Determining the influence of process parameters during ironing using FEA

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Abstract

The ironing process is very common in modern industry, so it is very important to determine the influence of process parameters on process stability. In this paper, the influence of two important parameters, friction and blank holding force, was analyzed using the finite element method. For both parameters, three values were considered that are within some theoretically acceptable limits, so the experiment was organized according to the Taguchi matrix L9. The Cocroft Latham damage model was used to analyze the process. In addition to damage, the influence of parameters on sheet thickness, stress state, forming load and other parameters was analyzed.

Keywords: Ironing, FEA, Cocroft Latham, damage, friction, blank holding force, UN SDG 9

1. Introduction

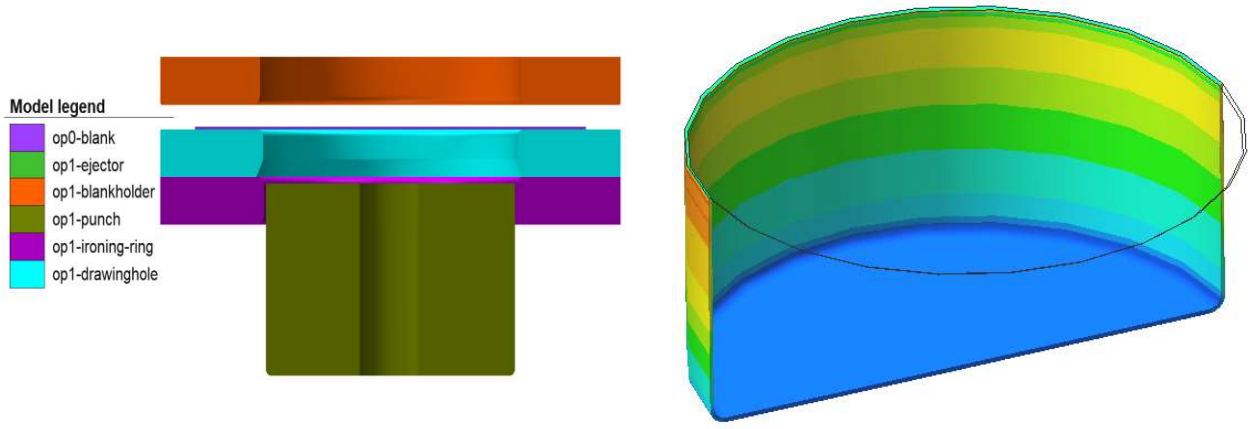
The process of deep drawing with thinning is of great interest for many industries such as automotive or military. In this paper, an industrial example of deep drawing with thinning is analyzed using FEA. Numerical simulation was performed in the Simufact forming software. The Cocroft Latham damage model [1] was used to analyze the results. The Cocroft Latham model is widely used for material failure analysis. The forming limit diagram [2] is most commonly used for sheet metal forming and failure assessment. The Cocroft Latham model is based on the idea that failure occurs when the accumulated plastic strain energy under tensile stress reaches a critical value..

2. Experiment plan and Methods

The considered process consists of two operations: deep drawing and ironing. The process layout is shown in Figure 1. The experiment was designed according to the Taguchi matrix L9 model, two factors with three levels each. As mentioned, friction and holding force were considered. The value of the contact friction coefficient ranges from 0.08 to 0.15 according to domestic literature. The value of the friction coefficient in the numerical experiment will have the values 0.08, 0.12 and 0.16. The value of the holding force will have the values 8 kN,

10 kN and 12 kN. Although the holding force has an effect only during deep drawing, it will be interesting to check whether it will have an effect on the final result of the process after ironing.

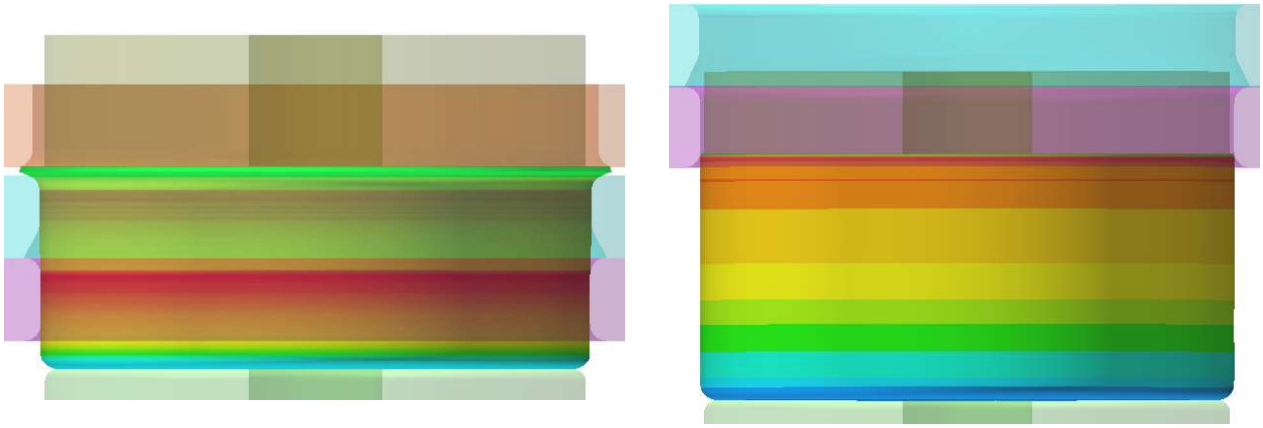
The results that will be analyzed are the value of the forming load, damage according to the Cockroft Latham model and wall thickness. The influence of the parameters on the value of the deformation force will be analyzed according to the less-better model, as well as for the damage model. For the wall thickness, the amount of deviation from the nominal value will be considered.



a) b)

Figure 1. a) Deep drawing and ironing die and b) final part

The operation flow is shown in Figure 2. The starting piece is a carbon steel sheet Ø102x0.6 mm. The steel designation according to DIN is 1.0303 (AISI 1005). First, standard deep drawing is performed, during which the sheet is slightly thinned by about 10%, so the sheet thickness is 0.54 mm. After deep drawing, the sheet is thinned, or ironed, to a dimension of 0.48 mm. Figure 2 a) shows the end of the deep drawing process, and the figure 2 b) shows the ironing process.



a) b)

Figure 2. a) End of deep drawing and b) ironing process

A Quadtree mesh of 0.16 mm size was used in the numerical simulation. There is a dilemma as to whether it is better to use the Coulomb friction model or the constant friction model to define the friction conditions in the numerical simulation of the ironing process, but it was concluded that the Coulomb model, or sliding friction, better fits the process. The experimental plan with parameter values is shown in Table 1.

Table 1. Experiment plan

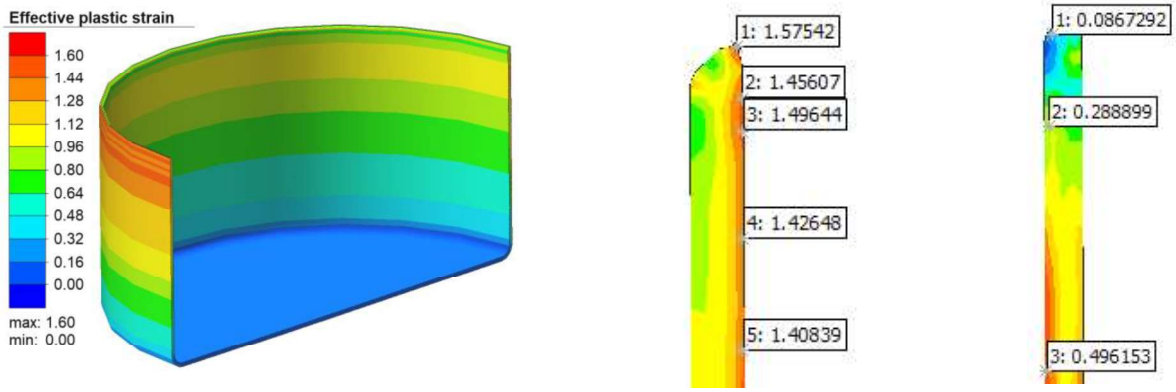
Experiment	Friction coefficient	Blank holding force
1	0,08	8 kN
2	0,08	10 kN
3	0,08	12 kN
4	0,12	8 kN
5	0,12	10 kN
6	0,12	12 kN
7	0,16	8 kN
8	0,16	10 kN
9	0,16	12 kN

3. Results

As stated, the values of the parameters according to the Cockroft Latham model, the deformation force of the drawing, the deformation force during drawing with thinning or ironing, and the thickness of the sheet will be considered from the results. The results are shown in Table 2 and Figure 3.

Table 2. Numerical experiment results

Experiment	Effective plastic strain	Cocroft-Latham	Deep drawing forming load, kN	Ironing load, kN	Thickness, mm
1	1,6	0,52	43,93	52,52	0,48
2	1,69	0,63	46,12	52,83	0,48
3	1,65	0,52	48,37	51,23	0,48
4	1,6	0,52	46,1	58,94	0,48
5	1,64	0,53	48,49	57,48	0,48
6	2,67	0,56	51,03	60,51	0,48
7	1,65	0,52	48,39	64,31	0,48
8	1,85	0,69	50,89	63,94	0,48
9	1,73	0,55	53,48	77,7	0,48

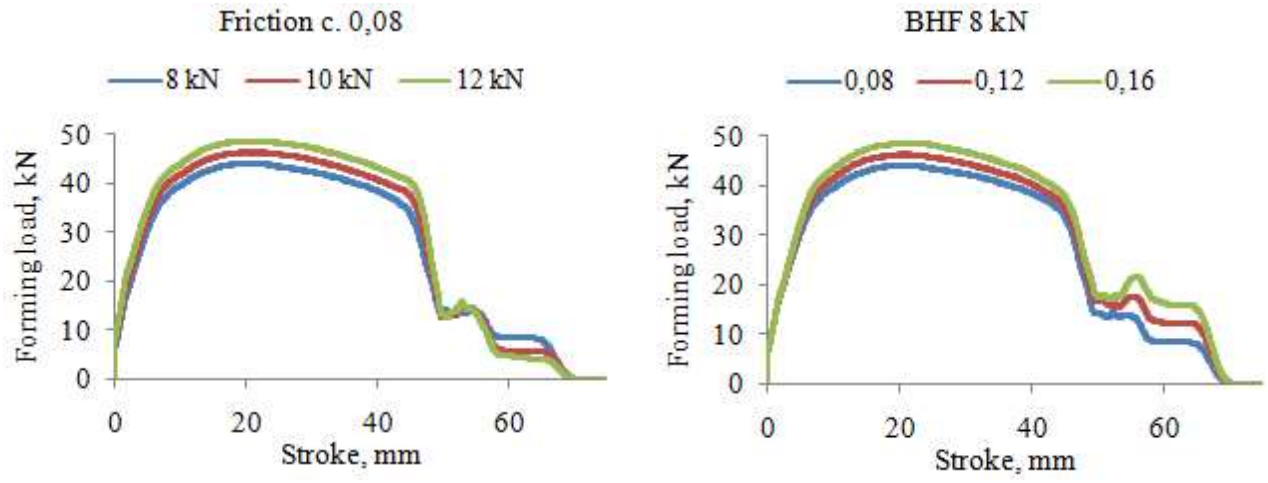


a) b) c)

Figure 3. a) Effective plastic strain at experiment no. 4, b) enlarged view and c) value of Cocroft Latham

4. Discussion

Based on the results shown in Table 2, it can be seen that the forming process will be successful for all combinations of parameters. The values of the effective plastic deformation and the Cockroft Latham criterion are within the predicted limits. The numerical experiment has shown that deviations of the holding force in the first operation or friction in the amount of ±20% do not lead to deviations in the sheet thickness. A clear influence is seen in the values of the pulling force and significantly less in the ironing force. The force-stroke diagrams are shown in Figure 4. An increase in the friction coefficient and holding force leads to an increase in the deformation pulling force, which coincides with the theoretical assumptions.



a) b)

Figure 4. Stroke – forming load diagram a) constant friction and different BHF and b) constant BHF and different friction coefficient

5. Conclusions

The deep drawing with thinning experiment showed that changing the friction and blank holding force parameters within theoretically acceptable limits will not compromise the success of the operation. Increasing friction and BHF leads to a significant increase in the of the deep drawing forming load. The use of the damage criterion is very practical because it provides the engineer with a clear view of how much the material can deform before failure occurs.

Acknowledgements

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