한국소성가공학회 '99추계학술대회 논문집 pp.26~29

타원형상 디프 드로잉 제품의 공정설계

최병근*, 배원락*, 박동환*, 박상봉**, 강성수*

A Process Design for Elliptically Shaped Deep Drawing Products

B. K. Choi*, W. R. Bae*, D. H. Park*, S. B. Park**, S. S. Kang*

* ERC/NSDM, School of Mechanical Engineering, Pusan National University
** Department of Die and Mould Design, Dongeui Institute of Technology

Abstract

Process design for elliptically shaped deep drawing products is various according to size, shape, and specification of products. This study presents two approaches to design the preform that is a key process for elliptically shaped products. One of these is that cross-section of punch is circular. Another is that, for the improvement of characteristics for final products, the cross-section of the punch is similar to rectangular shape. After forming the preform, process design of top-part drawing is the same. In the study, blank shape and dimension are obtained by applying a numerical formula and surface area constancy.

keywords : Elliptically shaped products, Process design, Preform process, Equivalent rectangular cup

1. Introduction

Product applied in this study is motor frame which is completely produced by multi-stage deep drawing and secondary operations, such as piercing and trimming. To fix bearing, roundness of top-part must be required, and not to leak of water, flatness also needs to be severe. To produce net-shape products, the stability of preform process is very important. There's a reason why elliptically shaped body and irregularly shaped top-part were formed simultaneously. Therefore, appropriate drawing coefficient must be maintained in preform process to prevent a locally thickness reduction, and the height of product must be computed by surface area constancy. If the rules are not kept, defects like tearing and folding can be expected in top-part. This paper presents cylindrical and rectangular deep drawing process for preform process. Following section will describe a process design for each approach briefly.

2. Process design

Forming condition of preform process which body shape consisting of a round in the major axis and a straight line in the minor axis must be determined carefully, because metal flow is different according to each direction in body shape. To produce preform, process design of intermediate operation was diversely proposed [1]. One of these is cylindrical deep drawing. The merit of this process is that punch and die are machined with ease. The demerit, however, is that cross-section of the punch was changed between the last cylindrical cup and preform. Thus, drawing coefficient in preform process is determined with the view of deformation relief. Another of these is similarly rectangular deep drawing. The merit of this process is a reduction of thinning in thickness, a good surface finish, feasibility of acquiring a flat flange, and increase of tool life, but it is difficult to machine punch and die because shape of tools is not rotationally symmetric.

Drawing coefficient sets the number of process sequence, and then cup diameter in deformed zone is computed. Cylindrical deep drawing process uses a Romanowski's drawing coefficient which is constructed on the ratio of thickness to blank diameter. Not existing in non-circular cup, drawing coefficient is defined as the ratio of width to blank size sometimes. Blank and process variables of two approaches mentioned above are proposed as follows.

2.1 Blank geometry and dimensions

Park et al. [2] presented three types blank geometry for elliptically shaped deep drawing. Among them, blank based on equivalent rectangular cup obtained by spreading out the elliptically shaped body with the same area was used in the study. There would be no problems in applying on the elliptically shaped product deep drawing because the results of experiment are relatively favorable. Especially, flange shape for trimming allowance and external appearance are fine. Blank dimensions can be calculated by means of eqn. (1). Fig. 1, 2 show cross-section of product and blank shape.

$$D_z = 1.13\sqrt{B^2 + 4(H - 0.43 r_c)(B - 2 r_c) + 2.38 R^2} \quad (1)$$
$$\text{, where } R^2 = r_c^2 + 2H r_c - 0.86 r_p (r_c + 0.16 r_p)$$

2.2 Approach to design the cylindrical deep drawing

In industrial practices, production consists of cylindrical drawing, preform, and top-part deep drawing. In this approach, use of drawing coefficient is based on the Romanowski's data in cylindrical deep drawing process, and determined by practical production in preform and bottoming one which is the first process in top-part drawing. Blank diameter and body diameter of the major axis in cylindrical process, the last cylindrical cup diameter and body diameter of the major axis in preform process, and body size of the minor axis and diameter of top-part in the top-drawing were set to be a comparative dimensions. Punch and die radius are dependent on the reduction of diameter in each operation. Methods of determination of drawing coefficient, punch radius and die radius are as follows.

2.2.1 Drawing Coefficient

An inverse design was performed from body diameter in the major axis to blank diameter, and then the result was rectified from blank to preform process. In top-drawing, procedure is the same, but comparative dimensions are top-part diameter and body size of the minor axis. Fig. 3 shows flow chart for determination of drawing coefficient in cylindrical deep drawing process and Fig. 4 shows one in top-part deep drawing.

2.2.2 Punch radius(Rp) and die radius(Rd)

It has been known that the cups fail due to tearing for a punch radius less than twice the thickness of the blank(t_0). If Rp is more than 10 times thickness, stretching may be introduced. The sharper punch, dies with greater nose radius must be used. And for a constant punch radius, the maximum load is decreased as the die radius is increased. For a constant die radius, however, the maximum punch loads do not change with change in the punch radius. Indeed, the function of the punch radius is mainly to transmit the punch load to the cup walls. Consequently within the region $4t_0 < Rp$, $Rd < 10t_0$, the radius does not significantly affect the limiting drawing ratio(LDR). Therefore, punch and die radius must be applied to be in 4 and 1Q times thickness for first drawing in cylindrical deep drawing. And It is known that punch and die radius are c(coefficient, $0.6 < c < 0.8$) times previous punch and die radius in redrawing process.

Owing to the characteristics of forming sequence for elliptically shaped deep drawing products in the study, shape radius is c(coefficient, 4 or 6) times thickness in a first drawing and c(coefficient) ,which was acquired by linear interpolation with much practical data, times the reduction of diameter in the redrawing processes.

2.3 Approach to design the rectangular deep drawing

This approach is classified according to the ratio of the width to length of rectangular cup and thickness of the blank to width. Because the ratio of the thickness to the width is more than 2 % in the study, cross-section of intermediate processes consists of semi-circle and straight line. Especially, the determination of dimension in just before preform process is very important, because corner gap affects metal flow seriously. The approach for the process design for elliptically shaped products, which require several operations, is established in the following sequence [3, 4]:

(1) The shape and dimensions of the blank are determined.
(2) The preliminary calculation of the number of cup drawing operations and the selection of values for the cup-drawing coefficient are carried out
(3) The technological variant of cup drawing is selected, taking account of the geometrical parameters of the components
(4) The shape and dimensions of the semi-finished parts resulting from intermediate operations are determined.

3. Results and Discussions

Fig. 5, 6 show process sequence of first approach to design the cylindrical deep drawing before preform, and total process sequence after preform. Fig. 7, 8 show a process sequence of second approach to design the rectangular deep drawing before preform. Among them, the results of prior to preform are in focus. The number of stages is the same for model PX and PY regardless of approaches. Moreover, because minimum deformation in preform process must be required, intermediate process for just prior to preform was not designed as semi-circle in the major axis. Therefore, in first approach, drawing coefficient was used as about 0.9. In second approach, diameter of the major axis is about 4mm more than the result of first approach, but size of minor axis is about 8mm less than the result of first approach in just prior to preform process. Thus, in calculating the dimension of intermediate process, the drawing coefficient must be applied carefully. But, the flat wall on the otherwise round causes unequal flow. At the flat wall, metal need not compress to flow over the die radius. Therefore, metal may flow too rapidly and leave loose metal in that part of the cup wall. Some restriction to metal flow, such as a draw bead, may be needed on the flat wall. This study doesn't make calculations of the height of intermediate process, nor gives design of bottom radius, which have to be studied in the future.

References

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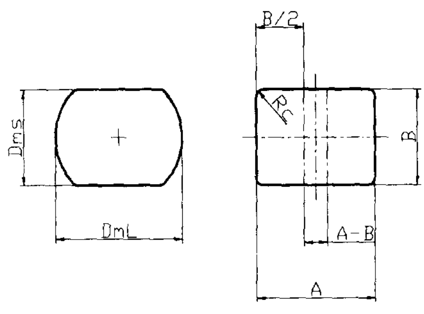

(a) (b)

Fig. 1 Dimension variables of cross-section

(a) elliptically shaped cross-section

(b) rectangular cross-section

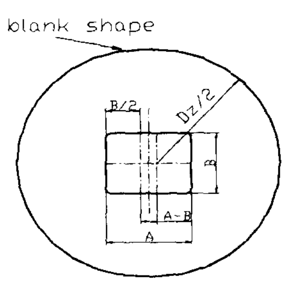

Fig. 2 Blank shape used for elliptically shaped deep drawing products

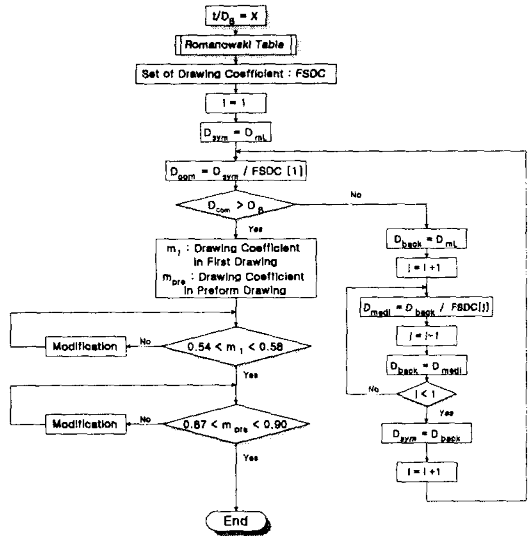

Fig. 3 Determination of drawing coefficient for cylindrical deep drawing

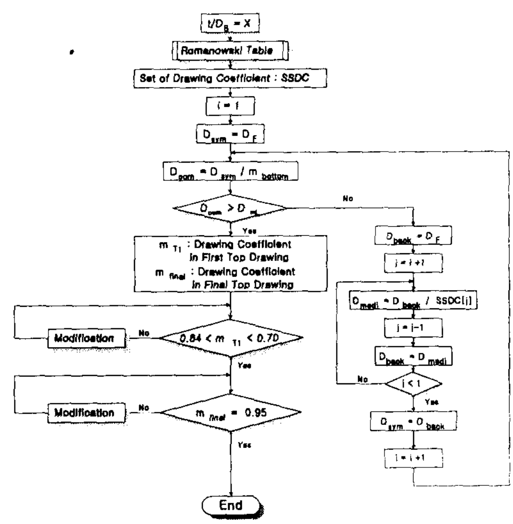

Fig. 4 Determination of drawing coefficient for top-part deep drawing

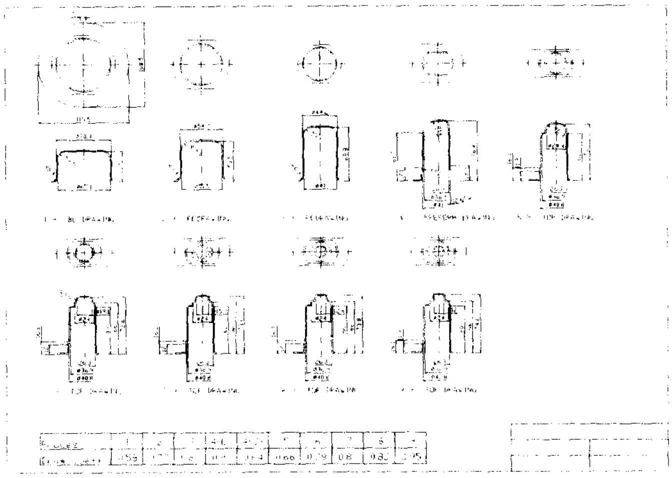

Fig. 5 A process sequence for Model PX

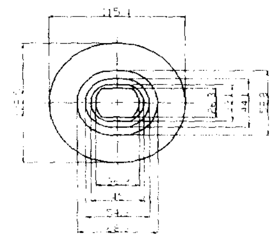

Fig. 7 Design of cross-section for Model PX

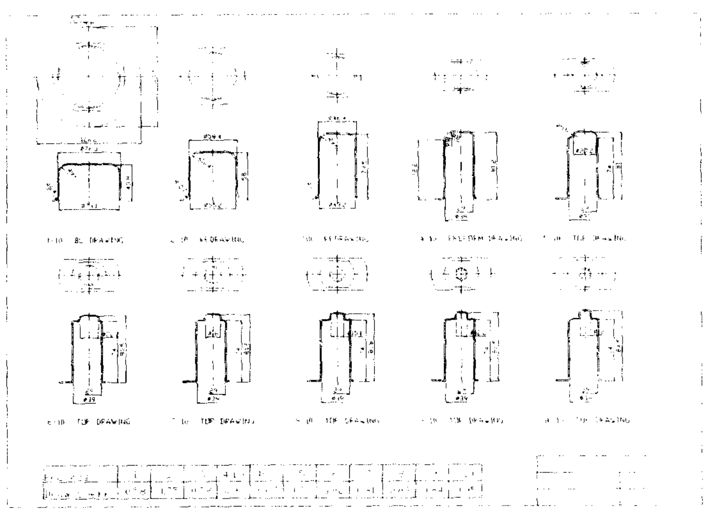

Fig. 6 A process sequence for Model PY

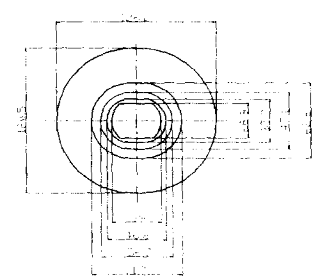

Fig. 8 Design of cross-section for model PY