BLANK HOLDER FORCE OPTIMIZATION OF HEMISPHERICAL PRODUCT USING NUMERICAL SIMULATION

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Abstract

Blank holder force is important parameter in drawing process and mainly because of wrinkle prevention. When complex parts are drawn the special case can occur – there is no way to produce the product by using constant blank holder force. In this case is necessary to use variable blank holder force. This contribution deals with influence of variable blank holder force on hemispherical product in drawing process. Based on maximal and minimal constant blank holder force determination were applicated 6 various curves of variable blank holder force. The best results were achieved by curve "F" which has 2 maximal values in start and end of process and one minimum in the middle with value of thick thinning ratio 12.2 % and obversely, the worst results by curve "B" which has maximal value of blank holder force until middle of process and than linear decreasing with value of thick thinning ratio 12.9 %. Influence of this variable blank holder force is remarkable and in term of product quality is possible to achieve optimal blank holder force in whole drawing process.

Key words

deep-drawing, sheet, simulation, blank holder force

Introduction

Production of sheet metal products is one of the basic flat forming production processes mainly because of high productivity, low price and minimal scrap. The drawing process is influenced by many factors (technological, material, designer) which cause product defects. Material wrinkle and fracture are two most common and serious defects in drawing process and it define drawing limits. Wrinkling occurs in flange of drawn part because of stress normal to thickness increasing. However, fracture occurs in consequence of tensile stress. To prevent these defects is used mainly blank holding force, which is a very important parameter and has a significant influence on the whole process of drawing. In the case of low blank holder force the material is wrinkled while increasing blank holder force means higher risk of material fracture.

In drawing process, there are stress changes in material and therefore should be also modified the blank holder force. Nowadays tendency is application of various methods of the blank holder force control during the drawing process, as well as in different parts of product. The contribution deals with applying different curves of blank holder force in drawing process [1, 2].

Experiment

There was used an experimental material for that work - sheet steel DC 01 EN 10130-91, thickness s = 1 mm, cold rolled from low-carbon plain steel of ductile quality. Specifications of material chemistry and mechanical properties are shown on Tab. 1 and Tab. 2. [3]

CHEMISTRY OF EXPERIMENTAL MATERIAL DC 01 Table 1

Steel quality	C [max wt. %]	Mn [max wt. %]	P [max wt. %]	S [max wt. %]
DC 01	0.10	0.50	0.035	0.035

MECHANICAL PROPERTIES OF EXPERIMENTAL MATERIAL DC 01 Table 2

Steel quality	S_y [max MPa]	S_u [MPa]	A_{80} [min %]
DC 01	270	340 ÷ 400	>32

• *FEM analyse*

Numerical simulation development of flat forming has significant improve lately. At the present is important and necessary to use numerical simulation and prevent any failure in process.

DYNAFORM is the complete die system simulation solution and has been used for this study. There is shown model of simulation on the Fig. 1 [4]

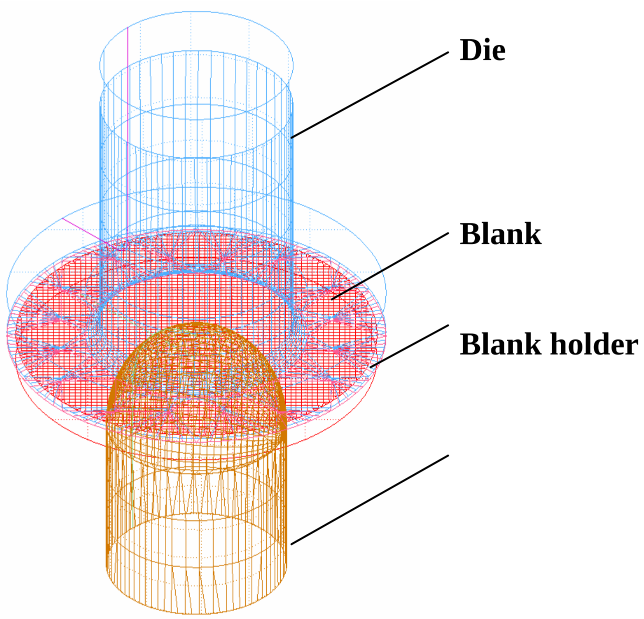


Fig. 1 *Simulation model*

- *Deep-drawing parameters:*

Die diameter (inside)	– D_1 = 103 [mm]
Die radius	– R_1 = 7 [mm]
Punch diameter	– D_2 = 100 [mm]
Blank diameter	– D_3 = 200 [mm]
Blank thickness	– a_0 = 1 [mm]
Drawing stroke	– h = 70 [mm]
Velocity	– v = 50 [$mm.s^{-1}$]
Friction coefficient	– f = 0.125

- *Drawing limits estimation*

As noted previously, in the case of low blank holder force there is wrinkle usually in the flange of the drawn part. When increasing the blank holder force, wrinkle is reducing. However, the large value of the blank holder force will cause fracture.

According the formula:

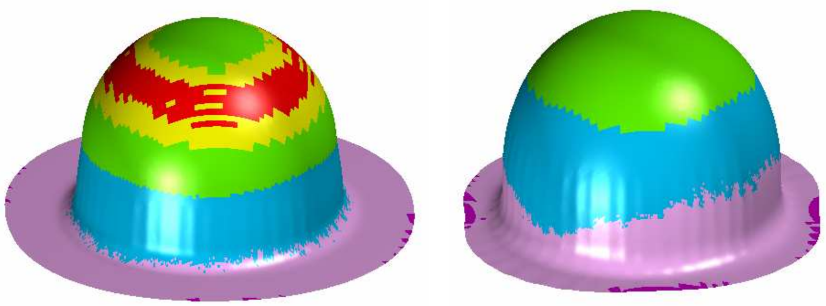
$$F_p = S.p = \frac{\pi}{4}\left[D_3{}^2 - (D_2 + 2.R)^2\right]p \qquad (1)$$

where D_3 – blank diameter; D_2 – product diameter; R_1 – die radius; p – blank holder pressure

has been calculated blank holder force F_p = 62 [kN] and by using numerical simulation has been estimated limits of drawing process shown in Tab.3. There are several ways to determine wrinkle and fracture, in this case was used forming limit diagram and thick incrassation ratio, thick thinning ratio respectively. [2, 5]

LIMITS OF BLANK HOLDER FORCES Table 3

no.	F_p (kN)	Thick incrassation ratio [%]	Thick thinning ratio [%]	Status
1	140	58.0	8.0	Fracture
2	130	40.1	9.9	Fracture risk
3	125	34.0	10.6	Correct
4	62	25.7	14.4	Correct
5	45	21.2	15.2	Critical wrinkle
6	40	20.3	16.3	Massive wrinkle



a) *b)*

Fig. 2 *Product with value of blank holder force*
a) F_p = 140 kN b) F_p = 40 kN

Results from Tab.3, fracture occurred, when was used the value of blank holder force 140 kN (Fig. 2a), while in case of 40 kN blank holder force, there was wrinkle attended (Fig. 2b). It is because of product is in shape of hemisphere and there is markedly wrinkle, therefore it is necessary to increase the blank holder force. Based on the above tests have been determined the safe range of blank holder force from maximum 125 kN to minimum 50 kN.

- *Variable blank holder force application*

As noted previously, variable blank holder force has been determined in safe range of 50 kN to 125 kN, based on the above tests. There are shown curves of blank holder forces depended on time steps on Fig. 3. The other parameters of drawing process haven't been changed.

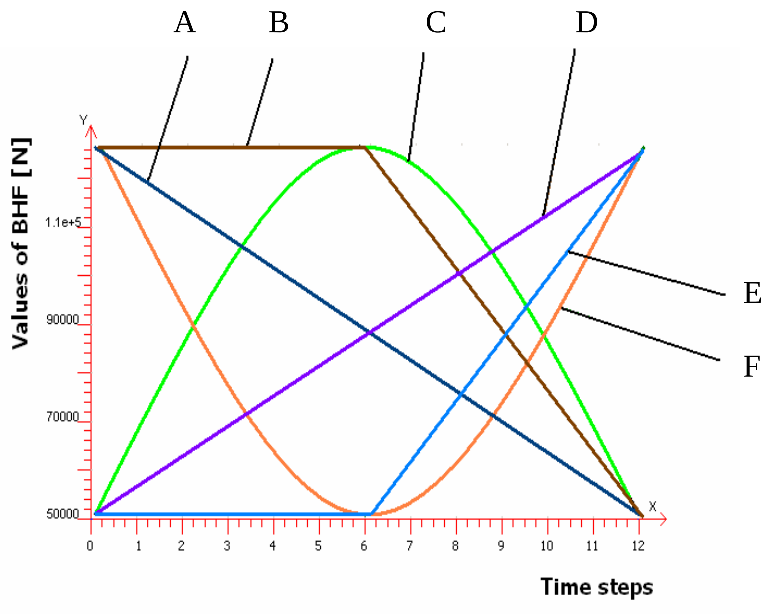


Fig. 3 *Curves of blank holder forces*

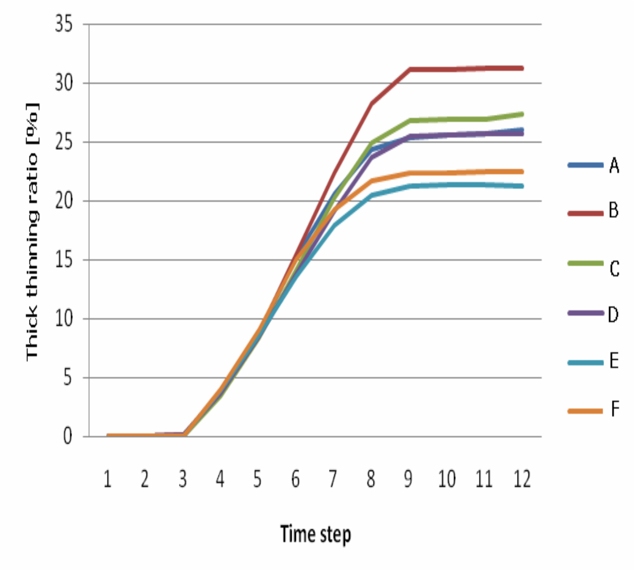
Results and discussion

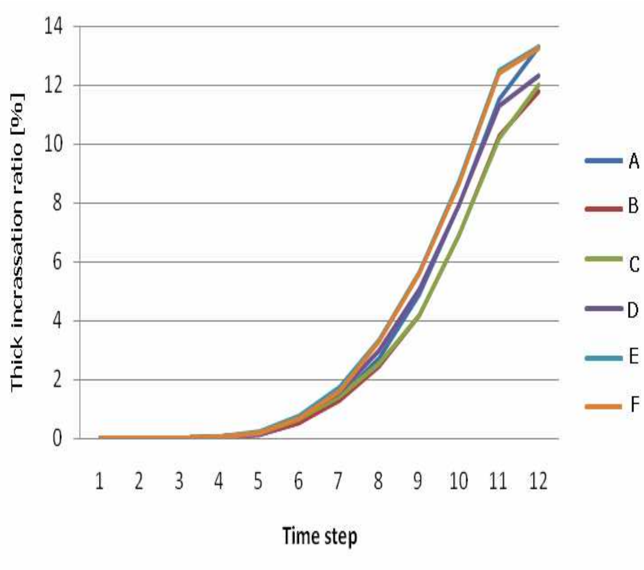
Constant blank holder force has been replaced by variable blank holder force in range of 50 kN to 125 kN according to Fig. 3. Influence on product quality is remarkable and the results of thick incrassation ratio (thick thinning ratio) depended on the time are shown on Fig. 4.

It appears from this that the best results we gained by using „F" curve, where the thick thinning ratio is 12.2 % and thick incrassation ratio is 22.4 %, while in case of „B" curve, thick incrassation ratio is 32.2 % and thick thinning ratio is 12.9 % and that were the worst results.

Thereinafter, in the case of chart of thick thinning ratio (Fig. 4a) after 8th time step there's no markedly change in drawing process, while in the case of chart of thick incrassation ratio after 8th time step there are still changes which have significant influence on the product quality. These changes were also important for process evaluation.

There are compared values of all curves of thick incrassation ratio and thick thinning ratio in Tab. 4. The best result („F"curve) with forming limit diagram is shown of Fig. 5.





a) *b)*

Fig. 4 *Chart of time step and:*
a) thick thinning ratio b) thick incrassation ratio

RESULTS OF ALL CURVES Table 4

No.	Curve	Thick incrassation ratio [%]	Thick thinning ratio [%]
1	F	22.4	12.2
2	E	21.3	13.1
3	D	25.7	12.9
4	A	26.1	13.4
5	C	31.6	12.6
6	B	32.2	12.9

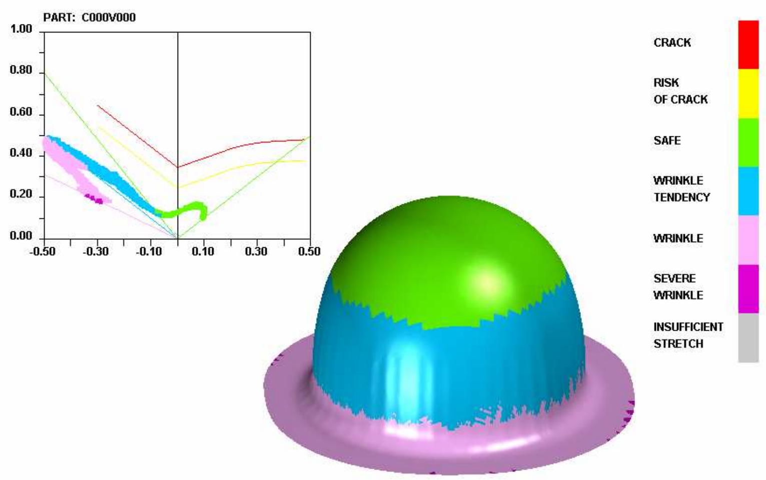


Fig. 5 *Product using „F_p“ blank holder force according to „F“ curve*

Conclusion

Contribution deals with influence and optimization of blank holder force on product quality by using numerical simulation. In drawing process, there are stress changes in material and therefore should be also modified the blank holder force. After determination of maximal and minimal constant blank holder force there were applicated 6 different profiles (curves) of variable blank holder force. The best results were achieved by curve “F” which has 2 maximal values in start and end of process and one minimum in the middle and obversely, the worst results were achieved by curve “B” which has maximal value of blank holder force until middle of process and than linear decreasing. Based on achieved results we can see that influence of blank holder force on product quality is remarkable. By using variable blank holder force in compare with constant blank holder force is possible to significantly improve drawing process and in term of product quality is possible to achieve optimal blank holder force in whole drawing process.

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