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Electrochemical Grid Etching Apparatus for Strain Analysis in Sheet and Tubular Blank

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Abstract

Strain analysis by grid marking is a useful method, which has been used effectively to solve the problems in metal forming. After the sheet metal is deformed into desired shape, strain distribution can be visualized and critical areas of strain will be found by FLD (forming limit diagram) and control can be planned by varying the forming parameters. However, the process parameters used for electrochemical grid etching could not be clearly to product the sound grid quality. The aims of this research are to establish the electrochemical grid etching parameters for strain analysis in sheet and tubular Blank. An electrochemical grid etching apparatus are built. In this work, a common low carbon steel tubing grade STKM 11A with 28.6 mm outer diameter and sheeting grade SPCC with 1mm thick are specimen. Circular grids are electro chemically etched onto the surface of sheet and tube samples. Subsequently, the grids on the blank surface are measured to observe the grid quality.

***Keywords**: Electrochemical Grid Etching; Strain Analysis; Forming limit curve; FLC*

1. Introduction

Sheet metal is one of the most important semi-finished products that used in the steel industry, and sheet metal forming technology is an important engineering discipline within the area of mechanical engineering [1]. Sheet metals are characterized by a high ratio of surface area to thickness. Sheet metal forming is basically conversion of a flat sheet metal into a product of desired shape without defect like fracture or excessive localized thinning. In recent years, considerable effort has been dedicated to the numerical methods capable of modeling sheet metal forming processes. The aim of this effort is to assess die modifications, specify the process variables during production and reduce the die try-out period [2, 3]. Several finite-element software packages are commercially available for sheet metal forming analysis. However, each software program may give a different result for the same case. It is very important to verify finite element results by experimental results. The strain measurement in a deformed sheet metal is needed for measurement comparison. The sheet metal operation is usually considered a plane stress problem due to the thickness being much smaller with respect to other dimensions. For this reason, surface strain measurements are very important in the analysis of sheet metal forming processes. The Forming Limit Diagram (FLD) was also determined from surface strain measurement [3]. The FLD is a graph of the major strain ($\mathcal{E}_1$) at the onset of localized necking for all values of the minor strain ($\mathcal{E}_2$), as shown in Fig. 1 [4]. Finite element software packages use FLD to evaluate deformation of sheet metal parts. It is quite possible to determine the limiting deformations such as necking and tearing [5].

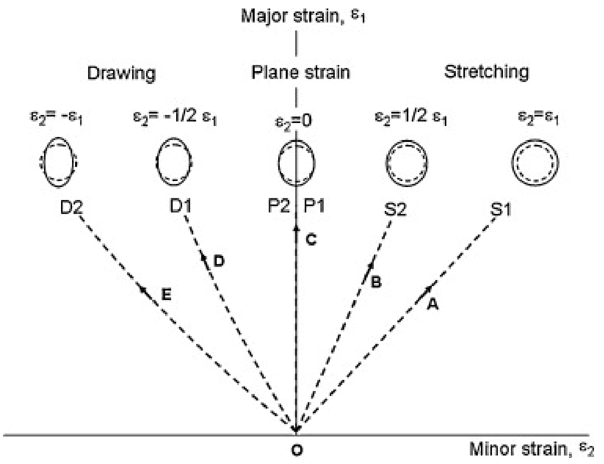

Fig.1 Schematic of several major strain/minor strain combinations in FLD

The principal methods of measuring strain or deformation are grid marking, strain gages, mechanical and optical extensometers, ultrasound thickness and shape measurements. Grid marking is one of the commonly used strain measurement methods for strain analysis in sheet metal forming processes due to the relative simplicity [6]. It consists of a very small diameter circle or square grid pattern (approximately a range from 1 to 8 mm). Grid marking is the process of printing line patterns in the area of interest on the sheet and tube metal blank [7]. The utilized grid pattern should be very precise in order to obtain accurate results from the strain analysis [8]. Strain analysis by grid marking is a practical method, which has been utilized effectively to solve problems in metal forming [9]. This system was first proposed in 1965. For grid marking measurement different measuring techniques are used. These include both manual and automated measurement methods. When sheet metal is formed, it is subjected to various stresses. These stresses produce non-uniform strains and might lead to wrinkling or fracturing in the formed part [9, 10]. The sheet metal is marked with line patterns such as circles and squares using various methods before the forming process are carried out. The forming process causes the line patterns to deform by an amount that depends on the local deformation experienced by the sheet metal. After the sheet metal is formed, the circles will become an ellipse unless deformation is pure biaxial stretching. The longest dimension of the ellipse is the major axis and the dimension perpendicular to the major axis is called as the minor axis. Whereby grid measurements are carried out, strains can be calculated. The grid analysis system supports the development of the Forming Limit Diagram (FLD), which may be used in studying the forming properties of sheets. The measured strains are compared by a forming limit diagram with FEM to estimate whether a fracture occurs in sheet metal. The aims of this research are design and build the electrochemical grid etching apparatus for Strain analysis in Sheet and Tubular Blank. In this work a common low carbon steel tubing grade STKM 11A, with 25.4 mm outer diameter and 1 mm thick is studied for tube etching. And common low carbon steel sheet blank grade SPCC, with 1 mm thick is studied for sheet etching.

2. Electrochemical Grid Etching

2.1 Electrochemical Grid Etching methods

This method is the most preferred method for applying grids since it is easy and quick. The basic principle of this method is shown in Fig. 2. In this process an electric stencil is placed on the cleaned blank. A felt pad soaked with electrolyte is placed on the top of the blank.

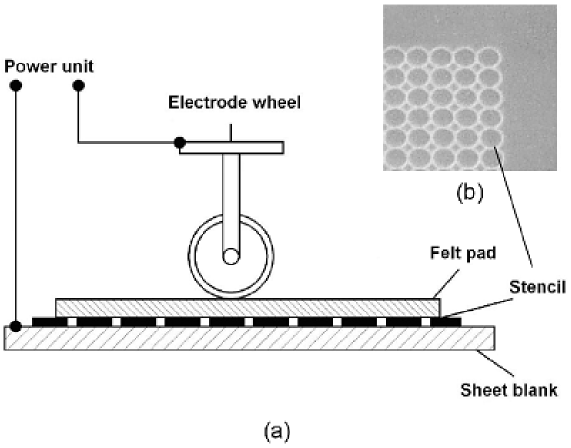

Fig. 2 (a) The basic principle of electrochemical etching method, (b) example of a stencil

It requires a low voltage power source, stencil, felt pad, and etching solution. First, a power source is attached to the electrode and the blank. The power unit is equipped with an AC/DC switch. A flat or roller type electrode wheel with an attached power source is reciprocated on the felt pad and thus current is passed from the electrode to the blank. The etching solution is pressed out through the contours of the stencil and reaches the surface of the sheet by means of the pressure of the roller wheel. Current varies from 15-50 ampere. The required time for electrochemical etching is a function of blank material and the applied voltage. The depth of etching is proportional to the time of application. As a result of the voltage placed across the electrode wheel and sheet metal, the pattern of the stencil is etched on to the sheet surface. After etching, the sheet metal should be washed with a neutralizing solution. The main advantages of this method are that its application is simple and cost effective, the applied grid patterns are permanent, it does not cause distortion on the sheet metal, it does not introduce stress concentrations and the applied grid is durable during forming. In addition, accurate grid patterns can be obtained by using this method. However, this method can only be performed on conductive metals. Nevertheless, it is widely used by the aircraft and defense industries. Required equipment and supplies for electrochemical etching are available commercially.

2.2 Grid stencil

Many types of circle grid patterns have been used, such as square arrays of contacting or closely spaced non-contacting circles and arrays of overlapping circles. With small closely spaced circles, it is possible to determine strain gradients accurately. After deformation the circle is transferred into ellipse. The direction of the strains is indicated by the major and minor axis of the ellipse. Circles of 2.5mm diameters have been found to be a good size. The patterns of Circle Grids are shown in Fig. 3.

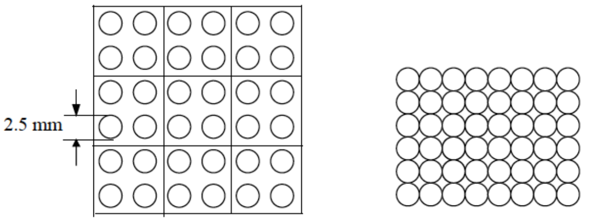

Fig. 3 Patterns of Circle Grids

2.3 Electrolytes and Cleaners

Electrolyte is the conducting medium for the etching current. It carries the necessary metallic salts to etch the metal, and to develop the black residue for dark, contrasting marks. Necessary inhibitors, depolarizers, surfactants, and stencil cleaning media are also carried by the electrolyte. In addition, the electrolyte also serves as a heat dissipater, and controls depth of mark through electrochemical action. Choosing the proper electrolyte and cleaner is necessary to obtain a clear, sharp and contrasting mark.

3 Electrochemical Grid Etching Apparatus

3.1 Mechanism design for Electrochemical Grid Etching Apparatus

The electrochemical grid etching apparatus for sheet blank and tubular blank are designed in this research. In this work a common low carbon steel tubing grade STKM 11A, with 25.4 mm outer diameter and 1 mm thick is studied for electrochemical grid etching apparatus set for tubular blank. And a common low carbon steel sheet grade SPSS, with 1 mm thick is studied for electrochemical grid etching apparatus set for sheet blank. The Electrochemical Grid Etching Apparatus is shown in Fig. 4.

3.2 Power Units

The power source as shown in Fig. 5 is attached to the electrode for supply electric current. The linear power supply unit is selected for this research. Current varies from 15 – 45 ampere depending on stencil size and line density both DC and AC in operating time 30 second and stroke type of supply of electricity to be stable enough for grid etching of mind steel with 1 mm thick.

Fig. 4 Electrochemical Grid Etching Apparatus

Fig. 5 Electrochemical Grid Etching Power Unit

3.3 Control unit for electrochemical grid etching Apparatus

The programmable logic controller (Mitsubishi Fxos-20MT-D) as shown in Fig. 6 is used to control the electrochemical grid etching apparatus. Ladder diagrams are designed the schematics used to control logic systems. All Ladder diagrams were simulated using the program code Melsoft series GX developer.

Fig. 6 Control box

3.4 Properly Parameter of Electrochemical grid etching Apparatus

The three-level design is used to optimize the loading conditions of the tube hydroforming process are created and investigated. Tree factors are thought to influence clearing: velocity of etching process (V), contact force (F) and electric current (I). Three velocity of etching process, three contact force and three electric current are chosen, and 5 replicates of a 3^3 factorial experiment are run. The influence parameters are shown in Fig 7. The result has been shown that the three process parameter had the significant influence on electrochemical grid etching process and the proper process parameter are 0.005 m/s of velocity, 36.49 N of contact force and 6 Amp electric current.

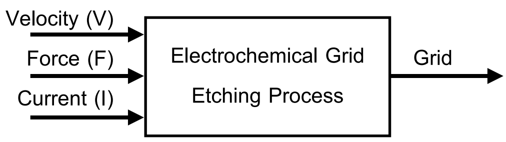

Fig 7. Model of a process

4. Result and Discussion

Successful grid pattern in using electrochemical grid etching process is mainly resulted from applications of proper loading parameter, i.e. speed, pressure force and electric current for the entire etching process. The results of the study showed that the level appropriate to adjust the parameters to make the minimum grid size discrepancy. And it is clear enough that the properly speed, pressure force and electric are 0.005 m/s, 36.49 N and 6 ampere consequently which make the clearly grid pattern as shown in Fig. 8.

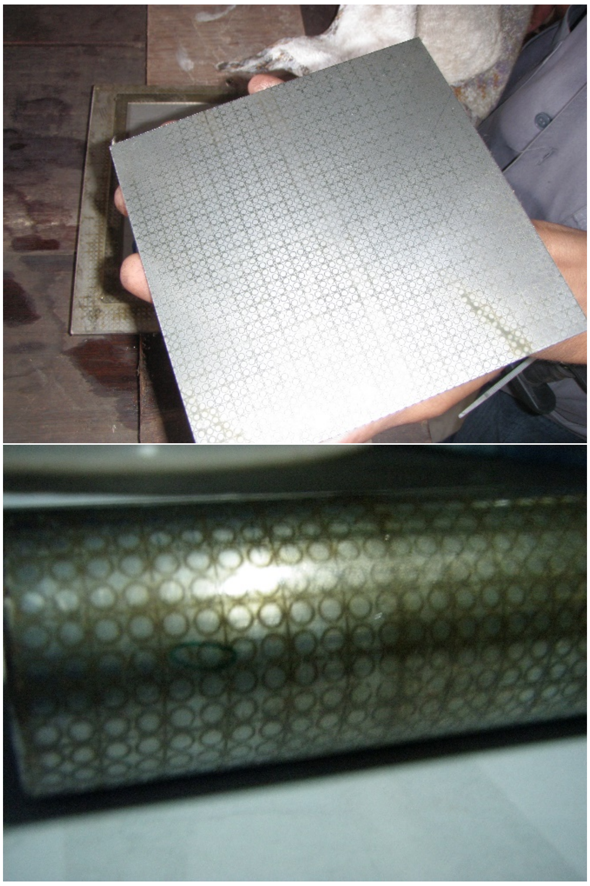

Fig. 8. A specimen (Sheet and tubular blank) etched as proper loading parameter

5. Conclusions

Grid marking and strain measurement methods used for determination of sheet metal formability were investigated and compared in terms of their usability and accuracy. Electrochemical etching and serigraphy methods for grid marking, and manual and automated strain measurement methods for measuring strain were dealt with and the following results were obtained.

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