# Parameters optimization for aluminum alloy magnet cover with stamping based on FEM simulation

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**Abstract.** In view of the phenomenon that defects such as fracture, wrinkling and springback may generate when box shaped parts are stamped, however better surface quality on parts have been required. The process of drawing, cutting and springback for magnet covers with arc top and straight sidewall are simulated using the finite element analysis software Dynaform. The influences of binder force and die fillet radius on the stamping properties are studied by single factor analysis method, the stamping properties of parts under every condition are analyzed and reasonable process parameters are obtained by analyzing quality indexes of the maximum thinning rate, the maximum thickening rate and the amount of springback under every working condition.

## Introduction

Magnet covers of motors are shell parts used for shielding magnetic field. To ensure no magnetic field leakage, the covers should have good tightness and magnetic shielding, and also have good connectivity and matching. The aluminum alloy with a better magnetic isolation is selected as the material of the magnet cover. When the thickness of the magnet is close to the wavelength of electromagnetic wave, the shielding effect is good. The wavelength of the high frequency electromagnetic wave is usually short, thus the thickness of the cover is often less than 1mm. Because of special box shape with thin wall, so the magnet cover is not suitable for machining. While the aluminum alloy has good plasticity and deforming performance, the box shaped part with thin wall is usually made by stamping[1]. Usually, drawing forming of box shaped part is a complex forming process, the defects such as wrinkling, fracture and springback are easily to appear during forming[2-3]. Influence of the process parameters on stamping of the box body is more complex, selecting process parameters ususlly depends on experience, and final process parameters are obtained by repeatedly trials[4]. The longer development period and the difficulty to master forming rule, and to choice appropriate parameters are the main problems for designers.

At present, the stamping process are simulated and analyzed by finite element simulation technology, the stamping laws and solutions of stamping defects can be easily solved by the intuitive, in depth analysis[5-6]. In this paper, the stamping process of certain type of magnet cover is studied, and the forming law and optimized process parameters are obtained using the finite element method.

## Establish FEM model and set process parameters

Figure 1 shows the part drawing of a certain type of magnet cover, the projection in B-B section of the top surface of the magnet cover is arched curve which is symmetric along the $Y$ axis, and the coordinates of the projection curve for top surface on the right side of the $Y$ axis are shown in Table 1. All of walls of the box are vertical edges, the surfaces transimit with small fillets whose radii are all 0.8mm, the material of part is aluminum alloy 316L, and thickness is 0.4mm.

Table 1 Curvilinear coordinates of the top surface

| $X$ /mm | 0 | 14.85 | 20.04 | 26.92 | 32.66 | 37.36 | 41.12 | 44.05 | 46.2 | 47.77 | 49.15 | 50 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $Y$ /mm | 17.4 | 17.4 | 16.95 | 16.22 | 15.44 | 14.51 | 13.48 | 12.39 | 11.3 | 10.24 | 9.27 | 8.5 |

Due to the thin thickness of sheet and the smaller transitional fillets, the defects such as fracture, small plastic deformation in straight wall forming area and springback after cutting are prone to appearing during stamping process[7]. In this paper, the forming, cutting and springback processes of parts are simulated by software Dynaform, and the FEM model of the magnet cover is shown in Figure 2.

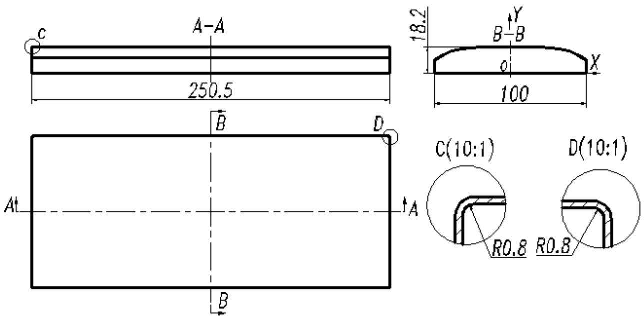



Figure 1. Part drawing of magnet cover

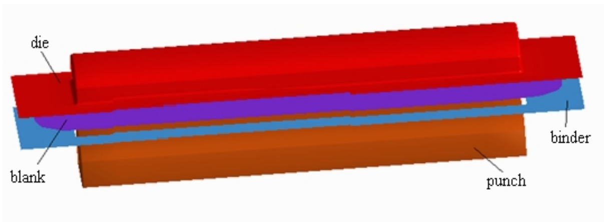



Figure2. Finite element model

The binder force and die corner radius are the important parameters for the stamping process. The influence of the process parameters on the forming of the part is studied by the single factor analysis method. In the stamping process, the theoretical calculation formula of the binder force $F$ is shown in formula (1).

$$F = qA \tag{1}$$

Where, $q$ is the binder force per unit area, and generally the value of $q$ is 2 ~ 2.5 Mpa; $A$ is the projection area of blank on the binder. As $A$ approximately equal 20000mm$^2$ for the part, $q$ is selected 2.3 Mpa, binder force is approximately 46 kN.

Die fillet radius $r$ is also the important parameter affecting the forming quality of parts and the value of process parameter usually is selected on the basis of experience data, that is, die fillet radius $r$ is from 6 to 10 times the thickness of the plate. The thickness of the part is only 0.4 mm, thus the value of die fillet radius $r$ is from 2.4 to 4 mm. Refer to the range of parameters, six parameters are set for the binder force and the die fillet radius, and other parameters select defaults in the software, thus process parameters are shown in Table 2. When binder force is separately analyzed, the die fillet radius is selected 3 mm, and die fillet radius is analyzed, the binder force is selected 50 kN.

The effects of process parameters on the stamping properties are studied by analyzing the indexs, such as the maximum thinning rate, the maximum thickening rate and the maximum value of springback. The maximum value of springback is measured in the longitudinal section and cross section by comparing the parts before springback to parts after springback, which are shown in Figure 3B and figure 3C.

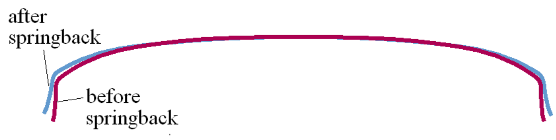
Table 2 Setting of process parameter

| NO. | binder force $F$/kN | die fillet adius $r$/mm | Stamping velocity $v$/(m/s) | friction coefficient $f$ |
|---|---|---|---|---|
| 1 | 30 | 1.5 | 4 | 0.125 |
| 2 | 40 | 2 | | |
| 3 | 50 | 2.5 | | |
| 4 | 60 | 3 | | |
| 5 | 70 | 4 | | |
| 6 | 80 | 5 | | |

## Influence of process parameters on the stamping performance

In the forming process, the thickness on the partial area of the flange increases, the maximum thickening area mainly distributes on four inlet corners of the box on the flange. The thinning area mainly distributes on the four walls of the part, and the maximum thinning area locates on the four corners of the part, which is shown in Figure 3a. After part drawed is trimmed, four straight edges outward bulge, and the maximum springback value locates in longitudinal section (A-A section in Figure 1) and cross section (B-B section in Figure 1). The springback value can be measured in two sections by the software Dynaform, such as Figure 3B and Figure 3C respectively list the parts before and after springback in longitudinal and cross section.

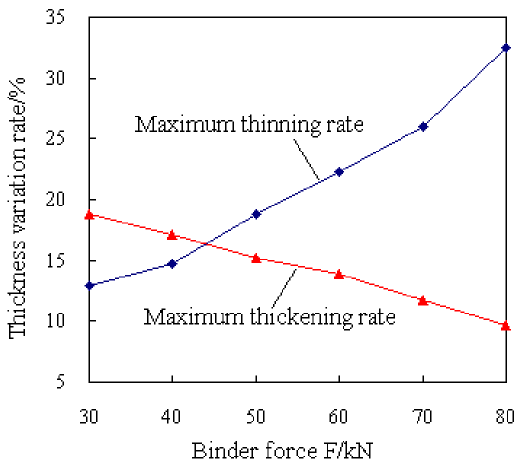

(a) Thickness variation

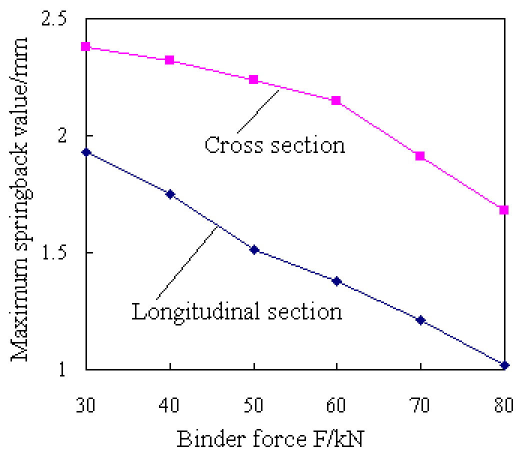

(b) Springback in longitudinal section c) Springback in cross section

Figure 3. Forming defects of part

**Influence of the binder force on the stamping performance.** Binder force is an important parameter affecting metal flow. When the binder force is inappropriate, defects such as wrinkle or fracture will appear. The range of six binder forces is from 30 kN to 80 kN, six groups of binder force condition are respectively simulated, then the maximum thinning rate, the maximum thickening rate and the maximum value of springback are measured, and the influence curves under binder force conditions are shown in Figure 4.




(a) Thickness variation rate




(b) Value of springback

Figure 4. Influence of binder force on stamping property of part

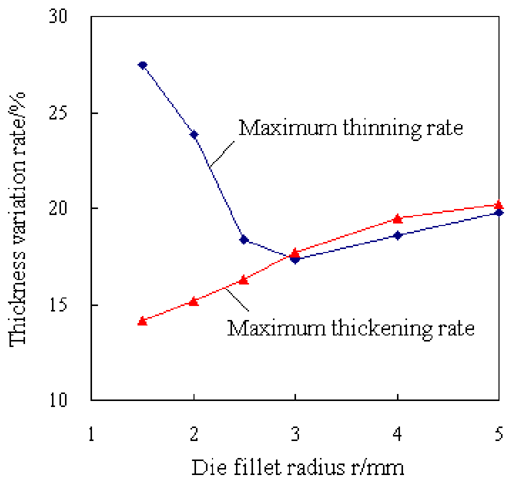
Figure 4a shows that with the increasing of binder force, the maximum thinning rate significantly increases, and the maximum thickening rate gradually decreases. When the binder force $F$ equals 30 kN, the biggest thinning rate and the maximum thickening rate are respectively 12.95% and 18.81%. When the $F$ equals 80 kN, the biggest thinning rate is 32.49% and the maximum thickness rate is 9.64%. The smaller the binder force, the smaller the thinning rate and the larger the maximum thickening rate. When the thinning rate of the thickness is small, fractures do not generate on the part. When thickening rate is large, the thickness of sheet obviously increases, thus evident wrinkles may generate on the flange, especially on the fillet attachment. With the increasing of the binder force, the thickening rate decreases, however the thinning rate is more than 30%, which indicates that fracture or slight fracture have generated on the parts, therefore, thinning rate and thickening rate should be controlled in the appropriate range.

Because of the good plasticity, aluminum alloy is easily to complete plastic forming, but the thickness of magnet cover and the transition fillets of part are all small, which will increase the difficulty of parts forming. Figure 4a shows that when the value of binder force is between 40kN to 50 kN, the thinning rate and the thickening rate are not too big or too small, the value is very close to the theoretical value of 46 kN.

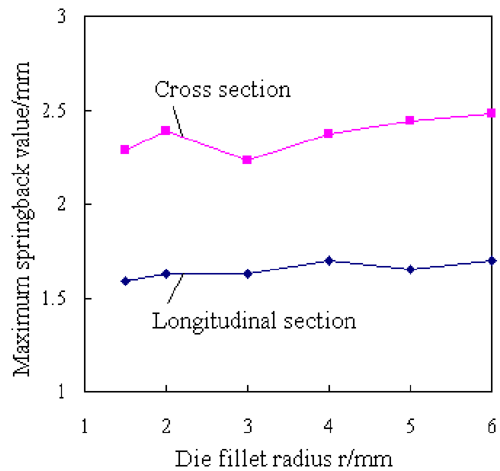
The springback value is the deformation amount of the part after cutting, and the amount of springback should be controlled in the certain range by adjusting proper process parameters. Figure 4b shows that the maximum springback values in the longitudinal section and cross section decrease with the increasing of the binder force. When *F* equals 30 kN, The maximum springback value in longitudinal and cross section are respectively 1.93 mm and 2.38 mm. When *F* is 80 kN, the springback value in longitudinal section was only 1.02 mm. However, the maximum thinning rate reaches very high value of 32.49%, so should not select 80 kN as the value of biner force.

Considering the effects of the binder force on three evaluation indexes, the results can be obtained. that is, when the value of the binder force is from 40 kN to 50 kN, the maximum thinning rate, the thickening rate and springback values are all small and the fractures, wrinkles and springback are not obvious, so the range of value of binder force is appropriate.

**Influence of die fillet radius on the stamping performance.** Die fillet radius is an important factor for the stamping process. The smaller the die corner radius, the bigger the resistance when metal flows into the die, and the bigger drawing force on straight wall and the apex angle, which will appear greater thinning or fracture on the local parts, especially obvious on the corner. When the radius increases, the area of binder will reduce, so the resistance for metal flow will also reduce.When metal flows from the flange into the straight wall, the effect of bindering becomes worse, thus wrinkles are easy to appear on the flange. Six die fillet radii condition are simulated by finite element software Dynaform, the curves of thickness variation ratio and springback value in the condition of die fillet radius are shown in Figure 5.




(a) Thickness variation rate




(b) Springback value

Figure 5. Influence of die radius on stamping property of part

Figure 5a shows that with the increasing of the die fillet radius, the maximum thinning rate first decreases rapidly, when radius value is up to 3 mm, the maximum thinning rate slowly increases. The maximum thickening rate slowly increases with the increasing of the die fillet radius. The greater the die fillet radius, the smaller the resistance when metal flows into the die cavity, and the thinning rate will significantly reduces. When fillet radius increases to a certain value, the bindering area on the flange significantly reduces, which leads to the unit binder force to enlarge and the drawing force to slightly increase, so the thinning rate will slightly increase. With the increasing of the die fillet radius, the flow property for the metal enhances, and the drawing force required during deformating reduces, thus the ability of complete plastic deformation weakens and the local area of the flange thickens. Figure 5a shows that the maximum thinning rate and the maximum thickening rate reduce when the die fillet radius is the range from 2.4 to 3.2 mm, so 2.4 to 3.2 mm is the proper value of die fillet radius.

Figure 5b shows that the die fillet radius has little effect on the maximum springback amount. The maximum springback interval under the longitudinal section is 2.31 to 2.46 mm, and under cross section is 1.61 to 1.70 mm.

Considering the evaluation indexes of thickness variation and springback value under die fillet radius, the die fillet radius should select 2.4 to 3.2 mm, and the fillet radius is 6 to 8 times the thickness of the plate.

## Conclusion

With the increasing of the binder force, the maximum thinning rate obviously increases, the maximum thickening rate slowly decreases, and the springback amount gradually decreases, so the appropriate binder force is from 40 to 50 kN.

With the increasing of die fillet radius, the maximum thinning rate firstly obviously decreases, and then slowly increases, and the maximum thickness rate slowly increases. The springback amount is little influenced by die fillet radius. Reasonable die fillet radius is 2.4 to 3.2 mm, which is 6 to 8 times the thickness of the plate.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