Evaluation of Forming Property of AISI 1008 by Tensile Test

Vipul Patel[1], Darshan Shah[2], V R Iyer[1], Jatin Dave[1]
[1]Institute of Technology, Nirma University, Ahmedabad
[2]Harsha Engineers Limited, Changodar, Ahmedabad

***Abstract*--In current engineering world, lead time for the development of new forming component is very crucial. Each and every industry uses sheet metal forming Simulation software for reducing Lead Time for the Development of new forming component. The accuracy of the simulations is to a large extent dependent on the quality of the material properties provided as input to simulations. Improving the quality of material properties is the key factor in order to further increase the accuracy of simulation. So Tensile Test is performed for AISI 1008 steel on universal tensile testing machine to determines the mechanical Properties.**

Forming limit Diagram (FLD) is the key factor for finding the formability of the material. FLD by tensile test enables fast and easy determination of forming limit and shows less scatter in results. This test procedure applied only to the negative side of the FLD.

***Index Terms*--Forming Limit, Uniaxial Tensile Test**

I. Introduction

LARGE efforts are being made in the industry in order to shorten lead times and reduce costs when developing new forming component. In order to manage this, physical testing has to a large extent been replaced with numerical simulations. Simulations are used to verify both the properties of the new forming Component as well as their producability. An area of which significant progress has been made is finite element simulation of sheet metal forming. Simulations have to a large extent replaced try-out tools as the process verification method. In this way, both lead-times and costs for the development of new forming parts have been reduced considerably. Much work has been made in the past in order to increase the accuracy of the finite element programs and in the modeling technique. One area of significant importance in order to further increase the correlation between simulations and reality is the experimental determination of relevant material properties. The accuracy of the simulations is to a very large extent dependent on the quality of the material properties provided as input to the simulations. Improving the quality of the material properties is the key factor in order to further increase the accuracy of the simulations. Material properties of main interest for sheet metal forming are stress–strain relations describing the work-hardening of the material and forming limits describing how much the material can be deformed without cracking. This study is focused on the forming limit properties. An improved method for material characterisation of sheet metal is a field that has gained a larger focus during the last years. The need for accurate material characterization methods is of great importance in order to further strengthen the use of the simulation technique for sheet metal forming applications.

This is becoming of even more important due to the increased use of new high strength materials in order to reduce weight and increase the crash performance. The problem with these new high strength sheet materials is that their increase in strength is compensated by a reduction in formability. Optimal usage of these new materials requires a deep knowledge of the material properties so that it is possible to be close to the forming limit. A fundamental problem in sheet metal forming is fracturing. It is therefore essential to be able to predict the risk of fracture with high accuracy. The forming limit curve (FLC) is the most commonly used fracture criterion for sheet metal forming applications. The FLC shows the amount of deformation (strain) a sheet material can resist as function of the deformation mode and is a relation between the major and minor strain. In the figure 1, the different main deformation modes are indicated. The minimum of the FLC is normally at the plane strain condition. In order to avoid fracturing of the material, it is necessary that the strain levels everywhere in the stamped part be below the FLC. A safety margin is normally introduced, resulting in an offset of the FLC. The risk of fracture is determined by evaluating how close the strain condition is to the FLC. It is not only sufficient to check the risk of fracture when designing a forming process. However, other problems such as excessive thinning, wrinkling or insufficient stretch may occur. These conditions are normally also evaluated by studying the strain levels. A forming limit diagram is constructed from the FLC and is normally used in the design of the forming process.

There is no unique standard for determining FLCs, the main routine when determining a FLC is however as follows, however. By forming a number of sheet specimens with varying widths, different deformation modes (strain states) are received. The sheet specimens are equipped with circle grids in order to enable strain evaluation. The specimens are stamped to fracture and the strain state is evaluated just outside the fracture zone. The limiting strain levels determined from these different specimens are then connected to a curve, by some kind of curve-fitting. The procedure for determining FLCs may differ concerning the geometry of the forming punch used, the specimen dimensions, the number of specimen geometries considered, the technique used for the strain states evaluation and the type of curve-fitting used. An example of tool and specimen geometries used for determination of FLCs is given in Figure 2. An example of a FLC is shown in Figure 2. In the diagram, the measured strain levels using different specimen geometries are shown.

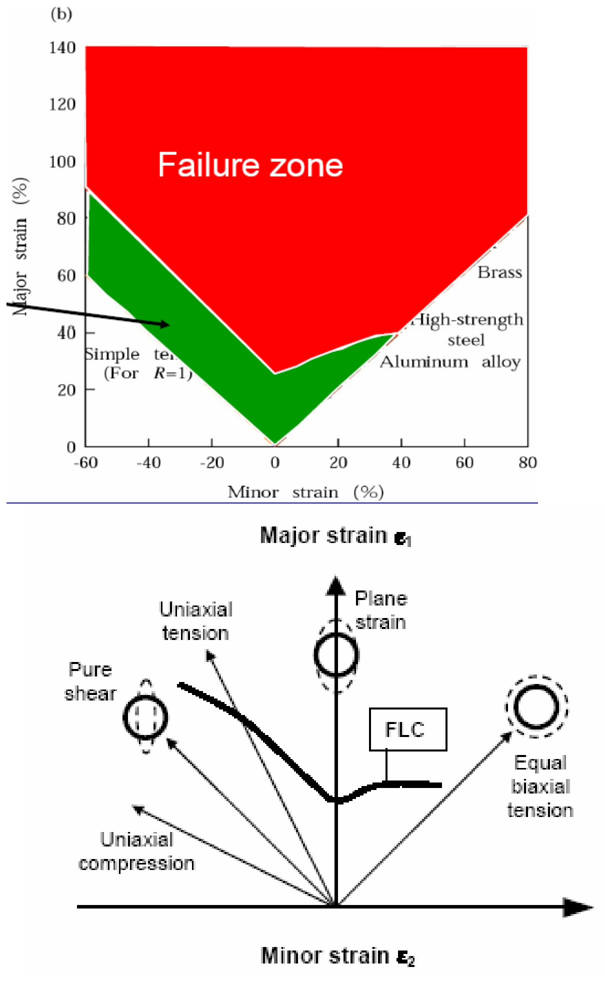

Fig. 1. Forming limit curve

The FLC concept has a number of limitations and uncertainties. One fundamental problem with the FLC concept is that it is based on the assumption of linear strain paths, i.e. the mode of deformation remains constant throughout the deformation process. However, this condition is not fulfilled in most practical cases, however. A lot of studies concerning the effect of non-linear (or broken) strain paths on the FLC have been conducted. In these studies, the FLC has been determined on specimens which have been subjected to different types of pre-straining conditions. Taking the effect of non-linear strain paths into account in practical process design is very complex, however, since an infinite number of different pre-straining conditions exist. Another problem with the FLC is that the experimental results are influenced by the friction conditions during testing. There is also a small deviation from linear strain paths due to bending effects during forming. A problem in practical forming process design is that the determination of the FLC is a rather lengthy procedure. In the automotive industry, there is often a shortage of time for the process design phase, which means that there sometimes is not enough time to perform a thorough FLC determination. Therefore, different theoretical and empirical formulas have been developed. Another drawback of significance is the large scatter in experimental results when determining a FLC. This is due to the overall testing procedure as well as the strain evaluation methodology. Despite the drawbacks with the concept of FLCs, it is, by far, the most commonly used fracture criterion for sheet metal forming applications. This is due to its, in many cases, good performance, its simplicity and for historical reasons.

II. OBJECTIVE OF THIS STUDY

The main objective of this study was to evaluate mechanical properties of AISI 1008 for determination of the formability of sheet metal through tensile testing. The mechanical properties of the AISI 1008 found by tensile test are shown in table1

Yield Strength (N/mm2)	Ultimate Strength. (N/mm2)	Rm	t (mm)	E (N/mm2)	n
275.000	327.000	1.616	2.000	192307.692	0.271

TABLE I
MECHANICAL PROPERTY OF AISI 1008

1) Specimen Geomtry:

The geometry of the test Specimen is as per ASTM Standard Which are shown in the figure

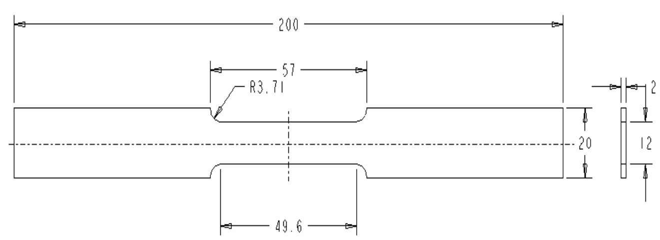

Fig 2. Tensile Test Specimen

2) Experimental Procedure:

Tensile testing machine is built up with a load frame of a solid T-slot table, columns and a hydraulically maneuverable crosshead. Control and data acquisition is performed by computer boards and specially designed programs. Test is performed on Universal Tensile Testing machine. To be able to clamp the specimen in the desirable manner, special attention was put on the rectangular jaw rather than circular jaw, and specially their surface towards the specimen.

Fig 3. Experimental Set up

After completing the Tensile Test the output was obtain in graph form which are load – extension diagram and stress – strain curve with yielding load, Ultimate Tensile Load and Final gauge length of the Tensile Test Piece.

III. Results from Tensile Test

TABLE II
RESULT FROM TENSILE TESTS

Specimen Type	Final Area mm^2	Disp. At Max Load (mm)	Ultimate Load (N)	Yield Load (N)
R001	14.21	19.000	7790.00	6375.00
R002	14.73	14.300	8190.00	6875.00
R003	14.21	12.800	7960.00	6250.00
R451	14.93	13.200	7700.00	6750.00
R452	13.96	13.300	7830.00	6312.50
R453	15.14	13.900	8000.00	6687.50
R901	15.62	13.100	7660.00	6312.50
R902	13.53	13.000	8050.00	6750.00
R903	15.08	12.900	7850.00	6250.00

TABLE III
RESULTS FROM NUMERICAL CALCULATIONS

Specimen Type	n	ε_0	K Mpa
R001	0.289	0.0174	587.495
R002	0.271	0.0029	599.726
R003	0.27	0.003	584.706
R451	0.239	0.0101	540.652
R452	0.255	0.004	563.649
R453	0.253	0.0037	573.523
R901	0.216	0.0039	524.825
R902	0.251	0.006	575.131
R903	0.208	0.0041	532.789

IV. Theoritical Determination of Forming Limit Diagram

There are so many models for Theoretical Determination of Forming limit Diagram. In this Paper, Forming Limit Diagram is Plotted using Combination of Swift and Hill model and NADDRG model.

The theoretical analysis is based on the plastic theory of Hill [9] taking orthotropic anisotropy into account, the equivalent stress σ_i and the equivalent Strain increment $d\varepsilon_i$ being defined as follows:

$$\sigma_i = \sqrt{\frac{3(1+r)}{2(2+r)}} . \sqrt{\sigma_1^2 + \sigma_2^2 - \frac{2r}{1+r}\sigma_1\sigma_2}$$

$$d\varepsilon_i = \sqrt{\frac{2(1+r)(2+r)}{3(1+2r)}} . \sqrt{d\varepsilon_1^2 + d\varepsilon_2^2 + \frac{2r}{1+r}d\varepsilon_1 d\varepsilon_2}$$

The associated flow rule in the principal axes of orthotropic anisotropy is expressed in the form:

$$\frac{d\varepsilon_1}{(1+r)\sigma_1 - r\sigma_2} = \frac{d\varepsilon_2}{(1+r)\sigma_2 - r\sigma_1} = \frac{-d\varepsilon_3}{\sigma_1 + \sigma_2} = \frac{d\varepsilon_i}{\frac{2(2+r)}{3}\sigma_i}$$

Where σ_1, σ_2, $d\varepsilon_1$ and $d\varepsilon_2$ are the major and minor principal stress and strain increment within the plane of a sheet, respectively, and $d\varepsilon_3$ is the thickness strain increment. The value r, which represents the anisotropic characteristics of the sheet, is the ratio of the width and thickness strain of a specimen deformed in uniaxial tension.

It has been proven that a good simulation of the forming limit strains can be given on the basis of the Swift diffuse instability theory and the Hill localized instability theory and here Swift's and Hill's theories are used to calculate the forming limit strains on the left and the right side, respectively, of the FLD.

Assuming that the stress–strain relationship of sheets can be expressed by Hollomon's equation:

$$\sigma_i = K\varepsilon_i^n \quad \varepsilon_i = \int d\varepsilon_i$$

Where K is a parameter of the material
n is the strain-hardening exponent.

According to Swift's and Hill's criterion combined, the formulae calculating the forming-limit strains can be written as follows, with

$$\alpha = \sigma_2 / \sigma_1$$

For $\varepsilon_2 < 0$:

$$\varepsilon_{j1} = \frac{1+(1-\alpha)r}{1+\alpha} n$$

$$\varepsilon_{j2} = \frac{\alpha-(1-\alpha)r}{1+\alpha} n$$

For $\varepsilon_2 > 0$:

$$\varepsilon_{f1} = \frac{\left[1+r(1-\alpha)\right].\left[1-\frac{2r}{1+r}\alpha+\alpha^2\right]}{(1+\alpha)(1+r)\left[1-\frac{1+4r+2r^2}{(1+r)^2}\alpha+\alpha^2\right]}.n$$

$$\varepsilon_{f2} = \frac{\left[(1+r)\alpha-r\right].\left[1-\frac{2r}{1+r}\alpha+\alpha^2\right]}{(1+\alpha)(1+r)\left[1-\frac{1+4r+2r^2}{(1+r)^2}\alpha+\alpha^2\right]}.n$$

After Using above Equation, with varying the value of stress ratio (α) the forming limit Diagram (FLD) is founr under:

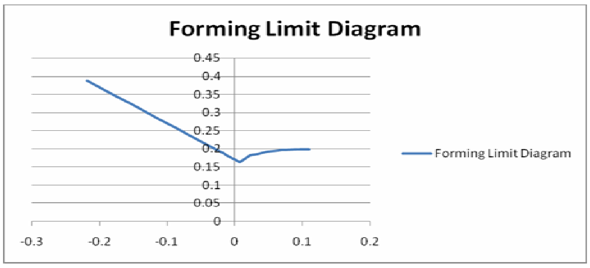

Fig 4. FLD based on Swift-Hill Model

1) NADDRG Model

For simplifying the experimental and theoretical determination of the FLD and utilizing the FLD more easily in the press workshop, the North American Deep Drawing Research Group (NADDRG) introduced an empirical equation for predicting the FLD in practice. This equation for calculating the forming-limit strain e10 in the plane-strain state in terms of engineering strain can be expressed as:

$$e_{10} = (23.3 + 360t)(n/0.21)$$

where $t_0 \le 0.125$ is the sheet thickness in inches. According to this model, the FLD is composed of two lines through the point e10 in the plane-strain state. The slopes of the lines located respectively on the left- and right-side of the FLD are about 45° and 20°.

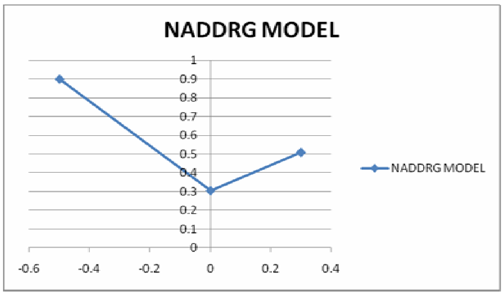

Fig 5. FLD based on NADDRG Model

V. Experimental Determination of Forming Limit Diagram

Using Tensile Test we can plot Forming Limit Diagram but it gives the value on the negative side of the FLD because it is the case of uniaxial tension. The circle grid marking on tensile test piece has been carried out by laser source to measure the formability. The accuracy of the forming limit Diagram largely is dependent on the accuracy of circle grid and its measuring system. .Measurement was done using tool makers microscope.

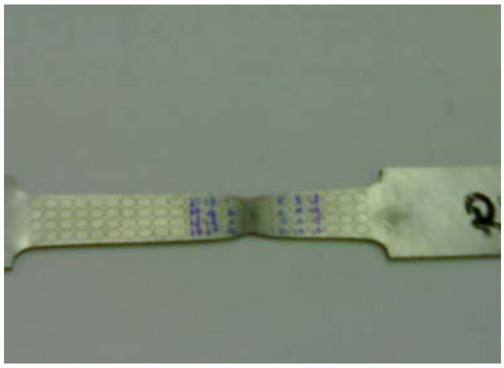

Fig 6. Deformed Specimen of Tensile Test

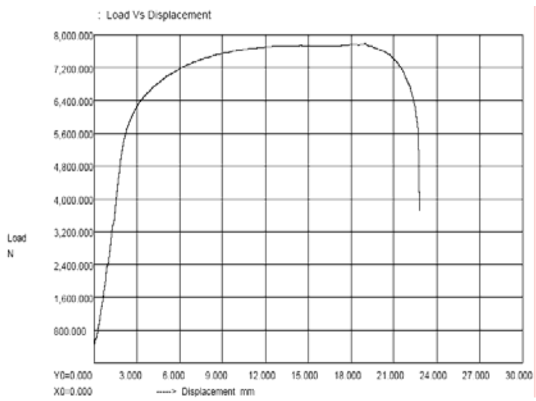

Fig 7. load vs Displacement curve

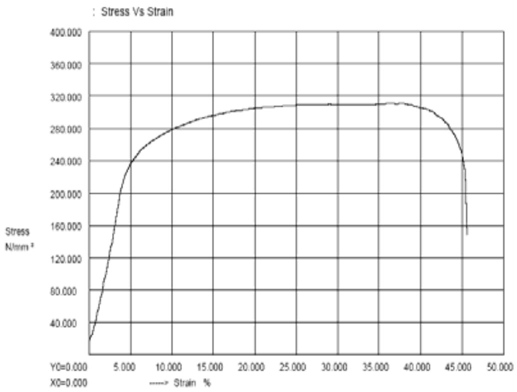

Fig 8. Stress Strain Curve by Tensile Test

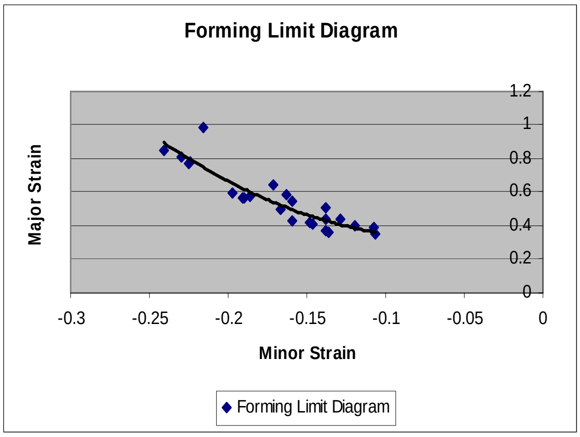

Fig 9. Forming Limit Diagram by tensile test

VI. Conclusions

The following conclusions apply:

• A test procedure for determining the forming limit in plane strain for sheet metal was developed. The main advantages with the method are that it enables a fast and easy determination of the formability. The results show small scatter as compared to the conventional methods and it can be carried out in a tensile testing machine. It does not require any forming tools or press.

• The grip arrangements are essential in order to get successful tests. With insufficient clamping of the specimen, localization and fracture will not occur at the desired middle region of the specimen where plane strain conditions apply.

• The specimen free length (Lf) has a large influence on the results. The specimen free length should be as small as possible in order to get a condition as close to plane strain as possible in the middle region of the specimen.

• A test procedure for determining the complete left-hand side of the FLC by tensile tests was outlined. By changing the geometry of the specimen, different strain conditions are achieved. The right-hand side of the FLC cannot be determined by this procedure.

VII. References

[1] Stefan Holmberg, Bertil Enquist ,Per Thilderkvist, Evaluation of sheet metal formability by Tensile tests, J.Materials Processing Technology 145(2004) 72-83

[2] www.cpforming.org visited on 27th September,2008.

[3] www.ercnsm.org visited on 27th September,2008.

[4] ASTM E8-04 Standard Test Methods for Tension Testing of Metallic Materials.

[5] Z.Marciniak,J.L.Ducan,S.J.Hu,Mechanics Of Sheet Metal Forming, page61-79.

[6] Z.Marciniak and K.Kuczynski,Limit Strain in the processes of strech-forming Sheet metal,Int.J.Mech.Sci,1967,vol 9,pp 609-620.