Acquisition Methods and the Influencing Factors of Forming Limit Diagram

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Abstract

Sheet metal,in all kinds of strain state, can achieve the value of ultimate strain of graphics named Forming Limit Diagram (FLD). It is used for expressing the lever of sheet metal in the event before local thinning (instability or necking) and fracture, as an important criterion to judge the sheet metal success or failure in the process of plastic forming. This article mainly discusses the concept of Forming Limit Diagram, theory, numerical simulation, and some common methods for Forming Limit Diagram, analyzes the relationship between Forming Limit Diagram and other performances, and briefly discusses several factors which affect the Forming Limit Diagram.

Keywords

Sheet Forming; Forming Limit Diagram; Numerical Modeling; Influencing Factors.

1. Introduction

Sheet metal forming is an important part of the metal forming, involving engineering field of mechanical engineering, forging, stamping, etc., which in the aerospace, automotive, light industry and home appliances. It has a very wide range of applications in the use of finite element simulation system of stamping process optimization, automotive sheet metal parts selection and also has important applications. Before Forming Limit Diagram has been come up, sheet metal uniaxial tensile tests were performed to evaluate the mechanical performance of the material forming properties. It is one of the most simple way. Material hardening exponent value (n) is large, the strain is distributed uniformly. And it is conducive to tension parts molded; thick anisotropy index r value is high, sheet metal is not easy to be thin, with the deep drawability. However, according to the scheme provided by the unidirectional tensile test of mechanical performance index, can only be qualitatively analyzed material to complete a process easily rather than directly used to estimate whether the specific parts stamping process is successful. The basic experiment of the sheet metal forming can only on the formability of sheet metal to make qualitative general evaluation of comprehensive, simulation experiment is only for a few typical process, under the condition of relatively single, so the results is difficult to make exact to the formability of complex parts, also can't very well to deal with specific problems encountered in the production. And the emergence of the forming limit diagram provides the foundation for sheet metal forming and sheet metal forming performance and is an effective tool to solve the problem of sheet metal stamping.

Forming limit diagram is an important milestone in sheet metal formability study. In 1965, in sheet metal forming experiments, in view of the deformation of each local complex parts, Keeler and Goodwin had used circular grid analysis method to evaluate forming limit diagram of sheet metal forming performance. Until today, FLD in sheet metal formability analysis, sheet metal forming process and play an important role in the study.

In 1975, Marciniak and Kuczynski, according to Hill who proposed instability theory in 1952, proposed a further FLD / MK model, making the study of sheet metal formability into FLD research stage.

Nowadays, people are using a variety of numerical simulation software for sheet metal forming property and making the FLD research enter a new stage.

2. Concepts of sheet metal Forming Limit Diagram

In 1965, Keeler and Goodwin firstly proposed the concept of Forming Limit Diagram (FLD), see Fig. 1.

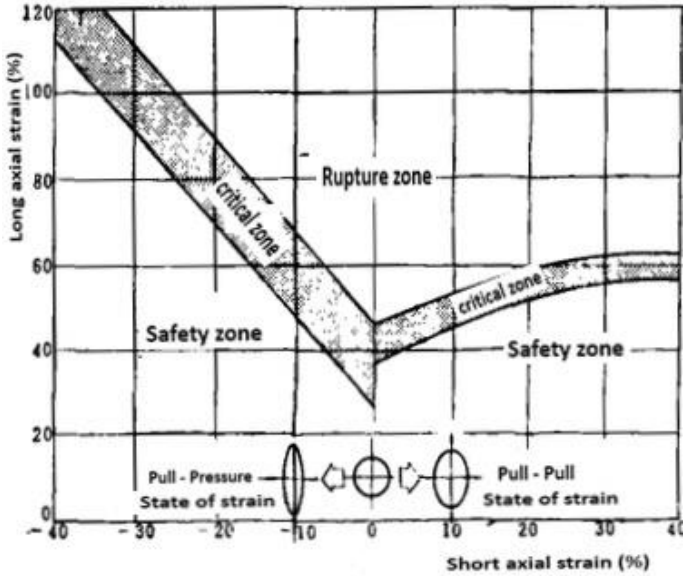

Fig. 1 The Forming Limit Diagram

3. Advances in numerical simulation of FLD

With the development of the finite element theory and technology and the improvement of computing capacity, in recent years, sheet metal forming numerical simulation technology began to widely used to analyze the problems such as wrinkling and rupture of sheet metal forming. Finite element simulation, to a certain extent, is also instead of the experimental and theoretical calculation to get the forming limit curve. But the accuracy of finite element simulation is the key to obtain the accurate and reliable FLD problem, which makes the division of work units in the simulation, the description of the hardening curve, the constitutive relation and anisotropy, and the determination of boundary conditions become important issues in the simulation.

Now the main softwares used to simulate the sheet metal forming are dynamic explicit and static implicit. And dynamic explicit such as Dynaform, Pamstamp; static implicit such as Marc.

4. Theoretical studies Forming Limit Diagram

The basis theory of FLD is tensile instability theory. Swift has proposed dispersive instability theory in the 1950 s and Hill put forward the concentrated instability theory which provided a theoretical basis for the sheet metal forming and sheet metal forming limit diagram research.

Later, there appeared a variety of sheet metal research theories or models, such as groove theory considering uneven material (M - K model), Considering the necking area velocity discontinuity (S - R theory model). In recent years, there are many domestic scholars on sheet metal forming and sheet metal forming limit diagram has carried on the thorough theory research, and verified the theory by experiments, thus, put forward a lot of instability theory and criterion. They studied on unified calculation of FLD problems, established two parts of a unified theory of FLD model.

5. The methods of obtaining FLD

Initial studies Keeler is determined by measuring the rupture strain on many parts of the plant to give ultimate strain under different strain paths, and by a simple method to destroy the grid position will be measured at the position of the material partial rupture limit strain. Since the parts stress state is difficult to control, to get the number of parts required a lot more strain path, it was keeler studied only double pull-state that is the right part of the FLD. Later, Goodwin got FLD left part by drawing a sample of different widths and cup of stretching. For material parameters obtained People always want to be able to get by a simple method in the laboratory, rather thanin the workshop a lot of experiments and measurements. So after the proposed concept FLD and attention, many scholars of test methods or obtain municipal production of various loading paths, proposed a wide range of new test methods. It comes down to what a few:

5.1 Frictionless complex experimental method

Such as using different width and shape sample to obtained the limit point of the left part of FLD, the use of a sample or oval tube hydroforming to get the right half of the limit point, we can get the whole combination of FLD. The advantage of this approach is that the experiment is not limited friction conditions, can be relatively accurately determine the dispersion of the material deformation process according to instability reflected tension or pressure. But the drawback is the need to use two different test equipment, equipment requirements higher.

5.2 Cylindrical punch test method

Later, Marciniak and Kuczynski made cylindrical punch molding limit test method, commonly referred to as M-K method, shown in Figure 2. With this mold by using samples with different widths, you can get different strain paths. The problem is easy to style fillet from breaking, it is usually better to add a layer of plastic material between the sheets and the punch as a spacer, spacer hole in the middle. The maximum deformation of sheet metal forming parts of a plane, substantially unaffected by friction and the third (thickness direction) of the pressure, it is also known as the inner surface of the test method. This method is used because the equipment is relatively simple, it is now one of the most commonly used test methods.

Fig. 2 Cylindrical flat punch test mold FLD diagram

5.3 Hemispherical punch test method

Similar experiments with a cylindrical punch, punch forming hemispherical use is also an important method, namely the use of hemispherical punch instead of a cylindrical punch, as shown in FIG. Initially proposed by the Nakazimati, commonly referred Nakazima method. This method uses a different shape samples obtained at different loading state hemispherical die stamping process, thereby finally get a different strain ways. This method does not require the forming process plus pads, but add some lubricant, can be directly formed. Since sheet metal bending deformation, not one plane, affected to a certain thickness of the pressure, it is usually referred to as non-planar test. The key question is affected by the test of friction, lubrication is not good enough under the circumstances it is difficult to obtain, etc. biaxially stretched strain state. Through trial and error, combined with the use of dry lubricant with Vaseline or lubricants such as polytetrafluoroethylene film, soft silica gel has been very good lubrication, strain path can be very close to the biaxial tension state.

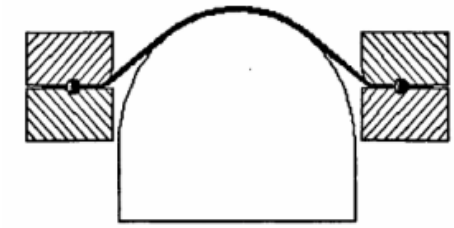

Fig.3 Hemispherical punch test diagram

6. The influence factors of forming limit diagram

6.1 Mechanical property

As the mechanical properties of the sheet metal is its elasticity, plasticity, stiffness and limitation of sensitivity, strength, hardness, etc. Keeler first think of material mechanical properties on the forming limit diagram without much impact, but the subsequent experiment results show that the mechanical properties of the material to the shape and the location of the forming limit diagram has a direct correlation. Even for different soft materials, there is no single forming limit diagram.

6.2 Strain gradient

Material deformation area of strain distribution, the strain gradient, the greater the compensation effect of surrounding material to the danger zone, the greater the strain, the stronger the dispersion effect is beneficial to improve the forming limit.

Can exist in the plane strain gradient, can also occur in the thickness direction. Therefore, increasing the thickness of the sheet metal or reduce punch radius of curvature can improve the forming limit.

Thick material can improve the resistance to localized necking ability; In addition thick; Material on the punch package, make internal and external layer fiber increased, the stress and strain on the difference of outer fibers like the back of a chair, deformation condition. Therefore, the thickness of the material's influence on the forming limit curve is stronger than the effect of curvature. As the Figure 4 show, Hiam of deep rolling steel plate, the experimental curves. As the Figure 5 show, Haberfield, etc with high quality deep drawing steel sheet have been the result of the experiment.

6.3 Method of measurement

Because of specimen and parts on the strain gradient, coordinates, the smaller the diameter of the base circle, ellipse being measured as close to the crack, the greater the ultimate strain obtained the closer to the real value of ultimate strain.

When measured with optical instruments, optical axis should be vertical, and measured the elliptical or the size is error. Of spherical surface parts can also use copy membrane carved, after reading under the microscope.

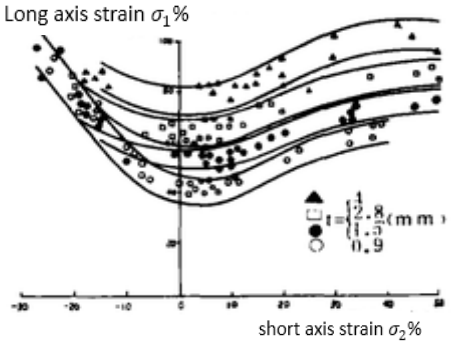

Fig.4 The forming limit diagram of different thickness

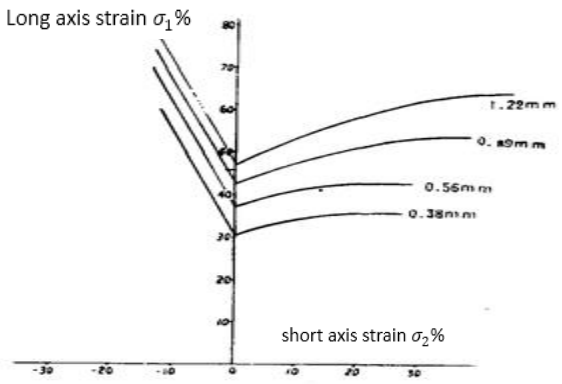

Fig.5 Forming limit curve of different thickness

6.4 Deformation rate

Ordinary press forming speed has little effect to ultimate strain.

With high speed forming, theperformance of material forming will be lower. Broomhead and Grieve in a circle and three sets of oval bulging die, respectively with hydraulic bulging and water hammer high-speed bulging get different forming limit diagram.

Increasing strain rate and reduce the value of n's influence on the forming limit curve is similar. Therefore, to increase the influence of strain rate on forming limit curve, boils down to reduce the value of n caused by the results.

6.5 The strain path

A hat for example, such as in different deformation phases of A fixed point of A measured strain, painting in the actual strain epsilon _1 for longitudinal axis epsilon _2 for transverse coordinate diagram, can see at this point the strain path (the way). Test results show that the ordinary suppress a single process, the strain path parts each point is near to a straight line, the deformation process can be thought of as basically conforms to the law of simple loading. The application in the production of forming limit curve, it is not difficult.

With multistep forming, parts of the strain path does not necessarily follow the law of simple loading again, and by the test piece or single process in the production of the forming limit curve is not necessarily can direct application. Due to complex loading details each are not identical, it is impossible to each one of the forming limit curve, but they can explore the change rule.

7. The forming limit diagram of the main research contents and development direction

Most current study of forming limit diagram still by using the electric erosion method to printed grid in the surface of the samples, with the method of hemispheric punch bulging to testing, and then use the grid analysis device to get round the ultimate strain of critical grid, which is the main content of the current limit stress diagram studies. Due to circular mesh is in proportion to the measurement of deformation exist deficiencies, there are scholars use of square mesh instead of circular grid for ultimate strain measurements, such as M.P.S klad measured with square grid to primary and secondary ultimate strain.

Now based on binocular stereo vision and digital image correlation method of sheet metal forming limit strain measuring system - BOSAS (binocular vision strain measurement analysis system) is also used in sheet metal forming on the measurement, the system can overcome the traditional grid method is hard to deformation process of dynamic monitoring and high degree of automation is not limited, and can be full strain distribution calculation specimen deformation stage, and the reconstruction of the geometry of

the specimens under different deformation time appearance. Transfer segmented displacement method and the finite strain theory, combining can calculate the ultimate strain under large deformation.

The strain path is one of the main influence factors of forming limit diagram, many scholars studied from two aspects of stress and strain effect on the sheet metal forming limit Arrieux strain path.

Through experiment and conversion calculation, such as draw sheet instability stress state and strain path independent, then puts forward the Forming limit stress diagram FLSD (Forming limit stress diag"Gramm). M.P.S klad also was analyzed by using the forming limit stress diagram unconstrained condition in sheet metal forming. Although forming limit according to the plastic stress and strain relationship into forming limit stress diagram, the curve shape has nothing to do with the loading paths, but still need to get the ultimate strain of sheet metal.

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