

STRAIN STUDIES IN SHEET METAL STAMPINGS

Amit Mukund Joshi
(B.E Mechanical, A.M.I. Prod. E)

➤ INTRODUCTION

Sheet metal is one of the most important semi finished products used in the steel industry, and sheet metal forming technology is therefore an important engineering discipline within the area of mechanical engineering. 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 localised thinning.

In automobiles the sheet metal is deformed into the desired and brought into the required form to get autobody pressings like bonnet, bumpers, doors, etc. In aircraft's sheet metal is used for making the entire fuselage wings and (body). In domestic applications sheet metal is used for making many parts like washing machine body and covers, iron tops, timepiece cases, fan blades and casing, cooking utensils etc.

The products made by sheet-forming processes include a large variety of shapes and sizes, ranging from simple bends to double curvatures with shallow or deep recesses. Typical examples are metal desks, appliance bodies, aircraft panels, beverage cans, auto bodies, and kitchen utensils. In many cases while deforming the sheet metal, the component fractures at certain point. The causes of failure are parameters related to forming process.

Traditional evaluation of formability is based on both intrinsic tests and simulative tests.

The intrinsic tests measure the basic characteristic properties of materials that can be related to their formability. These tests provide comprehensive information that is insensitive to the thickness and surface condition of the material.

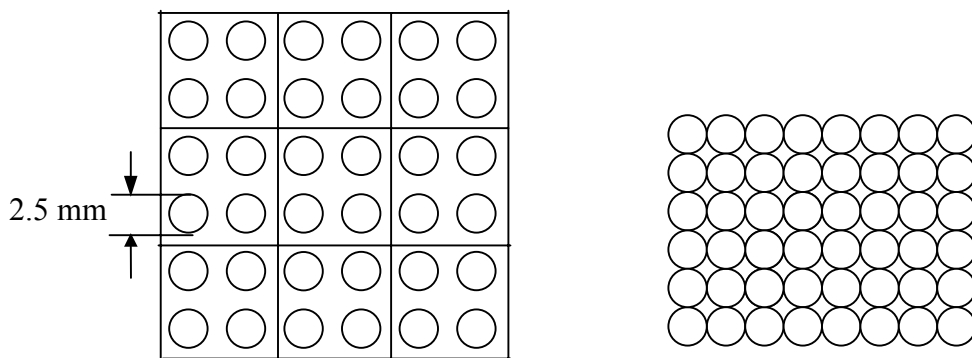
Examples of intrinsic tests are Uniaxial tensile test, Plane strain tensile test, Marciniak Biaxial Stretching test, Hydraulic Bulge test, Marciniak In-Plane Sheet torsion test, Miyauchi shear test, Hardness test. The simulative tests subject the material to deformation that closely resembles the deformation that occurs in a particular forming operation. Examples of these tests include Ericksen , Olsen, Fukui, Swift tests.

➤ **CONCEPT**

Strain analysis by grid marking is a useful method, which has been used effectively to solve the problems in metal forming. When sheet metal is formed, its surface is subjected to different stresses. This results into non uniform strains to be developed in the formed part. Thus there will be regions of high strains as well as low strains, which may lead to wrinkling or fracturing of the material. By the grid marking method the areas of high strain can be easily identified. The sheet is marked with the grid before forming process is carried out. 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.

➤ **GRID**

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.



Patterns of Circle Grids

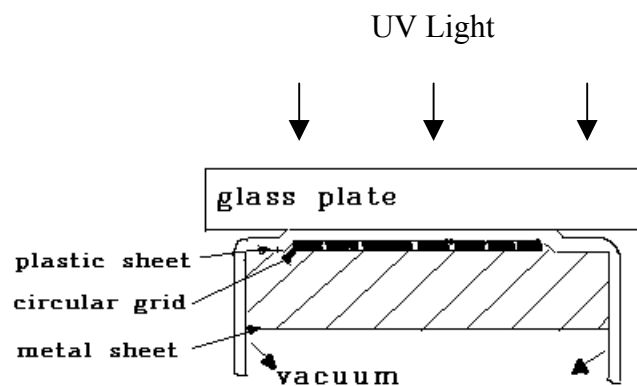
➤ GRID MARKING METHODS

There are various techniques available for applying the grids. Circular grids are normally made in two different ways. They can be made electro-chemically or photo-chemically, both processes having particular advantages and disadvantages.

- 1) **Photochemical etching** - This is an accurate method of grid marking. The following steps are involved in marking the grid by this method.
 - a) cleaning of metal surfaces.
 - b) Covering with photo resist.
 - c) Illuminating with UV light.
 - d) Developing
 - e) Etching
 - f) Surface Cleaning.

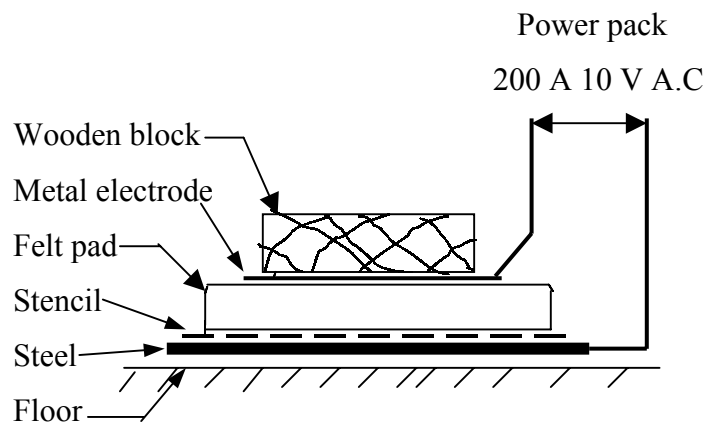
Cleaning of metals is achieved with toluene ($C_6H_5CH_3$) or trichlorethylene ($CHCl_3$) but can also be done in an acid bath for a shorter time. Photo resist emulsion is applied on the blank. Then the emulsion is covered with a photographic negative and exposed to strong ultra-violet radiation. The image of the negative is developed like a photographic print. Very fine, sharp lines can be printed on the blank in this way. The photogrid should be placed in close contact with the metal surface. This can be achieved by creating vacuum between the surface and the grid. A dark room is required for the development. The photogrid prepared in this way is removed by chemicals and rubbing. This difficulty can be overcome by further etching the metal surface.

After developing the resist already illuminated, the etchant is applied to the metal surface for etching uncovered metal. The different acid solutions used for etching are HCl, HNO_3 , HF, etc.). After etching the metal surface is cleaned with toluene or trichlorethylene.



Photochemical technique with vacuum between photogrid and the metal surface.

2) **Electrochemical Marking** - This method is the most preferred method for applying grids since it is easy and quick. 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 and an electrode (flat or roller type) is placed above the felt pad. A wooden block is kept above as shown in the figure. Leads from a 14 V power source are attached to the electrode and the blank. Current varies from 15 – 200 A depending on stencil size and line density. After applying pressure over the electrode the felt pad will squeeze, the electrolyte will pass through stencil and comes in contact with blank etching the grid pattern electrochemically into the blank. After etching the blank is washed with a neutralizing solution.



Set Up for Electrochemical Marking

Electrolyte – Proper electrolyte should be used for marking a specific metal. A basic solution of electrolyte is composed approximately as :-

potassium chloride	: 80 gms
Sodium chloride	: 90 gms
Nitric acid	: 100ml
Hydrochloric acid	: 100ml
Water	: 4.5litre

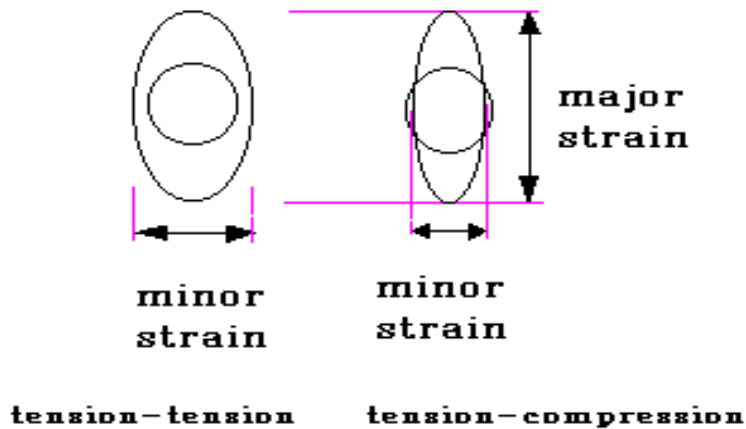
This solution has been found satisfactory on ferrous and non ferrous metals

➤ STRAIN MEASUREMENT

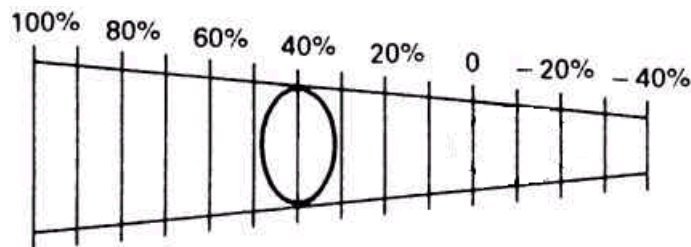
After sheet metal is formed the marked circles will deform into ellipses of different sizes. Strain is calculated from the following formula.

$$\text{Major strain} = \frac{(\text{major axis length} - \text{original circle dia.})}{\text{original circle dia.}} \times 100$$

$$\text{Minor strain} = \frac{(\text{minor axis length} - \text{original circle dia.})}{\text{original circle dia.}} \times 100$$

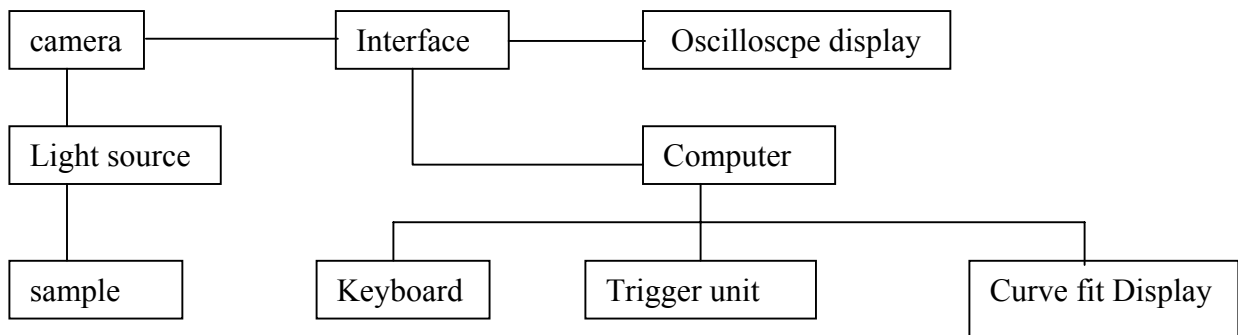


- 1) **Dividers and steel rule** - This is the most simple and quick method. This method is suitable for measurement on more or less flat surface. On curved surface the measured dimension will be less i.e. it will measure the chord length rather than arc length. The accuracy is also limited.
- 2) **Mylar Tape** – this is a transparent scale to measure the strain directly. This tape has diverging lines scaled to read directly in percent strain. This scale is produced by photographic printing from a negative on to film. The scale is placed over an ellipse over a sharp radius and then shifted until the diverging lines line up with the major axis of the ellipse. The percent strain is measured directly from the scale. The scale is next turned 90 degrees to read the minor strain.



Mylar Tape

- 3) **Travelling microscope** - This is the most widely used method for measuring the changes in the dimension of grid circles. There are two right angle slides on which work is mounted. The work is positioned under the microscope. Cross wire is aligned at one end and the measurement is taken. The cross wire is then aligned on the other end by moving the work table and the measurement is taken. The difference between the two readings gives the absolute measurement. This is an accurate method. Two persons can get different readings because of error in aligning the two axes.
- 4) **Grid Circle Analyser (GCA)** - They use a solid state digital array camera with a built in light source, a computer, keyboard, and CRT display. The image of given deformed circle is displayed on the CRT and a least squares curve fitting program selects the most suitable ellipse, which is displayed simultaneously. The major and minor strains computed from the equation for ellipse and the diameter of the original circle are displayed on the screen.



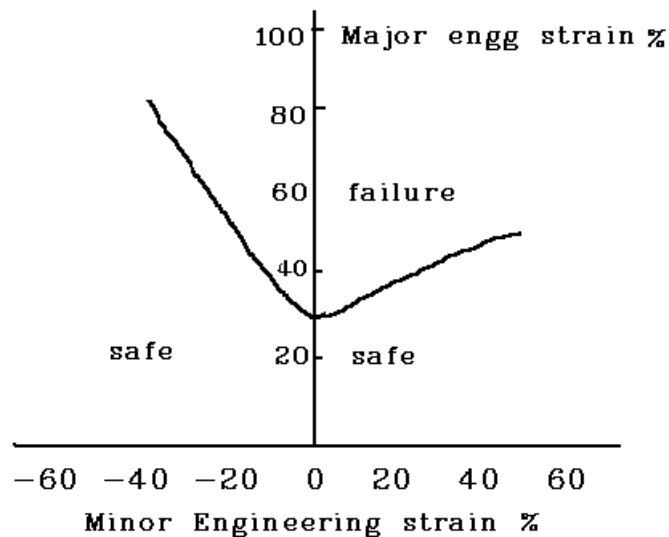
GCA Lay Out

➤ **FORMING LIMIT DIAGRAM CONCEPT**

To reduce experimentation through trial and error method which is both expensive and time consuming, Keeler and Goodwin proposed grid strain analysis. This involves etching a pattern of fine circles on the sheet metal before pressing. After pressing the circles will be deformed into ellipses which can be measured to indicate major and minor strains produced in the component. An estimate of how close the metal is to failure is obtained by reference to the FLD, which is a plot of the major and minor strains at fracture over a wide range of conditions. Forming limit diagrams indicate the limiting strains that sheet metals can sustain over a wide range of major – to – minor strain ratios.

Two types of tests are used to determine these limiting strains. The first category of test involves stretching test specimens over a punch – for example the hemispherical punch method producing some out of plane deformation. The hemispherical punch method for determining FLD uses circle gridded strips of the test material ranging in width from 25.4 to 203 mm that are clamped in a die ring and stretched to fracture by a steel punch (102 mm dia). The strains are measured in and around regions of visible necking and fracture. The forming limit curve is drawn above the strains measured outside the necked regions and below those measured in the necked and fractured regions.

The second test produces only in – plane – deformation and does not involve any contact with the sample within the gage length. This can be achieved by using uniaxial tensile test or marciniak biaxial stretching test with elliptical or circular punches.



Forming Limit Diagram

➤ **USE OF GRID ANALYSIS FOR PRESS SHOPS**

FLD can be used in conjunction with grid analysis to estimate how closely areas of high strain in a shell are to fracture. Thus the criticality of a press forming operation can be determined. Areas of high strain in the press formed component can be located and by studying the development of the strains during the press forming the cause of the strains can be usually found and remedied. Grid analysis can be used -

- 1) For die development
- 2) For selection of material and lubricant.
- 3) For fault finding.
- 4) For production control.
- 5) For monitoring die work.

References

- 1) Taylor B, Formability Testing of Sheet Metals, Metals Handbook, ASM.
- 2) Dinda, how to use circle grid analysis for die try out, ASM, 1981.
- 3) Rivenaes V, Simple and cheap grid marking, Sheet Metal Industries, 1974.
- 4) Keeler S.P, Circular grid system – a valuable aid for evaluating sheet metal formability, Sheet Metal Industries, 45,1968.
- 5) Keeler S P, determination of forming limits in automotive stampings, Trans SAE, 74, paper no. 650355, 1966.
- 6) B. Larsen, photo-chemical etching of circular grids, Sheet Metal Industries, 1974.
- 6) Crutchley. R, why photo etch, Sheet Metal Industries, 62, 1985.
- 7) Groebler Hans, electrochemical marking for sheet metal forming investigations, Sheet Metal Industries, 1974.
- 8) Brookes I. C, Davies G.M, grid marking in the press shop, Sheet Metal Industries, 1972.
- 9) Hobbs R. M, Duncan J. L, analysis of press performance, ASM.

Contact

Email – amitmech@hotmail.com, amitjoshi@email.com