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Analysis of sheet metal bending by using Finite Element Method

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***Abstract*-Out of all the traditional manufacturing processes like casting, forming, cutting, joining, sheet metal forming, deep drawing etc.., sheet metal forming is a special case of deformation process in which sheet metals of less than 6 mm are formed. It is the process of converting a flat sheet of metal into a part of desired shape without fracture or excessive localized thinning. Hence the formability assessment of the different metals i.e., Type 303 Stainless steel, mild steel and Aluminum is done. Theparameters such as normal stress, total deformation, maximum principal stress, equivalent stress (Von Mises) and maximum principal elastic strainare analyzed using ANSYS software.**

***Keywords*- Sheet metal, finite element analysis, deformation, formability.**

I.INTRODUCTION

A large variety of metallic parts are produced by deformation process. In fact, there are more than 1000 registered types of steels; each of these was originally designated for some specific use.

Forming process involve shaping material in the solid state whether the material is a continuous solid or powder. It is the essential property when the material is subjected to deformation .This process requires lot of energy depending on the type of metal, expenditure and capital investment to be formed differs.In sheet metal working operations, the cross-section of the work piece remains same and the material is subjected to shape changes. These operations are performed on thin sheets (< 6 mm) by means of a set of tools called punch and die. Forming can be done based on type of sheet, punch and die.

Sheet metal forming involves bending, punching, drawing, stretching and some other processes. Out of various bending operations, V-die bending is chosen for the sheet metal to be formed. The common failures encountered during sheet metal forming, wrinkling, puckering, and shape distortion factors. They are generally characterized by a high ratio of surface area to thickness. Sheet metal forming operations are so diverse in type, extent and rate that no single test provides an accurate indication of the formability of a material in all situations. Some processes can be successfully operated only when the forming properties of the work material are within narrow range.Certain factors which influence on overall operation of forming processes are stretching, elongation, anisotropy, grain size etc. Another important factor which influences sheet metal forming is Anisotropy or directionality of sheet metal. Anisotropy is acquired during the thermo-mechanical processing of the sheet.In other worlds, the same sheet metal can have good or bad formability depending upon the components of the forming system. It is interesting to contrast this to a typical mechanical property of sheet metal which is dependent on the sheet metal only rather than on the system conditions such as sheet thickness, process conditions, surface finish, sheet metal properties etc.

So many researchers have done the formability and analysis of sheet metals of different materials. [1] Misklos Tisza, Zoltan peter kovacs showed various aspects of damage limitations like fracture, necking etc. and studied as limits of formability. [2] V.Taylon, R.H.Wagoner and J.K.Lee investigated the formability of austenitic and ferritic stainless steel. [3]M.P.Miles,J.L.Siles,.H.Wagoner, K.Narasimhamdesigned new test and evaluated several coated and uncoated sheet materials which produces more stable and repeatable plain-strain states near fracture location. [4] M.Kleiber, J.Rojek, R.Stocki revealed that the reliability analysis does not require any change for sheet forming process. [5] Mehmet Firat, BilginKaftanoglu, OrhanEser showed that stamping simulations and FE analysis gives similar predictions in terms of formability and thickness distribution. [6] Thomas B.Stoughton, JeongWhan Yoon predicted fracture polygon from stress based FLC and analytical equation with the function of local fracture strain. [7] KjellMattiasson, Mats Sigvant presented yield criteria and evaluated with respect to their suitability and concluded that they both are ideally suited for sheet metal forming processes. [8] OzgurTekaslan, NedimGerger, UlviSeker supported that spring back varies according to functions of both material and die. [9] W.M.Chan, H.I.Chew, H.P.Lee, B.T.Cheok studied spring back angles of work piece by varying punch

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angle, punch radius and die radius.[10]K.M.Zhao, J.K.Lee obtained stress-strain curves after the parameters in combined hardening model are identified. [11] Li-Ping Lei, Sang-Moon Hwang, Beon-Soo Kang analysed free bending & square cup deep drawing. [12] Jong-Jin park, Yung-Ho Kim indicated about positive and negative forming methods. [13] Nader Asnafi studied modes of fracture in the sheet metals.

A.*Aluminum:*
Aluminum, being lowest densest metal which is relatively ductile and appears as silver gray. Though it is difficult to extract form ores, it forms strong bonds and their strength is very high. This property enhances Al to be used widely in various sectors. Analysis of aluminum type of sheet metal is done and the parameters are calculated after applying certain force of 115 N on the sheet. The sheet metal of 240X65X1 mm dimension is used for forming process.

B.*Mild steel:*
Mild steel is most common form of steel which exhibits low-tensile strength. Static analysis is done on mild steel by applying force of 105 N on the sheet metal and parameters are calculated. This forming process has the sheet metal of same dimensions which are considered before.

C.*Stainless Steel of Type 303:*
Stainless steel, also known as inox steel which differs from carbon steel by amount of chromium present is used. The sheet of type 303 is formed by applying a force of 260 N and the parameters are analyzed.
The properties of three different sheet metals are indicated in the table I.

Table I. Properties of Sheet metals

Type / Property	Stainless Steel	Aluminum	Mild Steel
Density (g/cc)	8	2.7	7.9
Ultimate Tensile Strength (Mpa)	690	45	420
Yield Tensile Strength (Mpa)	415	18	350
Poisson's Ratio	0.25	0.35	0.25
Young's modulus(Mpa)	210	$70X10^3$	210

II. EXPERIMENTAL PROCEDURE

In this, the arrangement the die is provided with fixed support so that it will not change the location if the forces are applied on the sheet metal. Similarly, the different sheet metals of 240X65X1 mm dimensions are set on the die and different forces are applied on the punch. These forces are calculated using UTM. The type of die used to for the sheet metal to form is of V-type. Other type of dies such as U-die, roller type can also be used for the sheet metal to be formed. This enhances differences in calculating parameters such as normal stress, total deformation, maximum principal stress, and maximum principal elastic strain. These parameters are analyzed later.

III. FINITE ELEMENT ANALYSIS

The setup of die, punch and sheet metal is drawn in the solid works software which is shown in figure1This arrangement is meshed and refined which is shown in fig.2 so that one can have a clear picture of the deformed part. After the setup is arranged in required format, different sheet metals are placed and forces are applied accordingly. The sheet metal is bent on 70^{o}V-die and the required parameters are calculated. Each type of sheet metal is deformed and forces are calculated using UTM. Static analysis is done using ANSYS V12 software for calculating the parameters.

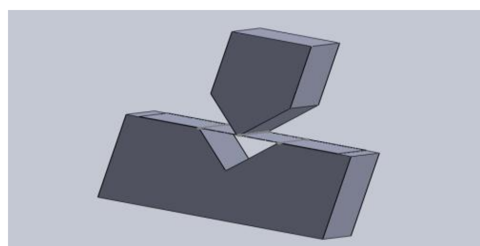
Figure 1.Showing solid model of the arrangement

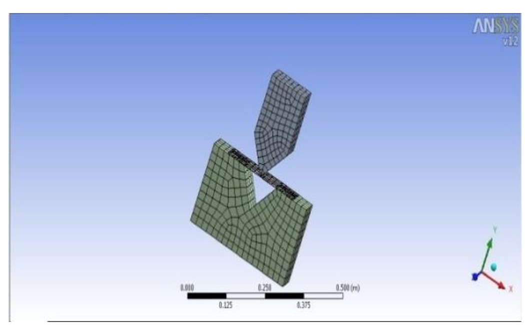

Figure 2. Showing mesh structure of the arrangement

After applying the fixed support for the base of the die and the force on the punch, which acts vertically downwards on the sheet metal and is deformed. By this we can analyze the required parameters. The figures below indicate parameters like normal stress, total deformation, maximum principal elastic strain, equivalent stress and maximum principal stress of different sheet metals like aluminum, stainless steel of type 303 and mild steel.

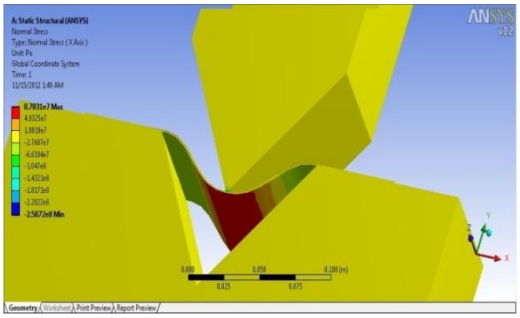

Figure 3. Showing normal stress for Aluminum

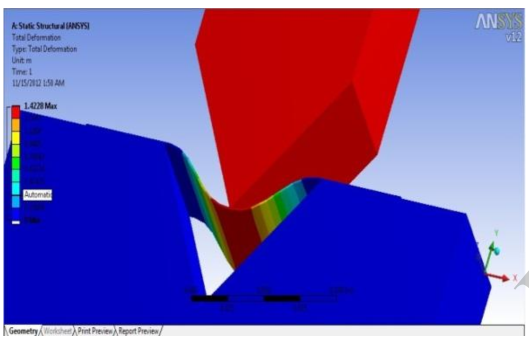

Figure 4. Showing Total deformation in Aluminum

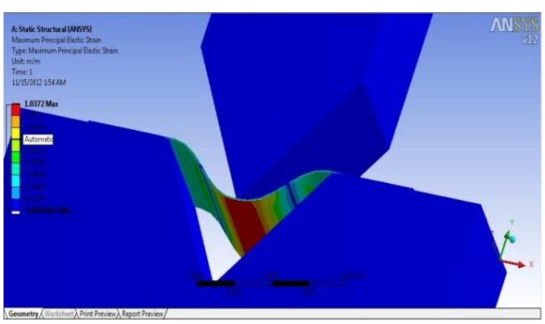

Figure 5. Showing Max principal elastic strain in Al

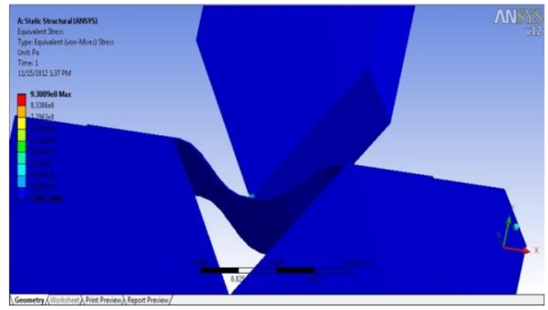

Figure 6. Showing Equivalent stress in mild steel

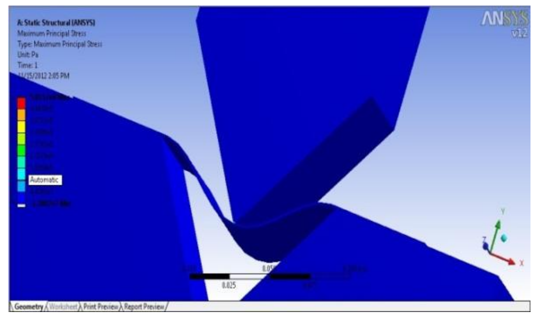

Figure 7. Showing maximum principal stress in stainless steel

IV. RESULTS AND DISCUSSIONS

After analysis of certain parameters by applying different loads and conditions on three different sheet metals, results are obtained. Here we consider all the maximum values which are obtained and graphs are plotted accordingly. Table 2 depicts all themaximum values of the different parameters like maximum normal stress, total deformation, maximum principal elastic strain, equivalent stress and principal stress.

TABLE 2.Parameters obtained of three different sheet metals

Type / Parameters	Alumin -um	Stainless steel type 303	Mild steel
Max. normal stress (Mpa)	87.831	245.2	114.83
Total deformation (mm)	1422.8	1.47	676.33
Max. principal elastic strain (m/m)	1.037	0.002	0.499
Equivalent stress (Mpa)	746.22	531.13	938.09
Max.principal stress (Mpa)	598.08	501.52	759.59

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From the analysis of three different sheet metals of different materials, we obtain the required parameters and the graphs are plotted accordingly. The results are formulated as:

1. Maximum normal stress for the stainless steel is very high when compared to aluminum and mild steel which is shown in figure 8.

2. Total deformation taking place is much higher in the case of aluminum whereas lower in mild steel due to its physical properties which is shown in figure 9.

3. Maximum principal elastic strain is much higher in aluminum and lower in mild steel which is represented in the figure 10.

4. Equivalent stress in mild steel reached altitude when compared to aluminum and mild steel and is represented in the figure 11.

5. Maximum principal stress is higher in mild steel and lower in stainless steel which is shown in the figure12.

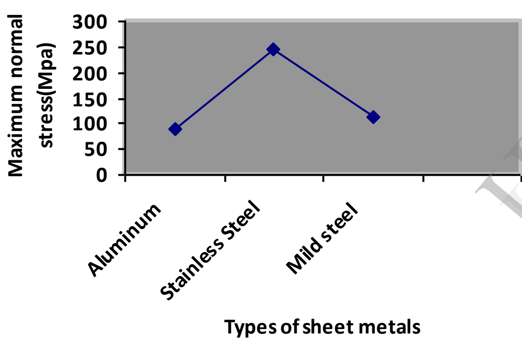

Figure 8.Types of sheet metal VS max. Normal stress

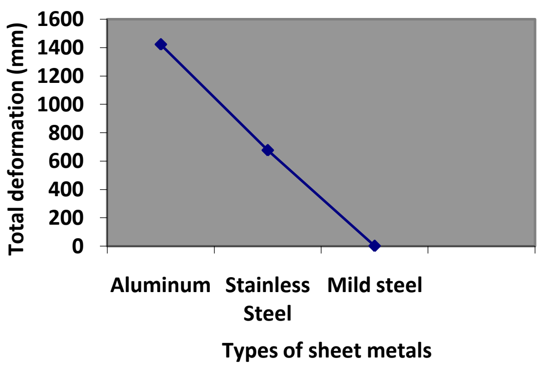

Figure9. Types of sheet metal VS total deformation

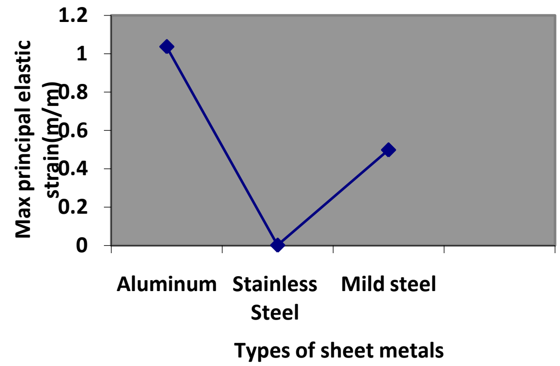

Figure10. Types of sheet metal Vs Max principal elastic strain

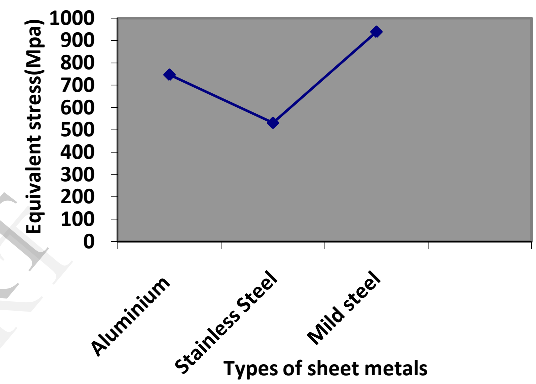

Figure 11. Types of sheet metal Vs Equivalent stress

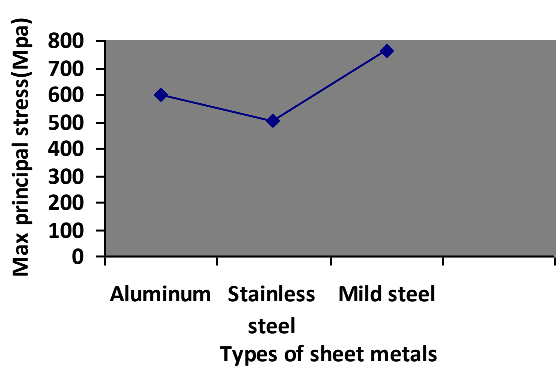

Figure 12.Types of sheet metals Vs Max principal stress

V. CONCLUSIONS

In this paper,different sheet metals are considered and different loads are applied and parameters are obtained. From all the graphs, we can conclude that normal stress is maximum onlyin the case of

Stainless steel. Total deformation and maximum principal elastic strain is higher for aluminum. Equivalent stress and maximum principal stress is higher the case of mild steel. So these three metals exhibit good properties as per the application of forces and variation of parameters.

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