NVEO
Natural Volatiles &
Essential Oils

Bending Stress Analysis In Sheet Metal Forming Process

[1]A. Dhilip*, [2]A.Archana, M.Brindha, [3]M.Kanmani, [4]B.P.Rajeshwari, [5]S. RubaDharshini

1,2,3,4,5 Department of Production Engineering, PSG College of Technology, Coimbatore
*Corresponding author's E-mail: dlp.prod@psgtech.ac.in

Abstract

The sheet metal forming process is a unique type of metal forming process which enables the deformation of metals that are less than 6mm in thickness. In our analysis, we considered three different materials i.e.Aluminium, Stainless steel and Carbon steel-1020- annealed, that undergoes Bending stress using V die. The analysis is carried out using Finite Element Analysis in ANSYS software. The Analysis aims to compare the three materials concerning Maximum Principal Stress in (Mpa), Maximum Normal stress in (Mpa), Equivalent stress in (Mpa) and Maximum Principle Elastic strain as inputs and Ultimate Tensile strength (UTS), Yield as output while performing bending Process. The outcome of the study shows us that the Stainless steel exhibits Lower Maximum Normal stress and Maximum Principal stress than that of Carbon steel 1020 annealed, even requiring the lowest Stress to start deformation and the Highest stress to reach failure in comparison with the other two materials. It also has the highest Hardness value compared with the other two. Sothe Stainless steel is expected to show less UTS having less max normal and Principal stress than Carbon steel 1020 annealed, but it has high UTS. Hence it is best suited for these conditions and applications.

Keywords: *Bending stress, Finite element analysis, V-Bending, UTS (Ultimate tensile strength*)

INTRODUCTION:

Metal forming is a metalworking method that involves mechanical deformation to shape metal parts and objects; the workpiece is reshaped without adding or withdrawing material, and the mass remains unchanged.

BENDING:

- Bending is a manufacturing procedure for creating a V-shape, U-shape, Edge bending, or channel shape usually performed in ductile materials as sheet metal and along a straight axis.
- Sheet metal forming includes bending, punching, drawing, stretching, and other processes. Among which V-Bending is chosen for our study
- Sheet metal is available in thicknesses ranging from 0.4 mm to 6 mm. Anything above that is a metal plate, while anything below that is referred to as foil.
- THEORY OF BENDING:
  The material is subjected to tensile stresses in the outward region, above the Neutral axis, and Compressive stresses in the inward region.
- SPRING-BACK EFFECT:

Residual tensions in the material cause a sheet of metal to spring again after it has been bent. Due to the elastic recovery, it is necessary to over-bend the sheet to a precise amount to achieve the requisite bend radius and angle.

GEOMETRY:

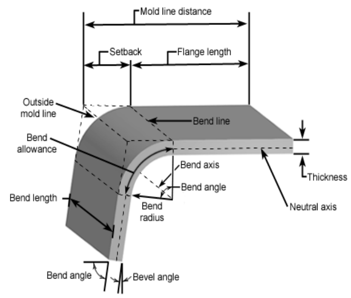

Fig 2.1 Geometry of the bent sheet

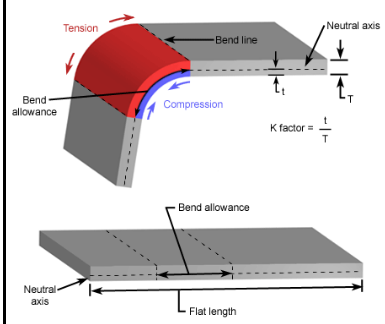

Fig 2.2 Illustration of bending stresses and Bending Allowances

LITERATURE SURVEY:

During the study of strength analysis given by Vaibhav Jain [1], the various factors of shape, bend lot size, travelling time ,sheet thickness were considered for bending operation. OmolayoM.Ikumapayi[4] gives us the different bending techniques as an overview from old age to modern age, theory behind the bending operation were explained. Groover[7] gives us the basic knowledge about the bending operation in sheet metal bending.Saravanan Sathiamoorthi[6] gives us the importance of tool radius and mainly about the spring back effect and its major factors.Mst.Nazma Sultana[3], provided with the mechanical properties of Mild steel under various loads and operations leading to heat treatment process .Chiharu Sekiguchi Hakoyama[5] gave the fracture limit and forming limit stress criterion for mild steel sheet metal bending process. From this study, the effective of Mild steel is to be obtained and the Max and Min normal and principle stress are also need to be calculated to find the efficient metal for certain applications.so thee most commonly used materials like Aluminium, Stainless steel and carbon steel which are used in similar to steel application are analyzed and considered for this study. Hence sheet metal bending operation is done in these three materials and the results are obtained and inferred for the better selection of material for required purpose. MrSachin[2] gives us the methodology for simulating bending operation .

METHODOLOGY:

The methodology for the study starts with the study of Sheet metal bending
selection of material for analysis, comparison and validation using finite element analysis method with theoretical analysis and finally the inference of the result.

EXPERIMENTAL PROCEDURE:

The examination of sheet metal bending of aluminium, stainless steel, and carbon steel 1020 annealed is shown in this experiment. Cast iron EN GJL 100 was chosen as the material for the die and punch. The layout of the die has a fixed support so that the location of the forces applied to the sheet metal does not change. All three sheet metal materials have the same common dimension of 280 x 50 x 4 mm. On a 110 º V-die, the sheet metal is bent and the requisite parameters are determined. Normal stress, total deformation, maximum principal stress, and maximum principal elastic strain are the parameters.

ALUMINIUM

This material has a low density, is nontoxic, has a high thermal conductivity, is corrosion resistant, and is simple to cast, machine, and form. It's also non-lustrous and non-magnetic. It's the second-most malleable and sixth-most ductile metal. Aluminum's characteristics enable it to be employed in a wide range of applications.

STAINLESS STEEL

Stainless steel, also known as inox steel, is a type of steel that differs from carbon steel in terms of the quantity of chromium it contains. This material has increased hot strength, hardness and ductility, as well as strength and corrosion resistance. It is a versatile and cost-effective metal that may be used for a range of applications. It's robust, making it ideal for building, and it's corrosion-resistant, allowing it to survive a long time without needing to be replaced or broken.

CARBON STEEL,1020, ANNEALED

Very high strength, extreme hardness and wear resistance, and moderate ductility, a measure of a material's capacity to endure being deformed without actually breaking, are all characteristics of high carbon steel. Buildings and bridges, axles, gears, shafts, railroads, pipelines and couplings, cars, refrigerators, and washing machines all utilise it structurally.

CAST IRON EN-GJL-100

Gray iron, often known as grey cast iron, is a graphite-microstructured cast iron. It gets its name from the grey colour of the fracture it causes, which is caused by graphite. It is the most common cast iron and, by weight, the most extensively used cast material. 2.5 to 4.0 percent carbon and 1 to 3 percent silicon by weight is a typical chemical composition for obtaining a graphitic microstructure. Graphite could make about 6 to 10% of the amount of grey iron. Because of its high damping capability, it is frequently utilised as the foundation for machine tool mountings.

Table 5.1 Properties of Sheet Metal Materials

Properties	Material		
	Aluminium	**Stainless Steel**	**Carbon Steel**
Density(kg/m^3)	2770	7750	7850
Ultimate Tensile Strength (MPa)	310	580	393
Yield Tensile Strength (MPa)	280	207	293.5
Poisson ratio	0.33	0.31	0.29
Young's Modulus in (MPa)	71000	193000	212400

FINITE ELEMENT ANALYSIS:

The Sheet metal operation involving the components like die block, the punch block and sheet metal setup is sketched and modelled by Design Modeler in ANSYS workbench software as shown in figure 6.1.

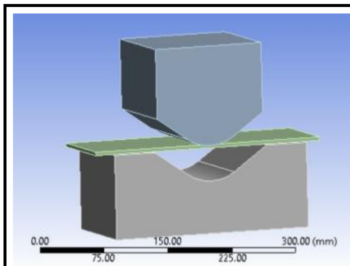

Fig. 6.1. Arrangement of the model

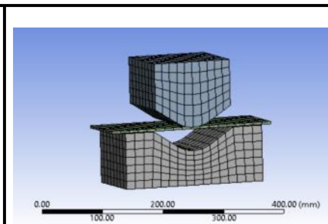

Fig. 6.2. Generated Mesh in the model

After Modeling, the model is imported in Mechanical APDL and the required materials for each part are set. The appropriate Contacts and Joints between the solids are chosen in the Connections. Then the arrangement is meshed with Hex type mesh of size 0.015 and refined for the analysis in the Mesh option as shown in figure 6.2 .The Static Structural Analysis is carried out to calculate the parameters.

SOLUTION INFORMATION:

1. Total Deformation:

   Total deformation gives the overall deformation of the element. The displacement from the punch to the die is constant for all three materials of sheet metal.
2. Maximum Principal Stress:

   The direction of fracture propagation will be perpendicular to the maximal primary stress.
3. Maximum Normal Stress:

   The sheet metal is bent by an axial force. Hence it is necessary to calculate the normal stress.
4. Equivalent Stress:

   It is a simple scalar quantity to determine if the material has yielded or failed.
5. Maximum Principal Elastic Strain:

   Shear strain causes angular distortion on the element. Shear strain is zero where principal strain occurs. Thus it is considered ON an important factor in this analysis.

SOLUTION INFORMATION OF ALUMINIUM:

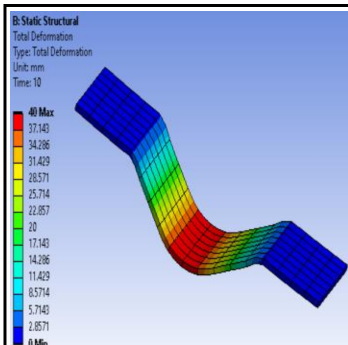

Fig. 7.2.1.Total Deformation (40 mm)

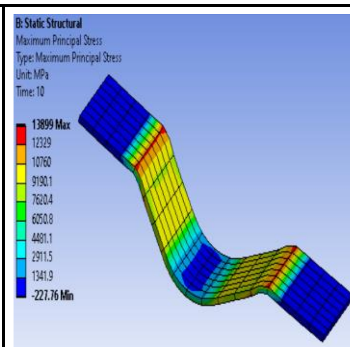

Fig. 7.2.2 Maximum Principal Stress (13899 Mpa)

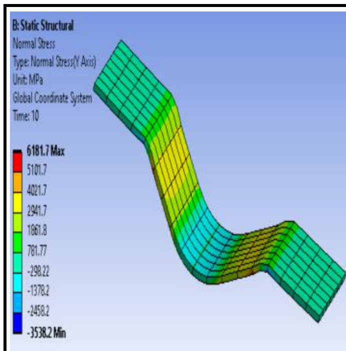

Fig. 7.2.3 Maximum Normal Stress (6181.7 MPa)

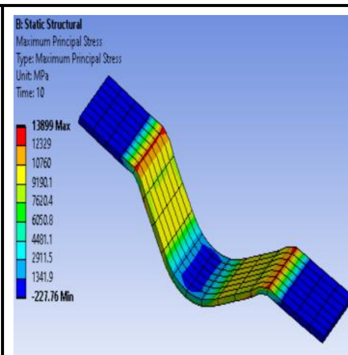

Fig. 7.2.4 Equivalent Stress (13327 MPa)

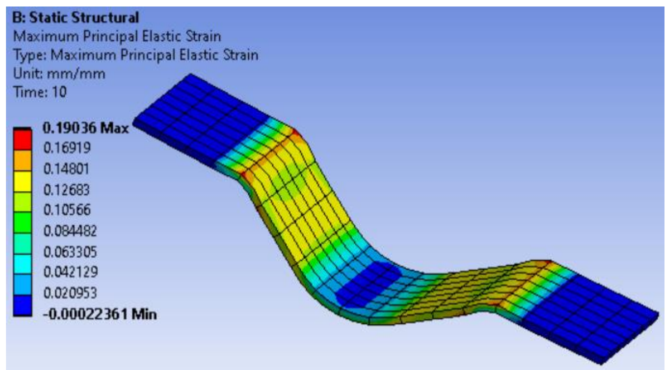

Fig 7.2.5 Maximum Principal Elastic Strain (0.19036)

SOLUTION INFORMATION ON STAINLESS STEEL:

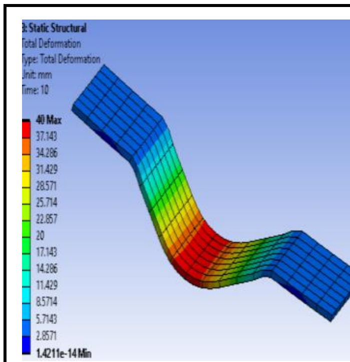

Fig. 7.3.1 Total Deformation (40 mm)

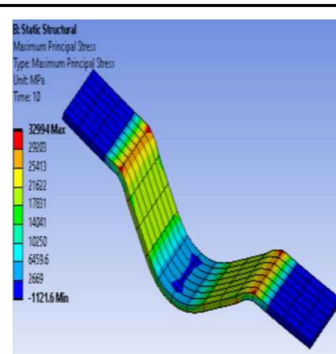

Fig. 7.3.2 Maximum Principal Stress (32994 MPa)

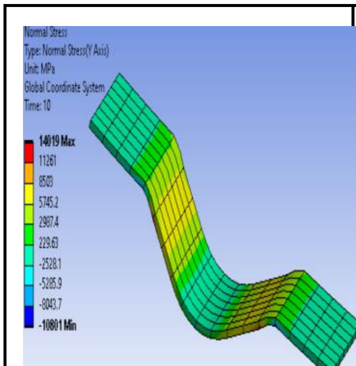

Fig. 7.3.3 Maximum Normal Stress (14019 MPa)

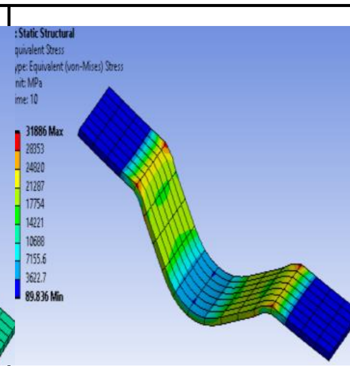

Fig. 7.3.4 Equivalent Stress (31886 MPa)

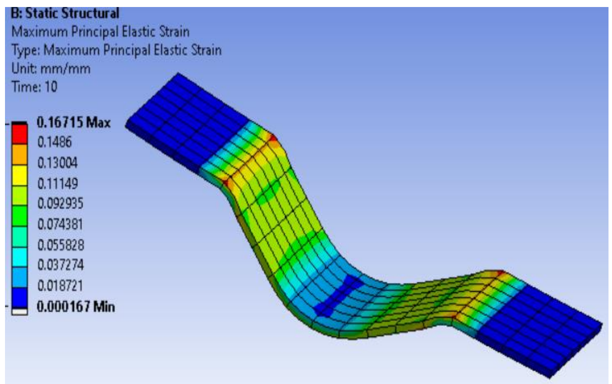

Fig. 7.3.5 Maximum Principal Elastic Strain (0.16715)

SOLUTION INFORMATION OF CARBON STEEL,1020, ANNEALED:

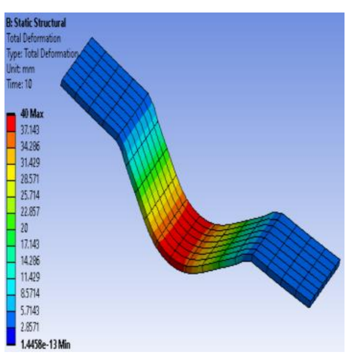

Fig. 7.4.1 Total Deformation (40 mm)

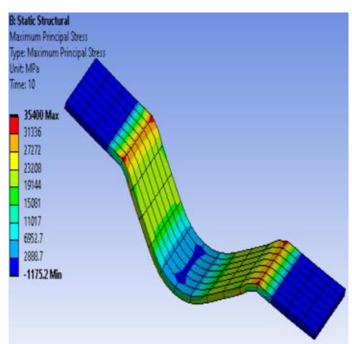

Fig. 7.4.2 Maximum Principal Stress (35400 MPa)

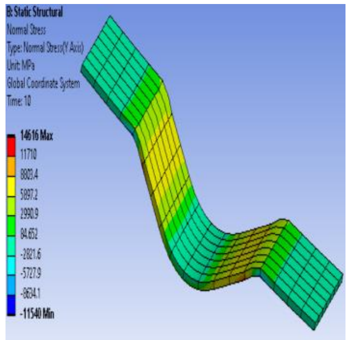

Fig. 7.4.3 Maximum Normal Stress (14616 MPa)

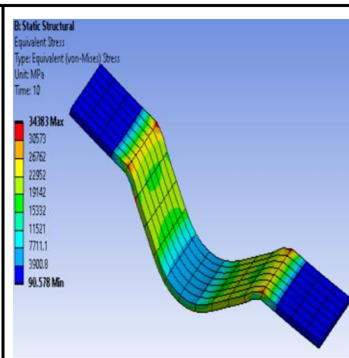

Fig. 7.4.4 Equivalent Stress (34383 MPa)

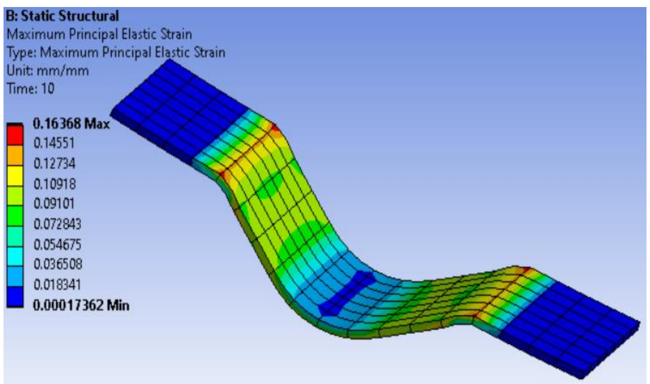

Fig. 7.4.5 Maximum Principal Elastic Strain (0.16368)

PARAMETERS	**MATERIALS**		
	ALUMINIUM	**STAINLESS STEEL**	**ANNEALED CARBON STEEL, 1020**
Total Deformation (mm)	40	40	40
Maximum Principal Stress(MPa)	13899 MPa	32994 MPa	35400 MPa
Maximum Normal Stress(MPa)	6181.7 MPa	14019 MPa	14616 MPa

Equivalent Stress(MPa)	13327 MPa	31886 MPa	34383 MPa
Maximum Principal Elastic Strain	0.19036	0.16715	0.16368

Table 7.1.Consolidated Table of the Solution

RESULTS AND DISCUSSIONS:

Numerical data are not sufficient to interpret the results. So, graphs have been plotted in MATLAB Platform on every output parameter between the three different sheet metals.

1. The total deformation graph is not plotted since it holds the same value for all three different types of sheet metals.

2. Maximum Principal Stress is much higher in Carbon Steel when comparing it to Aluminium , Stainless Steel as given in figure 8.1.

3. The Maximum Normal Stress is lower in Aluminiumthan Stainless Steel and Carbon Steel as given in figure 8.2.

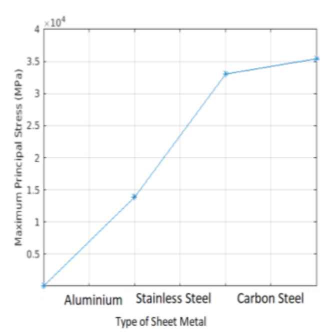

Fig. 8.1
Type of sheet metal Vs Maximum Principal Stress(MPa)

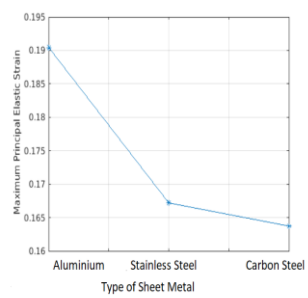

Fig. 8.2
Type of sheet metal Vs Maximum Principal Elastic Strain

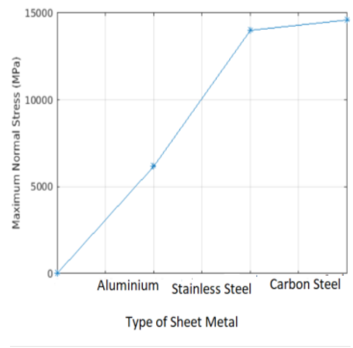

Fig. 8.3
Type of sheet metal Vs Maximum Normal Stress(MPa)

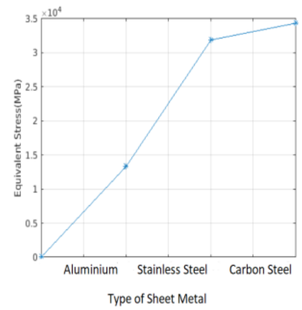

Fig. 8.4
Type of sheet metal Vs Equivalent Stress(MPa)

4. The Equivalent Stress is higher in Carbon Steel and Stainless Steel when compared to Aluminium as shown in figure 8.3.

5. The Maximum Principal Elastic Strain is high in the case of Aluminium, and low in the case of Stainless Steel and Carbon Steel when compared to Aluminium as shown in figure 8.4.

CONCLUSION:

- The Ultimate Strength of Aluminium, Stainless steel, and Carbon steel 1020 annealed is 310, 530, 393 Mpa respectively.
- The Yield Strength of Aluminium, Stainless steel, and Carbon steel 1020 is 280, 207, 293.5 Mpa respectively.
- The Maximum Normal stress and Maximum Principal stress for Aluminium are 6181.7 MPa and 13899 MPa respectively.
- The Maximum Normal stress and Maximum Principal stress for Stainless steel are 14019 MPa and 32994 MPa respectively.
- The Maximum Normal stress and Maximum Principal stress for Carbon steel 1020 annealed are 14616 MPa and 35400 MPa respectively.

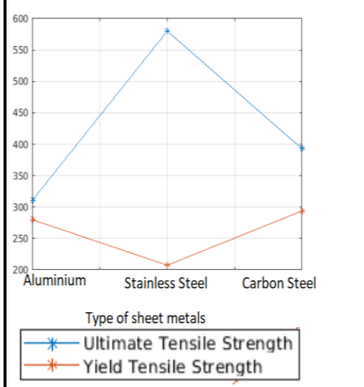

Fig: 9.1 Comparison between Yield Tensile Strength and Ultimate tensile strength of the sheet metals

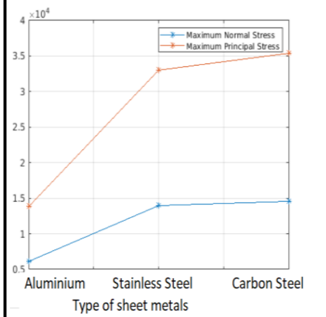

Fig: 9.2 Comparison of max normal stress with max principal Stress of the sheet metals

From these results, it is identified that,

1. Aluminium has less Maximum Normal and principal stresswhen its Ultimate tensile strength is the lowest Aluminum when compared with the other two materials.

2. Hence Aluminium has less stress for its failure and requires considerable stress to start plastic deformation hence Al can be used for less density, low weight, low cost, and Soft Bending applications.

3. Even Having the Highest Maximum Normal and Principal stresses, the Carbon steel 1020 annealed has the highest yield strength and low Ultimate tensile strength and it is less hard compared with Stainless steel due to the presence of carbon which reduces its ductility and Brittleness thereby it is not effective for Bending Operation, Which indirectly means that it requires high stress to start plastic deformation and breaks very Quickly and the Max normal and principal stresses are also high which is a risk factor and it is inefficient.

4. The Stainless steel has the Highest Ultimate tensile strength and the Lowest Yield strength when compared with the other two when its Maximum Normal and Principal stress is lesser compared to Carbon steel 1020 annealed [stronger].

5. It is interestingly found that the Stainless steel exhibits Lower Maximum Normal stress and Maximum Principal stress than that of Carbon steel 1020 annealed, even requiring the lowest

Stress to start deformation and the Highest stress to reach failure in comparison with the other two materials. It also has the highest Hardness value compared with the other two.

6. So the Stainless steel is expected to show less UTS having less max normal and Principal stress than Carbon steel 1020 annealed, but it has high UTS. Hence it is best suited for these conditions and applications.

7. Hence it is concluded that Stainless steel is the best suited for the Bending Operation when compared to Aluminium and Carbon Steel 1020 annealed when there is an application to withstand the higher load.

Acknowledgement

The authors are thankful to **Mr. Mohanraj. R**, Assistant Professor, Department of Production Engineering, PSG College of Technology, Coimbatore-641004, India for his constant support during all stages of work, to improve the quality of the research article.

REFERENCE:

1. Vaibhav Jain, Pooja Sharma," A study Strength analysis in sheet metal by bending process: A review", International Journal of Engineering Sciences & Research Technology,10(2016)2277-9655
2. MrSachinS.kaurase," Design & FE Analysis of Sheet metal While Bending", International Journal of Engineering Research and Technology,10(2016)2278-0181
3. Mst.Nazma Sultana, Md.Ferdaus Hasan, Mehedi Islam,"Analysis of Mechanical Properties of mild steel Applying Various Heat treatment",International Conference on Mechanical, Industrial and Energy Engineering, 11(2014) ,140160
4. Omolayo M. Ikumapayi,EstherAkinlabi,NkosinathiMadushele,Olawale Samuel Fatoba"A Brief Overview of Bending Operation in Sheet Metal Forming",Springer Nature Singapore Pte Ltd. ,10(2020),(pp.149-159)
5. Chiharu Sekiguchi Hakoyama, Tomoyuki Hakoyama, Hiroshi Fukiharu,ToshihikoKuwabara, "Fracture Prediction for Mild Steel Sheet and High-Strength Steel Sheet Subjected to Draw Bending Using Forming Limit Stress Criterion",Journal of Materials Processing Technology,1(2021),116313
6. SaravananSathiamoorthi,JeyasimmanDuraisamy,"Study on Effects of Spring Back on Sheet Metal Bending Using Simulation Methods",International Journal of Mechanical and Production Engineering Research and Development ,ISSN (P): 2249-6890; ISSN (E): 2249-8001 Vol. 8, Issue 2, Apr 2018, 923-932
7. Groover, Mikell P., 1939-. Fundamentals of Modern Manufacturing : Materials, Processes, and Systems. Hoboken, NJ :J. Wiley & Sons, 2007.