Metal Forming: Bending

Introduction:

Sheet metal working generally incorporates cutting and forming operations on thin sheets of metal. Typically, the thickness of sheet metal is between ¼ inch and 1/64 inch. There are different types of metal forming operations: Bending, Shearing, Blanking, Punching, Stamping etc. This lab provides an exposure to BENDING operation.

Bending is defined as the straining of the metal around a straight axis (Figure 7.1). During the bending process, the metal on the inside of the neutral plane is compressed, while the metal on the outside is stretched. The sheet metal is plastically deformed to have a permanent bent shape. Bending produces a little or no thickness change of the sheet metal.

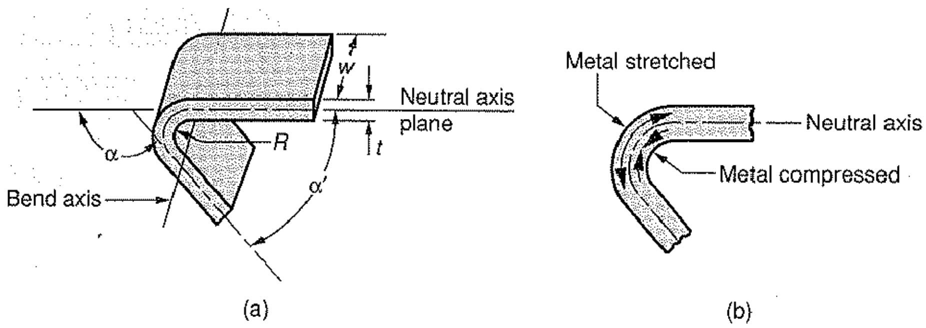

Figure 7.1. (a) Sheet metal bending, and (b) compression and tensile elongation during bending.

In the Figure 7.1, α = bend angle, w = width of sheet, R = bend radius, t = sheet thickness, and α′ = 180° - α, "included" angle. In this lab we will work on V-bending. Typically, a bending operation is performed using a punch and die. In V-bending the sheet metal is bent between a V-shaped punch and die. The operation is shown in Figure 7.2. When the bending stress is removed at the end of the deformation process, elastic energy remains in the bent part causing it to partially recover to its original shape. In bending, this elastic recovery is called **springback (SB).** It increases with decreasing the modulus of elasticity, E, and increasing the yield strength, Y, of a material. Springback is defined as the increase in included angle of the bent part relative to the included angle of the forming tool after the tool is removed. After springback, the bend angle will decrease (the included angle will increase) and the bend radius will increase.

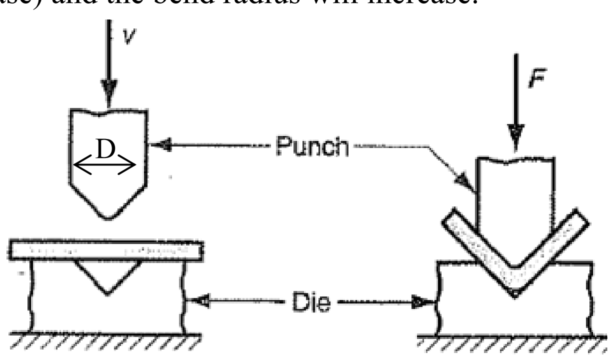

Figure 7.2. V-bending operation.

Metal Forming: Bending

$$SB = \frac{\alpha' - \alpha'_t}{\alpha'_t} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 7.1$$

where, α' is included angle of the sheet-metal part (bend angle) in degrees and α'_t is the included angle of the bending tool (Die angle) in degrees. Bending force can be calculated with help of equation 7.2.

$$F = \frac{K_{bf} TSwt^2}{D} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 7.2$$

where, F is bending force (lb), TS is tensile strength of the sheet metal (lb/in^2), w is width of the part in the direction of the bend axis (in), t is the sheet-metal thickness (in), and D is the die opening dimension (in). K_{bf} is a constant that accounts for differences encountered in actual bending process and is 1.33 for V-bending.

Objective:

1. To understand the basic bending operation
2. To study the effects of material properties (ductility, types, strength) on the bend radius, springback and bending force

Equipment:

1. Tooling dies with 0 bend radius, (1.5*thickness) bend radius and (3*thickness) bend radius
2. Arbor press
3. Work pieces
   a. Half Hardened C26000 brass: 1/8" and 1/16" thicknesses
   b. Precipitation hardened 6061 Al alloy: 1/8" and 1/16" thicknesses
   c. Mild Steel 1018 1/8" and 1/16" thicknesses
4. Protractor
5. Calipers/Micrometer

Procedure:

1. Insert the 0 bend radius die into the arbor press.
2. Insert the work piece into the holder.
3. Pull down the handle on the press firmly.
4. Check for material failure (cracking at the bend). Measure the bend radius. Record results on data sheet provided.
5. Repeat steps 1-4 for each type of material.
6. Repeat steps 1-5 for each bend radius

Lab Deliverables:

1. Prepare a report detailing the lab activity, observations, results and difficulties faced (follow the lab report instructions).
2. Plot the following function for the different materials (R vs t)

Metal Forming: Bending

$$R = t\left(\frac{50}{\%A} - 1\right)$$

R = Minimum bend radius
t = Material thickness
%A = Tensile reduction in area
%E= % of elongation at break

$$\%A = 100\left[\frac{\%E}{100 + \%E}\right]$$

The area of the graph above and to the left of this line is supposed to result in ductile bending without failure. The area below and to the right represents processing conditions that will result in material cracking. Plot the experimental values used in lab on this graph. Do these values make sense? What is the effect of ductility on minimum bend radius?(5)

3. What is the effect of ductility on spring back? Is there a consistent trend? Does this relationship make sense? Which material would permit better bend tolerances?(4)
4. Calculate the bending force for each case. Compare the bending forces required for hardened brass vs. annealed brass for different thicknesses and die opening.(6)
5. Tabulate the springback vs. thickness for the different materials and explain the trend based on their young's modulus.(5)

Appendix:

Table 1: Elastic properties of the given materials

Material	Poisson's ratio	Young's modulus (GPa)	% Elongation at break	TS (MPa)	Y_s (MPa)
C26000 Brass	0.375	110	23	425 (half hardened) 525 (hardened) 325 (annealed)	360
Al 6061 Alloy	0.330	69	12	310	276
1018 Steel	0.290	205	15	440	370

Section wise maximum marks: Intro – 10, Objectives – 5, Procedure – 15, Results and discussion – 15, conclusion – 10, Deliverables - 20

Metal Forming: Bending

References:

1. M.P. Groover, "Fundamentals of modern manufacturing," 3rd edition, (2007).
2. S. Kalpukjian, S.R. Schmid, "Manufacturing procedure for engineering materials," 2nd edition, p. 350-351.