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Formability Analysis and Its Parameters –A Review Paper

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ABSTRACT
This paper represents review of parameters which affects sheet metal formability and also about forming limit diagram (FLD).The parameters are punch nose radius, blank temperature, die arc radius, punch velocity, blank holding force(BHF),blank shape, spring back etc. The first section of paper represents about formability. Second section reviews different parameters that affect sheet metal forming. Section 3 explains that formability of sheet metal defined in terms of two dimensional strain maps. It also describes state of strain measures formability. It deals with different research work dealing with forming limit diagram (FLD). The forming limit diagram (FLD) gives an indication whether the material can sustain certain ratio of strains without failing is of great help.
Keywords:- BHF,FLD,Sheet metal formability.

I. INTRODUCTION

The forming of metals into desired shapes is almost the oldest fabricating technique. Metal forming is an economical method of manufacturing components because loss of material is too less. It is a process in which the desired shapes and size of components are obtained through the plastic deformation of metal. Sheet metals are widely used for industrial and consumer parts because of its capacity for being bent and formed into intricate shapes. Sheet metal parts comprise a large fraction of automotive, agricultural machinery, and aircraft components as well as consumer appliances.

II. FORMING PARAMETERS

Successful sheet metal forming operation depends on the selection of punch nose radius, die arc radius, punch velocity, blank holding force, spring back, blank size and shape, die clearance and lubrication. Forming limit diagram (FLD) and circle grid analysis helps to understand forming in sheet metals. The summary of some of the works conducted by different researchers regarding forming is listed below; they described the analytical approach and experimental results.

2.1 Punch nose radius

Dr.Waleed K.Jawad ,Jamal H.Mohamed[1] studied the effect of punch nose radius on deep drawing operation. In this work, six types of punches with various nose radii have been used to form a cylindrical cup of (44mm) outer diameter,(28mm) height, and(0.5mm)sheet thickness of mild steel of (0.15%) carbon content. A commercially finite element program code (ANSYS 5.4), was used to perform the numerical simulation of the deep drawing operation, and the numerical results were compared with the experimental work. The results show that, the value of work required to form parts with large nose radii is much more than the value required to form parts with small punch nose radii. The greatest thinning is seen to occur with hemispherical punch (Dome shaped punch) due to great stretching of the metal over the punch head. The maximum tensile stresses and the maximum thinning of the dome wall occur nearly at the apex of the dome.

2.2 Blank temperature

G. Venkateswarlu, M. J. Davidson and G. R. N. Tagore[2] extensively studied formability aspects of aluminium 7075 to develop useful components of complex shapes. In that study, the significance of three important deep drawing process parameters namely blank temperature, die arc radius and punch velocity on the deep drawing characteristics of aluminium 7075 sheet was determined. The combination of finite element method and Taguchi analysis was used to determine the influence of process parameters. Simulations were carried out as per orthogonal array using DEFORM 2Dsoftware. Based on the predicted deformation of deep drawn cup and analysis of variance test (Anova), it was observed that blank temperature has greatest influence on the formability of aluminium material followed by punch velocity and die arc radius.

2.3 Blank holding force

Y. Marumo, H. Saiki, L Ruan [3] has carried out the study regarding variation in the blank holding force required for the elimination of wrinkling and the limiting drawing ratio with sheet thickness. They found that blank holding force required for the elimination of wrinkling increased rapidly as the sheet thickness decreased. When the sheet thickness was very thin, the blank holding force was strongly influenced by the coefficient of friction. The limiting drawing ratio decreased as sheet thickness decreased and it decreased rapidly below 0.04 mm thickness.

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2.4 Intital blank shape

M. Ahmetoglu, T. R. Broek, G. Kinzel, T. Altan [4] have carried out the study of effect of process parameters such as initial blank shape and the blank holding force on the final part quality (i.e., wrinkling and fracture). During the initial experiments, it was found that the oval blank shape had the worst formability, from a fracture point of view, among the three blank shapes (i.e., oval, oblong, and rectangle). The oval shape reduced the fracture limit of AA 2008-T4. However, it caused smaller wrinkling heights in the flange along the sides of the rectangular pan. Control of the (BHF) as a function of time improves the formability and the quality of the final part. However, BHF control in time is not enough by itself. Since the deformation characteristics are not uniform around the periphery of the rectangle, the BHF has to be controlled as a function of location, too. Metal flow can be controlled by using draw beads on the sides of the rectangle.

2.5 An optimization strategy for the blank holder force (BHF)

H. Gharib, A.S. Wifi, M. Younan, A. Nassef [5] have proposed an optimization strategy for the blank holder force (BHF) which searches for the BHF scheme that minimizes the maximum punch force and avoids process limits. That strategy was applied to the linearly varying BHF scheme and compared to the constant BHF. They found that the optimized linear BHF scheme resulted in an improved cup forming when compared to that produced by the constant BHF scheme. The BHF scheme is optimized for different cases of drawing ratios and die coefficients of friction in order to analyze the nature of the optimum linear BHF scheme. It was found that the slope of the linear BHF scheme increases with the increase in the drawing ratio in a linear manner. Also, the intercept of the function showed a nearly linear variation with the drawing ratio. A general equation is deduced for the optimum blank holder force at any drawing ratio for the cup under study.

2.6 Spring back

W.M. Chan, H.I. Chew, H.P. Lee, B.T. Cheok [6] have presented a study of spring-back in the V-bending metal forming process with one clamped end and one free end. They found that spring-back occurs at the die-lip and V-region of the die model. Different die punch parameters such as punch radius, punch angle and die-lip radius were varied to study their effect on spring-back. Also, the effect of the punch displacement on spring-back was investigated. The H-convergence test was done to justify the number of elements used. Softwares used are Patran, Abaqus/Standard and Abaqus/CAE. Patran was used to model the nodes of the sheet metal and rigid surfaces of the die, pad and punch. Abaqus/Standard is used to simulate the punching process. The results were analyzed using Abaqus/CAE. Their analysis shows that spring-back angle of the valley region decreased with increment of punch radius and punch angle and spring-back is dependent on punch radius, punch angle and die-lip radius.

III. FORMING LIMIT DIAGRAM

The forming limit diagram (FLD) (Fig.3.1) gives an indication whether the material can sustain certain ratio of strains without failing is of great help. Keeler[7] pioneered the application of forming limit diagrams (FLD) for accessing the formability of sheet metal.

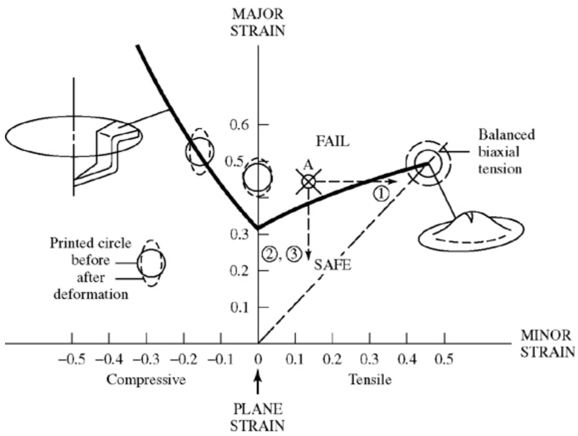

Fig.3.1 Forming limit diagram[8]

Many researchers have tried to determine the FLD diagrams for different sheet metals commonly used in forming operations either experimentally or theoretically. The experimental method consists of printing a grid pattern of circles of appropriate diameter (generally 2 mm to 4 mm) on the surface of sheet. The sheet is deformed as required but in stages. After each stage the grid pattern is examined. The advantage of printing circular grids is that during the deformation the circles will get deformed into ellipse with major and minor axes directed along the principal directions of strain. The measurement of the axes and knowing the original diameter we can determine principal strains and their directions. As the forming progresses, at some region neck formation may occur. The ratio of strains is determined at the region. This is a point on FLD diagram or curve which separates the safe and unsafe regions.

In 1967, Marciniak and Kuczynski proposed their analytical model for limit-strain prediction based on the initial in homogeneity of a material, which has been foundational for much of the subsequent work in this area and is commonly referred to as theM–K theory [9]. They attributed changes in limiting strain values to the loading history of the specimen, the ratio of the principal stresses, and several material properties, including the initial in homogeneity. They noted that the largest limiting strains in the biaxial stretching region were obtained during equal biaxial tension, whilst the minimum values occurred in plane-strain.One of the primary applications of the circular grid system and FLD proposed by Keeler was the analysis of strain distributions in actual stampings to improve part quality and optimize die design [10]. Since Keeler's experiments continued to verify his earlier results, showing that the lowest formability exists under plane strain conditions, he proposed restricting the inward flow of metal from the flange in order to induce biaxial tensile strains, thereby increasing the forming limits. The preceding studies focused on the determination of forming limits solely in the region of biaxial tension. However, in 1968, Goodwin used a combination ofcup- and tension-tests to obtain a failure band in both the negative and positive quadrants of minor strain, creating the general form of the forming-limit diagram.

In order to reveal the effects of planar anisotropy on formability, Marciniak et al. performed an experimental study involving steel, aluminum, and copper [11]. These tests were performed under proportional-straining conditions, and showed that the forming limits were significantly different in the rolling direction compared with transverse direction. This demonstrated that the limit curve does not consist of mirror images which begin at the principal axes and meet at the state of equal biaxial tension; instead, the limit strains are generally somewhat greater in the rolling direction.

A further investigation of variations in the forming limit diagram was conducted by Ghosh and Hecker, who concluded that the limit strains obtained in punch stretching operations were considerably higher than those resulting from in-plane stretching tests [12,13]. Their in-plane stretching tests employed the use of a polyethylene spacer on either side of the nose of a punch in order to induce in-plane deformation. They theorized that the friction and curvature present during punch stretching cause strain localization to take place at a much lower rate than for in-plane stretching. Up to this point, most work on constructing the forming-limit diagram had employed the use of grid strain analysis on actual automotive stampings or on test specimens deformed by punches of various geometries. In 1975, Hecker introduced a methodical approach involving the stretching of sheets of various widths over a hemispherical punch to obtain strain conditions ranging from uniaxial tension to balanced biaxial tension[14]. Using the onset of localized necking to define a single limit of failure, Hecker obtained a forming-limit curve lying mostly within the Keeler– Goodwin band. The advantage of his technique is the ability to determine an entire forming-limit curve with specimens of different widths and:or the use of different lubricants. An analytical model describing neck growth in sheet metals under various loading conditions, from which a predicted forming-limit diagram can be calculated, was subsequently developed by Lee and Zaverl [15]. Their results corresponded to those of the lower, in-plane forming limits. However, the analysis did not account for the effects of strain history and its influence on such properties as the plastic strain ratio.

IV. SUMMARY

The forming limit diagram (FLD) introduced by Keller and Goodwin probably the most widely used method for representing sheet metal formability and extensive literature has been proposed in the last decade. The forming limit diagram typically represents the maximum permissible range of major and minor strains that a typical sheet material can undertake without failure. The forming limit diagram is experimentally measured for each sheet material by placing a grid of circle on the sheet sample and then deforming the same. A comparison of the original and the extensions in the marked grids on the sheet sample provide an estimate of the major and minor strain of the sample. The permissible range of the major and minor strains is actually available for a wide range of sheet metals and used considerably for designing of deep drawing operations, in particular.

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