICE OF DRAWBEAD TYPE ON THE SPRING BACK: COMPARATIVE STUDY BETWEEN TWO TYPES OF DRAWBEAD

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The stamping process is mainly used in the automotive industry to manufacture parts. However, there is a major problem with the geometrical variations of the part which lead to assembly difficulties, this problem is known as the spring back, that is to say the propensity of the sheet to recover its original shape after being deformed, this results in a geometric variation of the part which affects the final assembly. In this article, we started by modelling the drawbead force and then examined the consequences of drawbead on the spring back, which is one of the essential elements of the stamping process. We have demonstrated that the type of drawbead chosen plays a crucial role in the spring back of the part. We have therefore carried out a comparative study between two types of drawbead, the bead and the step bead. The result shows that the use of a step bead as a type of drawbead improves spring back.

Key words: step bead, spring back, stamping, drawbead, sheet metal.

1. Introduction

The spring back is the tendency that the sheet to return to its original shape after the stamping operation [1, 2], it is considered as one of the issues found hugely in stamping process and more particularly within the automotive industry, It is crucial to correctly predict the spring back in order to achieve the desired shape [3]. Without the required shape, assembly of parts becomes extremely difficult and time-consuming. This also results in an increase in the time required for the assembly process.

Different parameters can be modified to reduce the springback, such as the thickness of the blank, Tejyan *et al.* [4] has shown that the thickness of the blank may have an impact on the spring back. Their results indicate that springback is advantageous with high thicknesses.

Asgari *et al.* [5],have demonstrated that an increase in the coefficient of friction results in a more significant plastic deformation when the matrix comes into contact with the tôle. It appears that increasing the coefficient of frottement from *0.1* to *0.2* does not significantly alter plastic deformation, but increasing it by more than 0.2 appears to increase plastic deformation even more.

Sharad *et al.* [6], studied the impact of the presence of holes in the blank on the spring back through an experimental study on *U*-shaped profiles, the results showed a greater decrease in the spring back.

The shape of the blank also plays an important role, it will be possible to choose the shape of the blank well not to impact the result of springback. A study [7] demonstrated by numerical simulation that the use of a sinus blank will increase the spring back values.

The geometry of the tool plays an important role in the manufacture of stamped parts. A comparative study [8] with punch diameters of *39 mm* and *118 mm* shows that an increase in the diameter of the punch leads to a production of cups without geometric defects.

The direction of rolling also plays an important role in improving springback, Pritima *et al.* [9], have concluded that the springback angle is greater in the transverse direction (*90°*) than in the *0°* direction, Kebdani

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and Radi [10], have also concluded that the direction of rolling also plays an important role in improving springback. They have also demonstrated that the thickness of the blank may affect the spring back, the spring back is strong for high thicknesses [10]. Similar conclusions have been drawn in other studies [11].

Kitayama *et al.* [12], have conducted research on an automotive component, focusing on the need to select an ideal blankholder force. He knows that too little blankholder force causes wrinkles, while too much blankholder force can cause a crack. Gong *et al.*[13] Have also demonstrated that the blankholder force is one of the most critical factors influencing the springback

Drawbeads have been demonstrated to improve springback behavior as wel [14], although they also raise the required forming forces.

In addition to the last point mentioned,.There are two types of drawbead, the step bead and the round bead [15]. They are mechanical brakes inserted into the blankholder surface to limit slippage and thus control the flosw of material during the drawing operation as shown in Fig.1, what plays a crucial role in the spring back. This article explores how both types of drawbead influence the spring back.

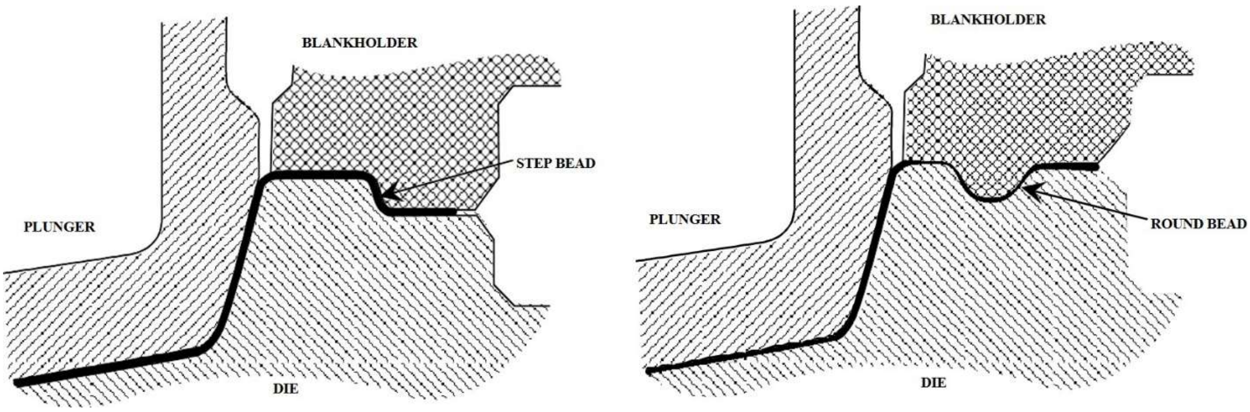


Fig.1. Representation of the step bead and the round bead.

2. Restraint force modeling

The drawbead force is essential for designing and implementing drawbead in stamping processes. This force comes from friction and deformation [16, 17].

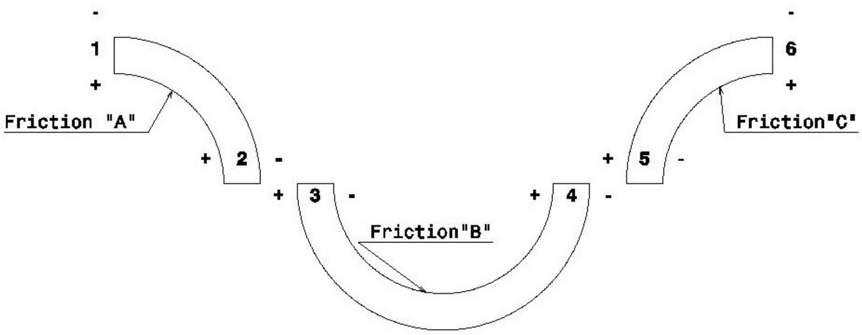


Fig.2. Development of deformation and friction in the drawbead.

Figure 2 shows how deformation and friction develop in the drawbead. The material penetrates the drawbead at point 1 and creates a bend and deformation, while contact of the blank at zone A (between point 1 and 2) creates a friction force.

The material moves between points 3 and 4 and produces the same effects. This sequence of deformation and friction explains the drawbead force.
Levy [18] demonstrated that the DBRF drawbead force is equal to:

$$DBRF = a_0 + a_1 \cdot x_1 + a_2 \cdot x_2. \tag{2.1}$$

Based on the work formula approach:

$$V \cdot W_v = F \cdot d \tag{2.2}$$

where:

V, W_v are respectively the blank volume and the work by volume.
F and d are respectively the distance at which the force is applied and the resultant force.
The work by volume can be calculated as follows:

$$W_v = \int_0^{\partial} \partial d\varepsilon = \left(\frac{K}{1+n}\right) \cdot \varepsilon^{1+n} \tag{2.3}$$

The maximum deformation can be presented as following formula:

$$\varepsilon_m = \ln\left(\frac{R/(t+1)}{R/(t+0.5)}\right) \tag{2.4}$$

where R, t, ε are respectively the radius, thickness of the blank, and the deformation.

This hypothesis utilizes the terms K and n, based on the assumption that the effects of the three successive cycles during the material's movement through the drawbead are proportional to these terms.

Considering that the deformation generated in a distance d Eq.(2.2) equal to the thickness of the blank, Eq.(2.4) becomes:

$$\varepsilon_m = w \cdot t \cdot \left(\frac{K}{1+n}\right) \ln\left(\frac{R/t+1}{R/t+0.5}\right)^{1+n} \tag{2.5}$$

where w is sheet's width.

Even so, when the frictional force is proportional to the normal force, as described by Coulomb friction.and estimating that the drawbead force is proportional to the sum of the force F Eq.(2.5) and the friction force, the *DBRF* force is:

$$DBRF = a_0 + a_1 \cdot x_1 + a_2 \cdot x_2,$$

with:

$$x_1 = F, \tag{2.6}$$

$$x_2 = \mu \cdot x_1, \tag{2.7}$$

μ is friction coefficient.
Where a_0, a_1, a_2 are parameters that are determined by adjustment of experimental data [17].

3. Evaluation of spring back using a step bead

3.1. Experimental analysis findings

To illustrate the importance of the step bead, we used the experimental example of a vertical reinforcement assembly defect that is in docking with the panel and the central reinforcement as shown in Fig.3.

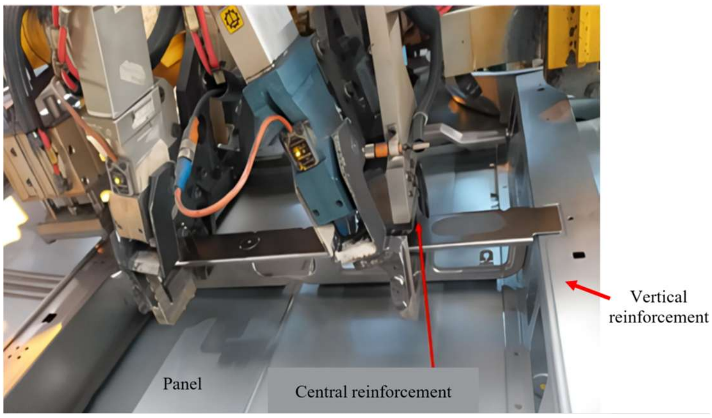


Fig.3. Position of the vertical reinforcement in the assembly tool.

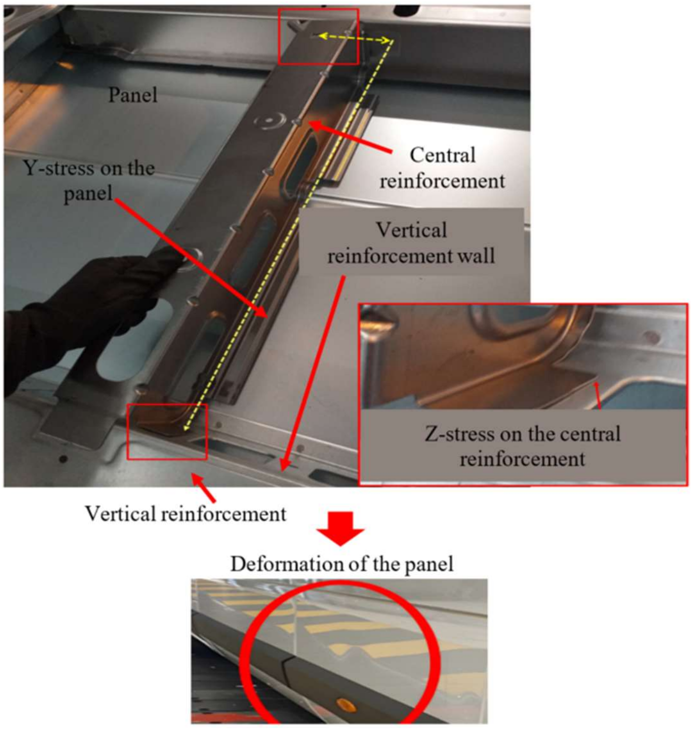


Fig.4. Deformation of the panel following the opening of the vertical reinforcement wall.

This is a *U*-shaped part with high spring back, which is manifested by the wall opening that causes a *Z*-stress at the central reinforcement, which in turn causes a deformation of the panel due to *Y* stress exerted by the central reinforcement on the panel as shown in Fig.4.

This vertical reinforcement is stamped by a double-effect process and has steps implanted only at the ends, as shown in Fig.5.

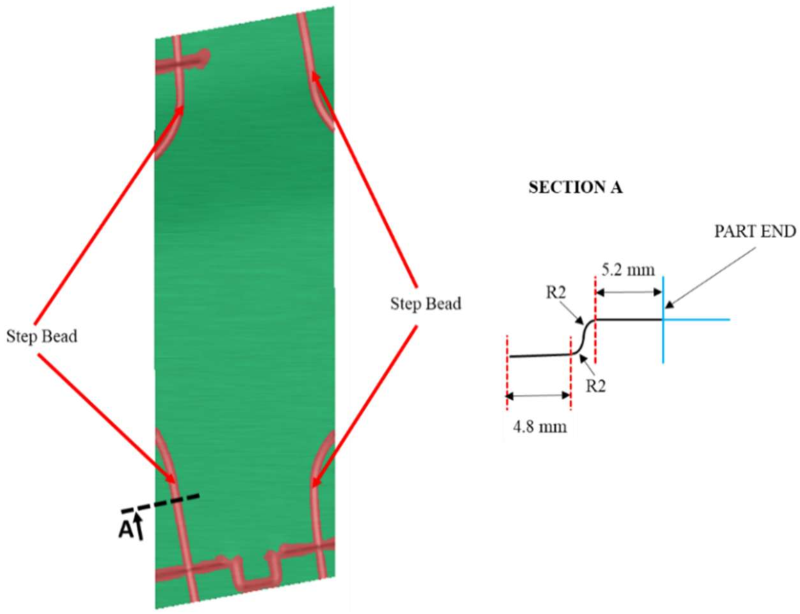


Fig.5. Representation of the step bead on the blank during blanking holder.

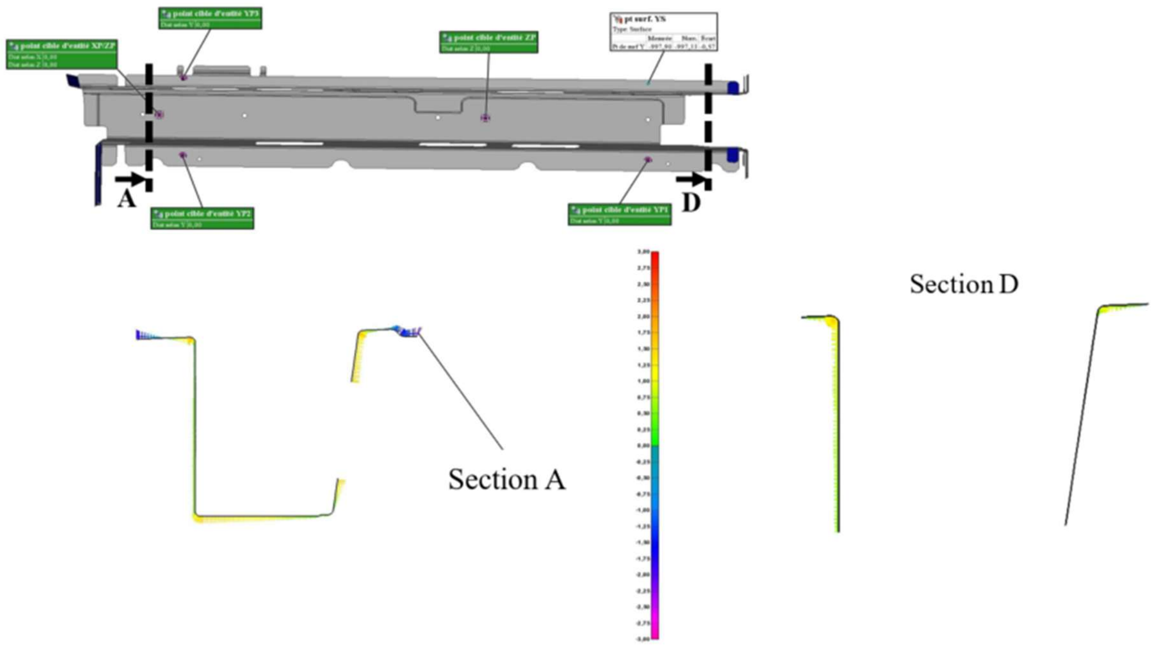


Fig.6. The result of areas not exposed to the effect of step bead during blanking holder.

The information concerning the part and the process is shown in the table below:

Table 1. Data for the range of the vertical reinforcement.

Thickness (*mm*)	Material type	Nuance	Modulus of Young (*GPA*)	Ratio of Poisson	*Rm* (*MPa*)	Process type
1.2	medium strength steel	E335D	*210*	*0.3*	*439*	double effect

To further our analysis, we carried out a scan of the actual finished part to visualize areas with high spring back value via POLYWORKS software, while positioning the part to maintain the physical assembly conditions of the part as shown in Fig.6. The result of areas not exposed to the effect of step bead during blanking holder are shown also in Fig.6.

The result of Fig.6 show a strong spring back value in areas not exposed to the effect of step bead (sections B-C), visible through large openings in the side face up to *3 mm* (red area).

Figure 7 shows the scan results for areas exposed to the effect of step bead during blanking holder.

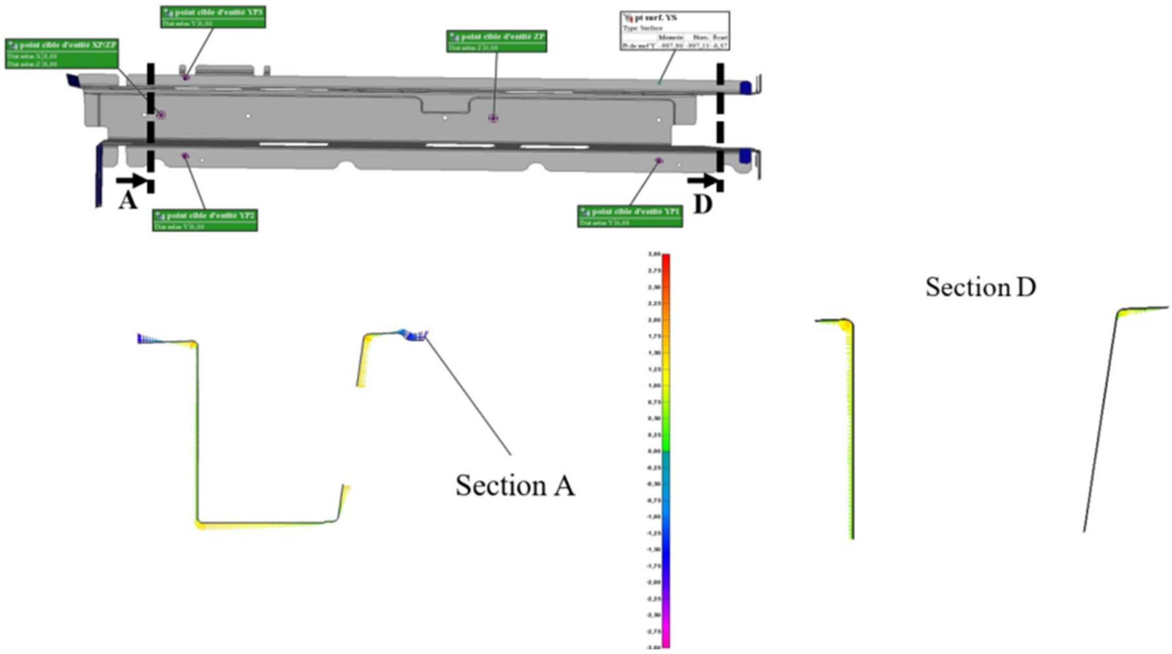


Fig.7. The result of areas exposed to the effect of step bead during blanking holder.

The result of Fig.7 shows that the gap between the part designed (nominal) and stamped part does not exceed *1.5 mm*, unlike the results in Fig.6 where the gap reaches *3 mm*. which shows that the presence of step bead at the ends has reduced springback in these areas. Hence the importance of the step bead for reducing springback.

3.2. Numerical simulation study

3.2.1. Rear door sash frame

This study used a rear door sash frame as an example as shown in Fig.8. The information concerning this part is set out in the table below:

Table 2. Data for rear door sash frame.

Thickness (*mm*)	Material type	Nuance of material	Modulus of Young (*GPA*)	Poisson's ratio	*Rm* (*MPa*)	Process type
0.85	Medium strength steel	ES	*210*	*0.3*	*307.7*	simple effect

The type of process used is simple effect, with a step bead placed around the stamped part and two symetrical part(right/left) per press shot as shown in Fig.9.

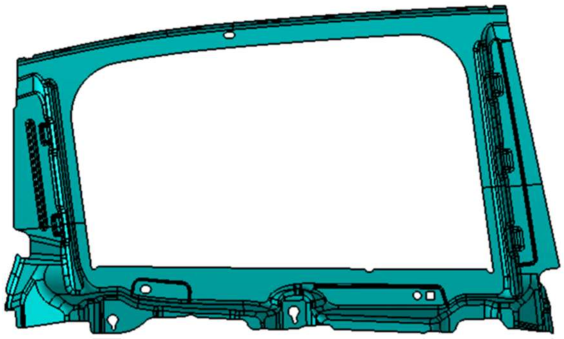
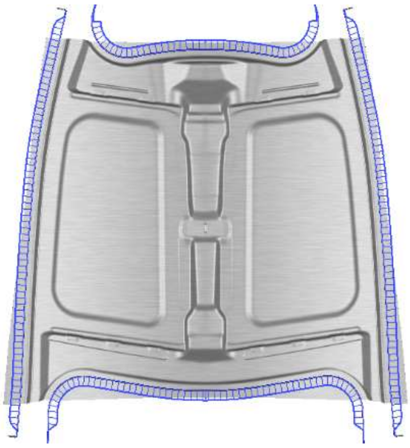


Fig.8. Rear door sash frame.



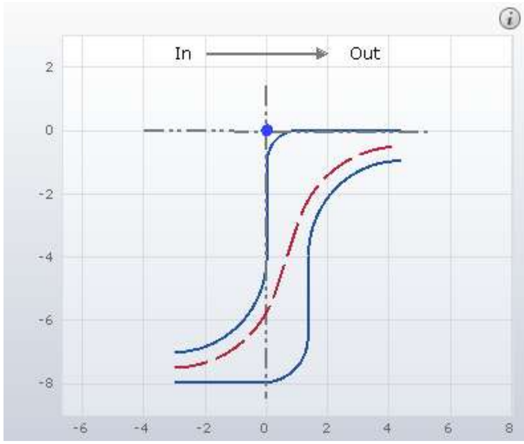


Fig.9. Representation of the step beads in the process of the rear door sash frame.

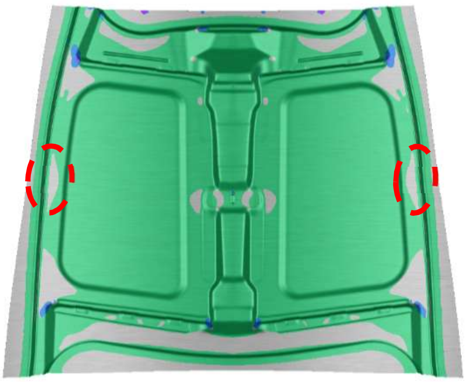


Fig.10. Formability of the rear door sash frame with a nominal blank holder Force of 95T.

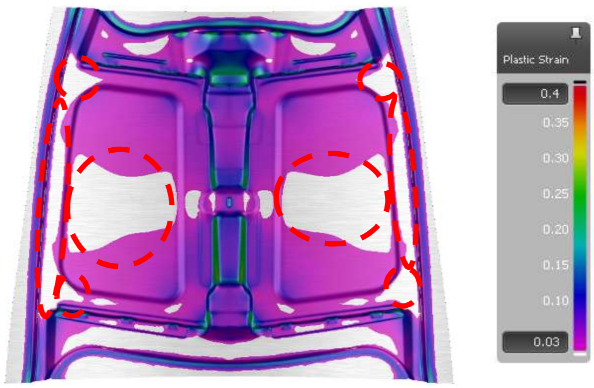


Fig.11. Plastic strain of the rear door sash frame with a nominal blank holder Force of 95T.

To evaluate the spring back of the part, an analysis can be performed on the formability result by identifying the areas lacking tension and the plastic strain result, good plastification with fewer areas lacking tention indicates that the part has the best spring back.

The results of the formability of the part and the plastic strain are shown in Figs 10-11 respectively.

Based on the formability result, all areas are well stamped without problems and visualized through green zones, except for a few grey areas which represent a lack of tension, the areas in red are the grey areas that must be treated as a priority, because they exist on the part and may have a geometric impact, the other grey areas will be in the scraps after trimming in the other operations.

Although the plastic strain results shown in Fig.11 are good, some areas where plastic strain is less than *3*%, such as functional areas surrounded by red, represent docking zones that influence the geometry of the part and thus the final assembly of the part, which requires us to do another test by increasing the blankholder force to increase the effect of the step bead.

This second test was carried out with a blankholder force increased by *30*% from the nominal value, the results are shown in Fig.12.

Fig.12. Formability of the rear door sash frame with a blank holder Force of 123.5T.

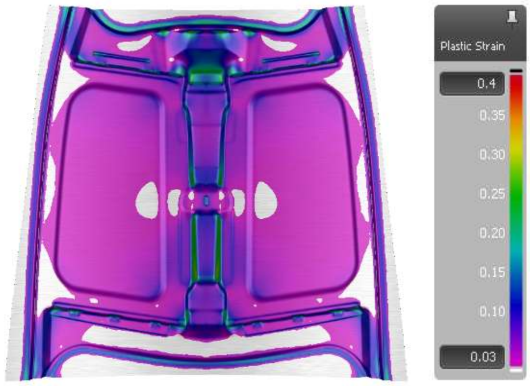


Fig.13. Plastic strain of the rear door sash frame with a blank holder Force of 123.5T.

We find that the grey areas which represent a lack of tension have been corrected by becoming green as shown in Fig.12 and better plasticification with a plastic strain exceeding *3*% as shown in Fig.13 with increased blankholder force, so an increased blankholder force can also play an important role in improving the springback by generating more restraining force of the bead. This allows for more tension of the blank and better plastification.

From this we conclude that the step bead allows a better results of the spring back, because it generates more tension and allows a better plastification. This allows a better result of springback.

3.2.2. Partition wall

This study used a rear door sash frame as an example as shown in Fig.14.The information concerning this part is set out in the table below:

Table 3. Data for partition wall.

Thickness (*mm*)	Nuance of material	Young's modulus (MPA)	Poisson's ratio	*Rm* (*MPA*)	Process type
0.7	CR3	*210000*	*0.3*	*291*	simple effect

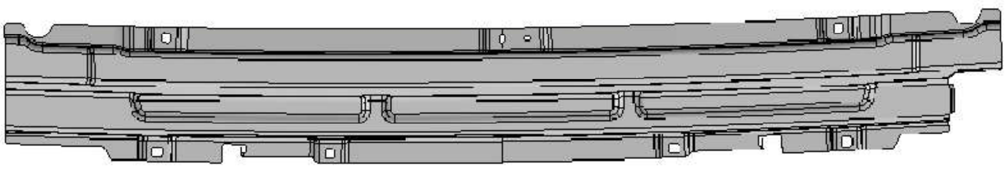


Fig.14. Partition wall.

The type of process used is simple effect, with a step bead placed around the stamped part as shown in Fig.15.

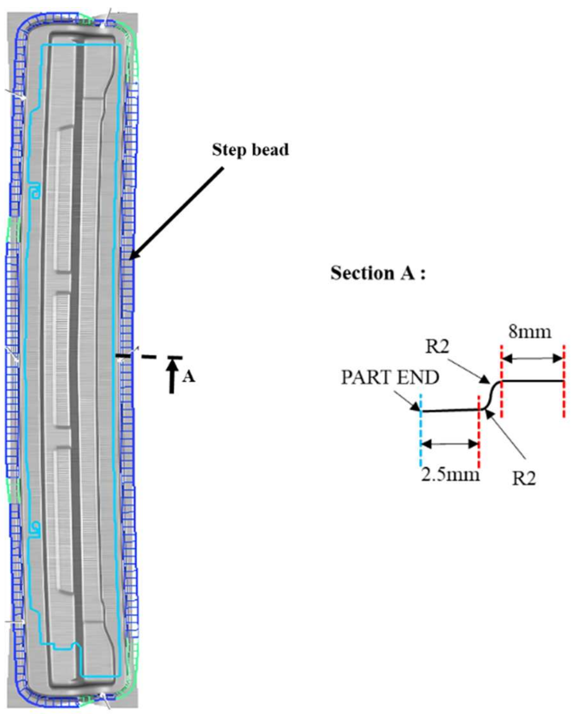


Fig.15. Representation of the step bead in the process of the partition wall.

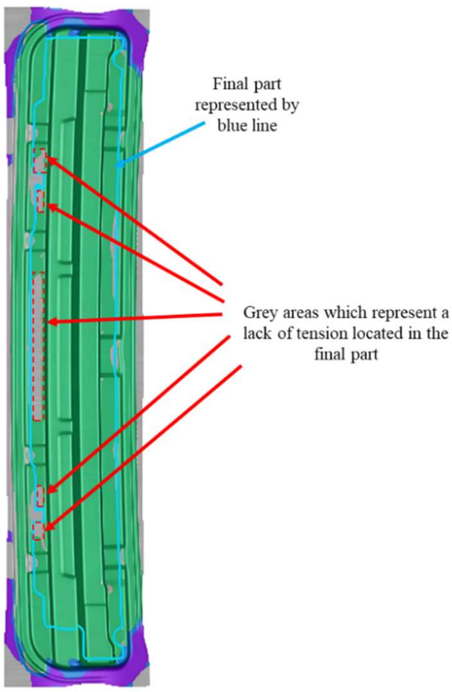


Fig.16. Formability of the partition wall with a blank holder Force of 89.63 T by using step bead.

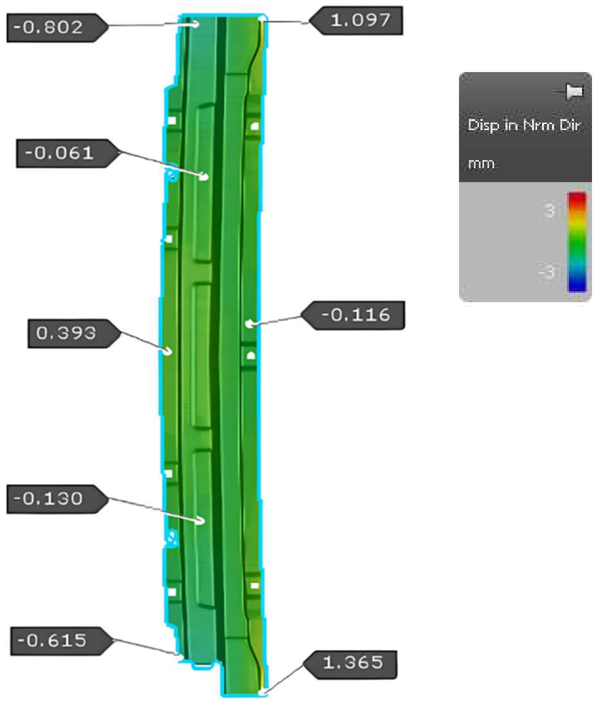


Fig.17. Spring back result of partition wall with step bead.

This section will study the springback by analyzing formability and the results of spring back, as shown in Figs 16-17.

Based on the formability result, all areas are well stamped without problems and visualized through green zones, except for a few grey areas which represent a lack of tension located in the final part , the blue line represent the final part after trimming.

Figure 17 shows the spring back result of the final part after trimming. Values between *0.061 mm* and *1.365 mm* indicate good spring back result.

4. Evaluation of spring back using a round bead

4.1. Numerical simulation study

4.1.1. Partition wall

In this section, we used the previously utilized partition wall with the same data (material, press type, thickness, etc.), just changing the step bead by a round bead around the part as shown in the Fig.18.

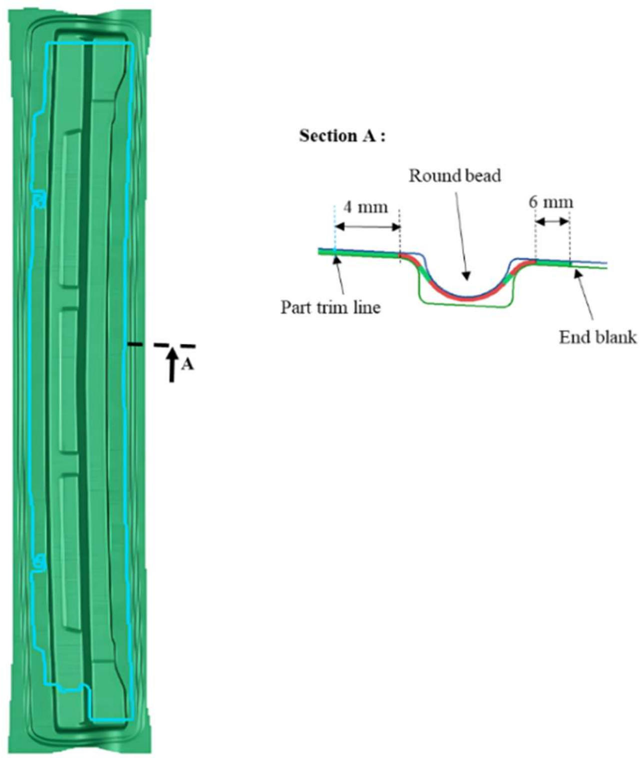


Fig.18. Representation of the round bead in the process of the partition wall.

As done previously in the previous section, we will study the springback by analyzing formability and the results of spring back , as shown in Figs 19-20.

The formability results in Fig.19 show a higher proportion of grey areas located in the final part., which explains the insufficient tension and that these areas do not pass to the plasticity zone, so they remain in the elastic zone, the blue line represent the final part after trimming

Figure 20 shows the spring back result of the final part after trimming. Values between -*1.801 mm* and *2.248 mm* with red areas and purple areas, indicate bad spring back result.

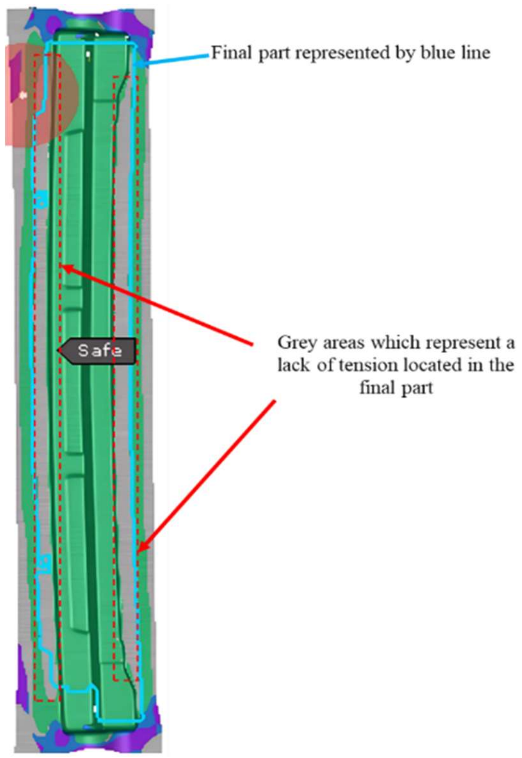


Fig.19. Formability of the partition wall with a blank holder Force of 89.63 T by using round bead

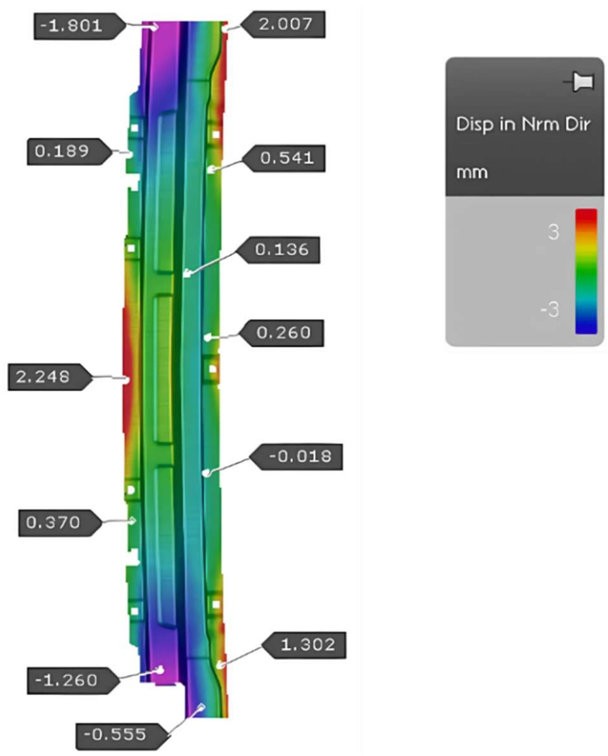


Fig.20. Spring back result of partition wall with round bead.

4.1.2. Sill outer reinforcement

To verify the springback in the process using a round bead, simulations were made on a sill outer reinforcement as shown in Fig.21.

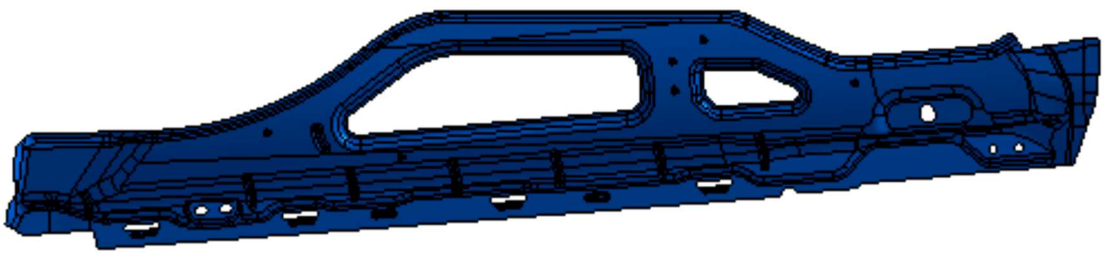


Fig.21. Sill outer reinforcement.

The information concerning this part is set out in the table below:

Table 4. Data for the range of the sill outer reinforcement.

Thickness (*mm*)	Material type	Nuance of material	Young's modulus (*MPA*)	Poisson's ratio	*Rm* (*MPA*)	Process type
0.8	medium strength steel	E335D	*210000*	*0.3*	*439*	simple effect

The type of process used is simple effect, with a round bead placed around the stamped part and two symetrical part (right/left) per press shot as shown in Fig.22.The results of the formability of the sill outer reinforcement and the plastic strain are shown in Figs 22-23 respectively.

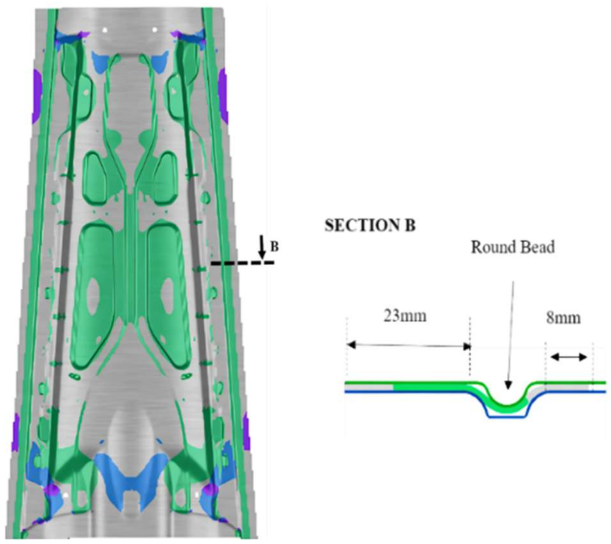


Fig.22. Formability of the sill outer reinforcement with a blank holder Force of 80T.

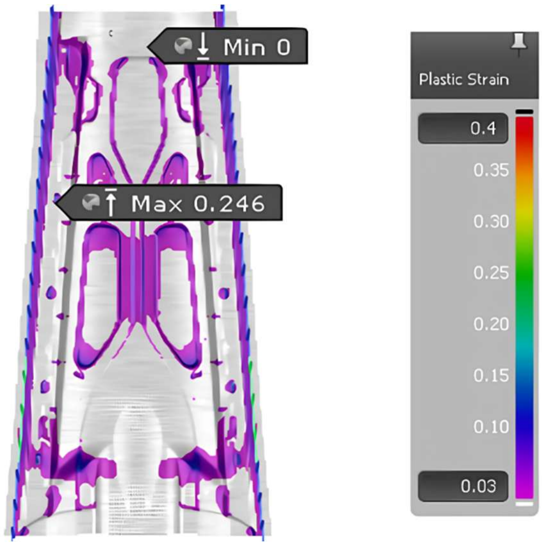


Fig.23. Plastic strain of the sill outer reinforcement with a blank holder Force of 80T.

The formability results in Fig.22 show a higher proportion of grey areas than green areas, which explains the insufficient tension and that these areas do not pass to the plasticity zone , so they remain in the elastic zone.

To further the study, the analysis of plastic strain in Fig.23 shows that the plastic strain in most areas (white areas) is less than 3%, confirming the previous results of formability.

Fig.24. Formability of the sill outer reinforcement with a blank holder Force of 104T.

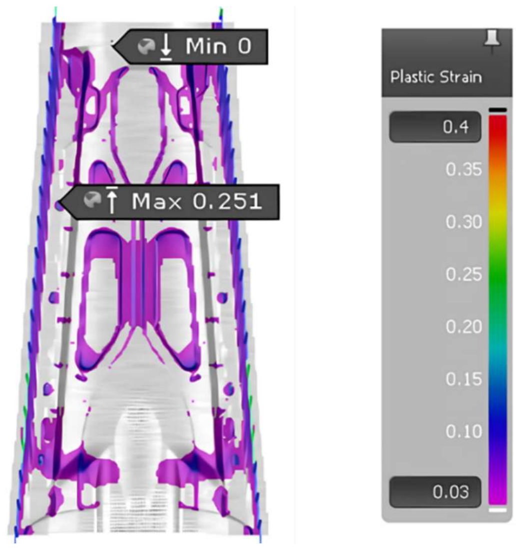


Fig.25. Plastic strain of the sill outer reinforcement with a blank holder Force of 104T.

To check if a good plastification of the part could be achieved, we made tests by increasing the blankholder force to 104T in order to increase the effect of the round bead, the results of formability and plastic strain are shown in Figs.24-25 respectively.

Figure 24 shows that most of the areas remain in the elastic zone without going into the plastic zone despite the increase in blankholder force, Figure 25 confirms the result of formability with white areas of less than 3%, what impacts the spring back of the part

From this, it can be concluded that the round bead do not permit better plastification of the part because they do not generate enough tension. This will affect the results of the springback.

5. Discussion and results

The objective of the study is to decrease the spring back based on the drawbead. To prove the importance of the step bead, we analyzed the assembly defect of a vertical reinforcement seen in Fig.3, the spring back visualized by an opening of the wall of the part by a gap between *2 mm* and *3 mm* along the wall, at the level of the area not exposed to a step bead in the middle of the part as shown in Fig.6. By contrast, the part does not undergo a remarkable opening of the walls to the edges as shown in Fig.7 that show a maximum gap of *1.5 mm* which does not cause assembly defects, showing that the use of the step bead contributes to a *50*% improvement in the spring back. Another numerical analysis was made on the rear door sash frame by analyzing the formability and plasticity of the part, the formability and plastic strain gives a good result except for some small areas which one still wanted to plasticize, because it is an skin part, as shown in Figs 10-11, The blank holder force was increased, which gave us a part without any grey area and with good plastic strain exceeding *3*% as shown in Figs 12-13, another simulation of the spring back of the partition wall with a step bead around the part shows a good result with values that vary between *0.061* and *1.365* as shown in Fig.17. The three examples show the importance of the steps in reducing the spring back.

To see the effect of the round bead, the same partition wall was used while maintaining the same properties mentioned in Tab.3, the simulation of the spring back shows a strong spring back in some areas with values that vary between *-1.801 mm* and *2.248 mm*, Another numerical analysis was made on the sill outer reinforcement by analyzing formability and plastic strain with a round bead implanted around the part, the result of formability is not good with more grey areas, especially at the level of the docking zones, and plasticity of less than *3*% in most areas , which means that most areas have not been plasticized as shown in Figs 22-23, the reason why the blank holder force was increased to 104T, but without any effect on the result as shown in Figs 24-25.

So the round bead do not well plastized the blank, so that all the zones enter in the plastic zone, unlike the step bead which allows to obtain a better plasticity and consequently a better spring back.

6. Conclusion

The study indicates that step beads may reduce springback more effectively than round beads. The conclusions established by this analysis were the following:

- The sash door frame used as an example, using a step bead with increased blankholder force results achieve a good plastification of the part, which leads to favorable spring back result , It is known that the shape of the part can influence the reduction of springback, especially thanks to the presence of stamped surfaces favoring its plastification. However, this part has few stamped surfaces, indicating that the form plays a limited role in improving springback, thus leaving most of the positive effect to the step bead.
- Using step bead to reinforce areas with high spring back value can result in a smaller wall opening (as in the case of vertical reinforcement).
- The sill outer reinforcement used as an example, consisting of several stamped shapes that should normally positively improve the plasticity of the part and therefore the improvement of the spring back, which proves that the contribution of form in this case does not result in a good result, because there are still grey areas in the formability results , which leaves a large percentage of contribution to the round bead used, the latter did not participate positively despite the increase in blankholder force. so the addition

of a round bead in the process did not allow to stretch the part well, which gave a bad plastification and then bad spring back result of the part.

- Using round bead, it has been shown that the part remain in the elastic zone without going into the plastic zone, even if the blankholder force increases, there are still grey areas in the formability results(as in the case of sill outer reinforcement).
- Simulations were carried out on the same part (partition wall), while changing just the drawbead type, the results proves that the step bead allows a better spring back result.

Applications

The results of this study will help the plants predict the selection of drawbead to improve the spring back.

This approach can be applied not only to the automotive industry, but to any industry using stamping processes.

Other parameters can also be studied to improve spring back.

Nomenclature

d – distance over which the force has applied
F – resultant force
R – radius.
t – thickness.
W_v – work per unit volume
w – width of sheet.
V – volume of the sheet.
ε_m – maximum deformation
μ – friction coefficient

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Received: February 6, 2025
Revised: May 22, 2025