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Development of An Optimal Layout Design System in Multihole Blanking Process

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ABSTRACT

The blanking of thin sheet metal using progressive dies is an important process on production of precision electronic machine parts such as IC leadframe. This paper summarizes the results of simulating the progressive blanking process by means of LS/DYNA. In order to verify the influence of blanking order on the final lead profile and deformed configuration, simulation technique has been proposed and analyzed using a commercial FEM code, LS/DYNA. The results of FE-simulations are in good agreement with the experimental result. After then, to construct rule base in progressive blanking process, FE-simulation has been performed using a simple model. Based on this result rule base is set up and then the blanking order of inner lead is rearranged. Consequently, from the results of FE-simulation using suggested method in this paper, it is possible to predict the shift of lead to manufacture high precision leadframe in progressive blanking process. The proposed method can give more systematic and economically feasible means for designing progressive blanking process.

Key Words : Optimal blanking order, Leadframe, Lead shift, FE-simulation, Progressive blanking process

1. Introduction

IC (Integrated Circuit) leadframe is a primary to intermediate form of IC manufacturing process and consists of a chip supporting single frame structure, which enables the manufacturing of IC package. It plays the role of connecting the chip and outside electrically as well as providing a route to discharge heat built up in the chip.

The blanking of thin sheet metals using progressive dies is an important process on production of precision electronic machine parts such as an IC leadframe. In the research of leadframe, Jimma et al [1] researched the dimensional accuracy of the sheared lead related to the influence of the design parameters and blanking conditions for blanking an I-shaped tongue model that seems to be a model of the IC leadframe. In order to verify the influence of the stripper force and its shape, Cheon et al [2] proposed and analyzed the two-type model using DEFORM-2D. Lim et al [3] investigated the sheared lead related to the influence of the design parameters such as clearance, holding pressure and bridge allowance for blanking a square shape model.

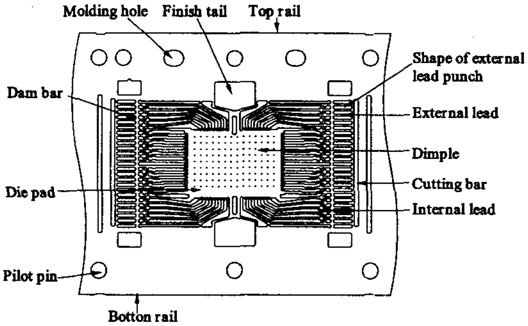

Fig. 1 The leadframe of 48TSOP LOC type

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Chan et al [4] proposed a strain-hardening plane-stress bending model to predict the deformation behavior and springback of narrow strips.

The use of computer simulation using FEM is increasing for investigating and optimizing deformation process. Altan et al [5] performed parameters study in blanking process by means of a modified DEFORM-2D FEM code. But, in spite of the efficiency of commercial FEM code for simulating forming operations, the numerical approach for studying multihole blanking in sequence is still in primitive stage.

The objective of this current research, therefore, is to verify the influence of blanking order on the final lead profile and deformed configuration in progressive blanking process. To do this, simulation technique has been proposed and analyzed using commercial FEM code, LS/DYNA. The simulation technique proposed in this paper includes four steps such as forming, trimming, springback and rezoning for each blanking process based on ideas of fracture mechanics [6]. To verify the efficacy of the simulation technique, the results of FE-simulations are compared with experimental results. The emphasis is on shifting of inner leads that shape fixability is required most. The analysis model is 48TSOP(Thin Small Out-Line Package) of LOC (Lead On Chip) type as shown in Fig.1

2. Simulation of blanking process

2.1 Concept

When the blanking tool contacts the sheet material, there are elastic and plastic deformations. The concept of blanking process is shown in Fig. 2 under the assumption that the crack is stable propagation. At the beginning of the second phase, the cutting elements penetrate the materials. Subsequently, the stresses within the deformation zone grow until the shear strength of the material is reached, and then the material is sheared along the cutting edge. The third phase consists of crack growth and ends when the material is completely separated [6].

The model for the blanking process presented in this paper is based on ideas of fracture mechanics. To simulate progressive blanking process, a rezoning algorithm is used for the numerical treatment of the second phase. Therefore, the forming process of a blank is performed just before the crack is initiated. Then the trimming process is performed along the punch perimeters. To investigate on dimensional accuracy of the sheared blank influenced by residual stress after forming and trimming process, the analysis of springback is executed at each blanking process. First of all, it is important to decide crack initiation according to sheet material and process parameters.

The procedure of progressive blanking process is shown in the Fig. 3. The commercial explicit code used was LS/DYNA based sheet metal forming simulation solution package. The pre-processing consists of four specific steps for identification of the problem such as modeling, mesh generation, material properties and process condition. After identification of the problem, forming simulation is performed until crack initiation and then interactive trimming function is used to trim a blank along the projection of the trim lines, i.e. punch perimeters. After trimming, forming tools such as punch, die and blank holder are eliminated by users and then springback of blank is simulated. The next blanking process is performed repeatedly until the final blanking process with previous deformation history using rezoning presented by LS/DYNA. Following the procedures, the progressive blanking process can be simulated.

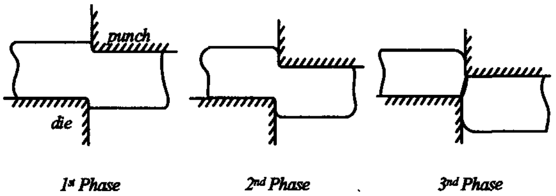

Fig. 2 Three phases of blanking

2.2 Material model

The material used in the 48TSOP is copper alloy. The thickness of the materials is 0.254mm, lead pitch is 0.5mm and lead width is 0.25mm. To find out the material properties, the tensile test was done by a universal test machine INSTRON whose capacity is 10ton.

The specimen is made by ASTM E-8 standard requirements. The material properties of copper alloy are shown in the Table 1. The chemical composition of C7025 is *Ni*: 2.2~3.2%, *Si*: 0.25~1.2%, *Mg*: 0.05~0.3% and *Cu*: 95.3~97.5%.

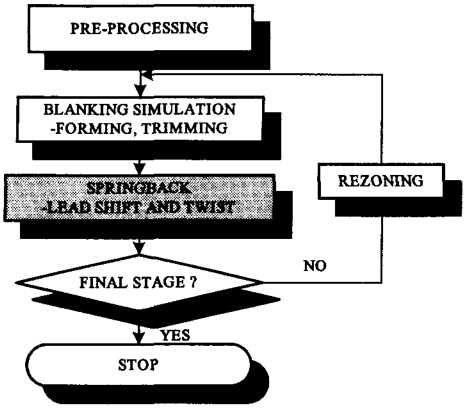

Fig. 3 Procedure of FE-simulation in the progressive blanking process

Table 1 Material properties of the leadframe materials

Leadframe material	*Tensile strength (MPa)*	*Yield stress (MPa)*	*Young's modulus (GPa)*	*Elongation (%)*
Copper alloy	*715.11*	*562.48*	*67.56*	*7*

Table 2 Conditions of FE-analysis for 48TSOP

Parameters	*Values*
Punch velocity (m/s)	*0.16*
Coulomb friction coefficient (μ)	*0.1*
Punch penetration (%)	*45*
Stripper force (kN)	*0.45~0.5*
Stress-strain (MPa)	$\bar{\sigma} = 886.3(0.008+\bar{\varepsilon})^{0.088}$

3. Analysis of 48TSOP leadframe

3.1 Process conditions

In the simulation conditions as summarized in Table 2, the blanking velocity of the press is set at 0.16m/s. The stripper force is 0.45~0.5kN considering the initial and final stripping force of spring. The friction coefficient is 0.07 from the straight pulling friction test and clearance between punch and die is 10μm as 4% of the material thickness.

To know the crack initiation of 48TSOP leadframe according to process condition (Table 2), the optical cross section was taken for a sheared 48TSOP inner lead as shown in Fig. 4. In this figure, it can be known that the crack initiation point is about 45% of lead thickness.

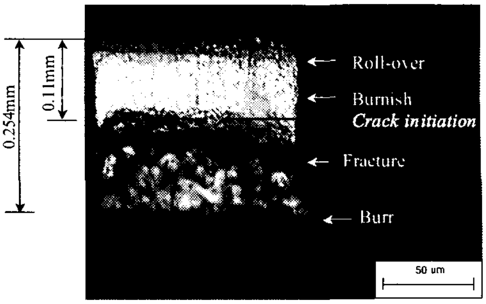

Fig. 4 Optical cross section of a sheared inner lead for copper alloy

3.2 Lead shift of 48TSOP leadframe

Fig. 5 show the shape of 48TSOP inner leads after final blanking process according to conventional blanking order using suggested method in this paper. Owing to symmetry, only a half of the blank was considered for FE-simulation. To know the shifting tendency and dimension of the lead, each shift of inner leads is measured at top and bottom points of lead ends. Fig. 6 shows the distribution of effective stress after final blanking process. The stress is concentrated on the final blanking area because the lead width is the narrowest in the final stage. Therefore the shifting tendency is to be higher.

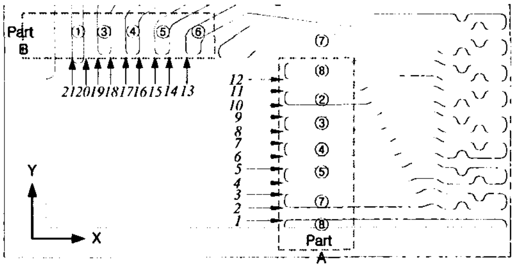

Fig. 5 Blanking order (①~⑧) and inner lead (1~21)

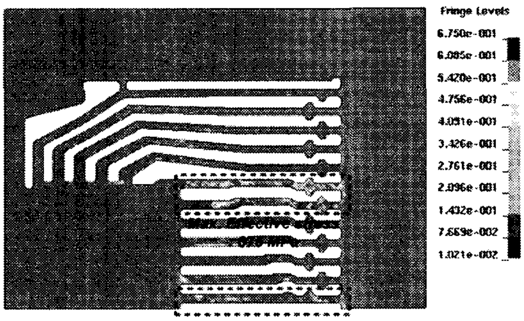

Fig. 6 The distribution of effective stress

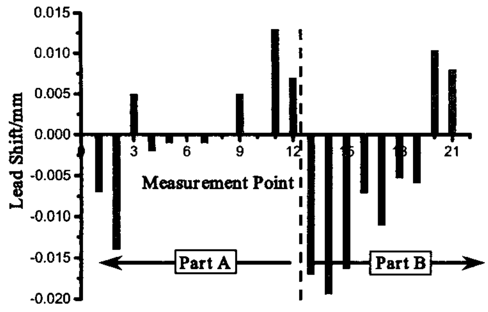

Fig. 7(a) Lead shift in experiment

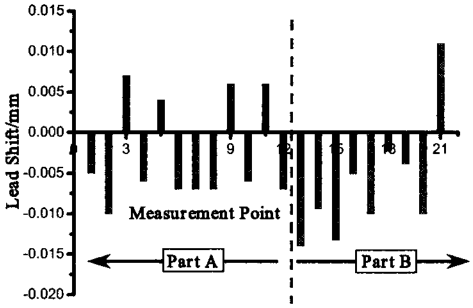

Fig. 7(b) Lead shift in FE-simulation

The experiment of progressive blanking process for 48TSOP is performed using 60ton hyper-hydraulic press. The shift of lead after final blanking process is measured at each measuring point as shown in Fig.6 using a *Microscope (m-60)* presented by NIKON.

Fig.7 shows the comparison of results between FE-simulations and experiments. The work of Jimma [2] shows similar experimental results.

Although the results of FE-simulation are not exactly right, the simulated shifting tendency of lead is fairly close to the results of experiments. Therefore, it can be claimed that FE-simulation according to the proposed procedure is able to properly deal with defect of leadframe in advance.

3.3 Rule base for layout design

A simple model shown in Fig. 8 is used to investigate the effects of cutting length and lead position on shift of lead. According to variables of the simple model as shown in Table 3, FE-simulation is executed considering lead shapes such as a straight and a bent shape models. Cutting length varies from 2mm to 8mm for each shape and the blanking position varies from 0.635mm to 2.667mm. In this study, a simple model is studied by simulating blanking of copper alloy (Table 1) sheet with the specifications as in Table 2.

Table 3 Conditions of FE-analysis for simple model

Variables	*Values (mm)*
a (lead length)	*0.746, 1.496, 2.246, 2.996, 3.746*
b (lead decrement)	*0.375*
c (lead width))	*0.125*
D (lead position)	*0.635, 1.143, 1.651, 2.159, 2.667*

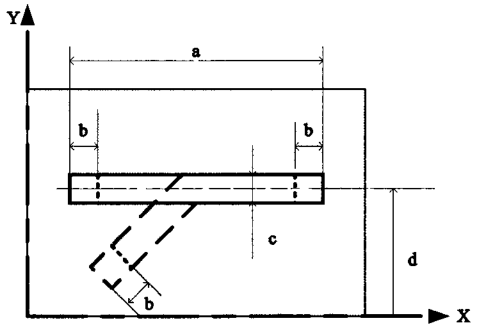

Fig. 8 Simple model for rule base

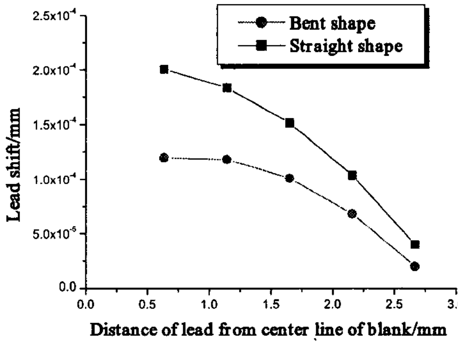

Fig. 9 The effect of lead position

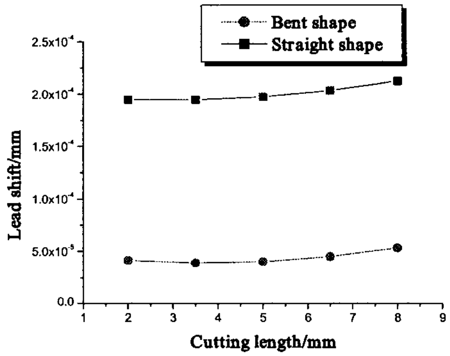

Fig. 10 The effect of cutting length

Fig. 9 shows results of lead shift according to lead position. The results predict that the lead shift will decrease as the distance of the lead from the centerline increases. Also, when the lead shape is straight, there is greater change that the lead becomes located further from their nominal position. Fig. 10 shows the results of lead shift with respect to cutting length. The results predict that the lead shift will increase when the cutting length increase. Similarly, lead shift of straight shape is bigger that of bent shape.

From the results of FE-simulations for the simple model, basic rule base can be constructed and summarized for progressive blanking process as follows: (1) The lead shift increases as the blanking stage increase. (2) The lead shift increases as the cutting length increases. (3) The lead shift increases as the lead position become nearer from the center of the blank. (4) According to lead shape, lead shift is different. Lead shift of straight shape is bigger than that of bent shape.

Based on basic rule base and procedure of FE-simulation suggested in this study, blanking order can be rearranged in order to minimize the lead shift for 48TSOP leadframe.

4. Results

To assess the efficacy of the predictive model, basic rule base is applied to 48TSOP leadframe. There is problem to apply basic rule to 48TSOP leadframe because blanking order different that put the importance to some rule. Therefore, because cutting length is different certainly, blanking order is determined by depending on cutting length of lead. The cutting length is calculated by punch perimeters concerning one set (two or three leads) in actual manufacturing process as shown in Fig. 5. The material and process conditions are the same as those of Section 3.

The results of FE-simulation with the modified blanking order are shown in Fig. 11. There is tendency that the lead shift increases as the blanking stage increase.

The predicted maximum lead shift for 48TSOP leadframe based on this study is about 24μm. For this leadframe, maximum lead shift was measured by experiment and found to be about 30μm. Therefore, the predictive model underestimated the lead shift by about 20%. The discrepancy between the predicted and experimentally measured values is likely the results of some factors. First, the concept suggested in this study for blanking process is based on the assumption that the crack propagation is stable. Second, it is difficult to simulate actual blanking process because of uncertainty in the dieset's actual clearances.

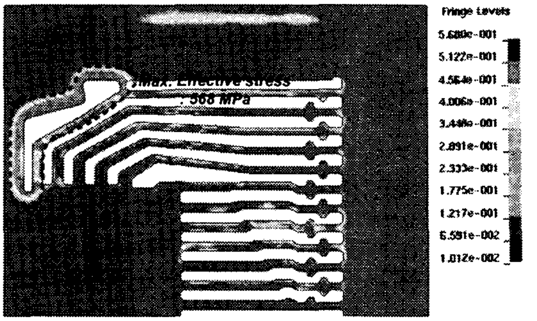

Fig. 11(a) Stress distribution in modified blanking order

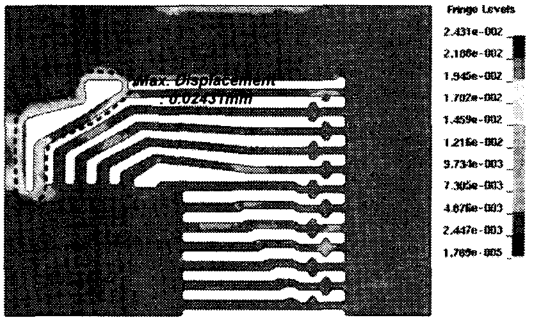

Fig. 11(b) Displacement in modified blanking order

5. Conclusions

In this paper, FE simulation technique has been proposed and analyzed based on the ideas of fracture mechanics in order to verify the influence of blanking order on the final lead profile and deformed configuration. Although the results of FE-simulation are not exactly right, the simulated shifting tendency of lead is fairly close with the results of experiments. Therefore, using the commercial FEM code (LS/DYNA) it is possible to predict the lead shift to manufacture high precision leadframe and it is able to deal with defect of leadframe in advance.

Based on basic rule base for progressive blanking process obtained by analysis of a simple model, it has been found that lead shift of straight lead is more serious than that of bent lead. Also, lead shift increases as the cutting length increases. The combination of FE-simulation and physical testing results in a reduction of the necessary experimental effort. The proposed method can give more systematic and economically feasible means for designing progressive blanking process. These results might be used as a guideline to optimize blanking order.

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