

# Design and Analysis of Rotary Draw Tube Bending

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## Abstract

Tube bending is the metal forming processes used to permanently form pipes or tubing. One has to differentiate between form-bound and freeform-bending procedures, as well as between heat supported and cold forming procedures.

Form bound bending procedures like “press bending” or “rotary draw bending” is used to form the work piece into the shape of a die. Straight tube stock can be formed using a bending machine to create a variety of single or multiple bends and to shape the piece into the desired form. This process can be used to form complex shapes out of different types of ductile metal tubing. Freeform-bending processes, like three-roll-push bending, shape the work piece kinematically, thus the bending contour is not dependent on the tool geometry. Plastic deformation of tubes can be achieved in numerous ways. One of the most useful type is tube bending machines which is used in many industries such as aerospace, automotive, HVAC systems and so on. It is important that all components of system should mate properly after producing and because of this bend shaping requires sensitive operation on each component to ensure regularity of production processes with high quality end-product. However it brings some troubleshooting like wrinkling, springback, breakage and ovalisation. This failure depends on geometry of the material such as bending radius, tube thickness and also friction factor between dies and the tube. Effects of all parameters should be examined before generating the theory for a best solution. Therefore, prediction of the required moment for the proper bending process with low cost and shortened production time is needed.

## I. INTRODUCTION OF ROTARY DRAW BENDING

Rotary draw tube bending is the most flexible bending method and is used immensely in industry on account of its tooling and low cost. The tooling consists of a bend die, clamp die, pressure die and wiper die. In this bending technique the tube is securely clamped to

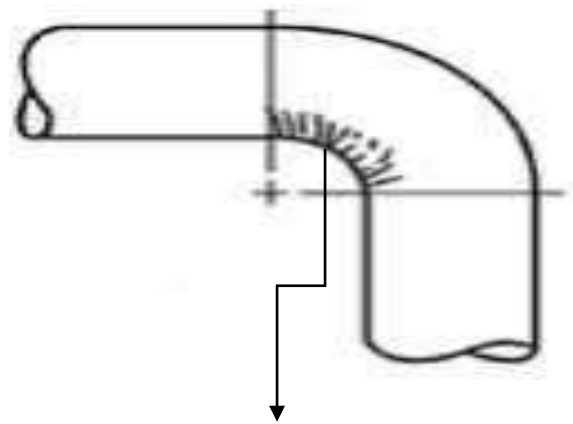
the bend die by using the clamp die. The bend die rotates and draws the tube along with it. The pressure die prevents the tube from rotating along with the bend die. The pressure die may be stationary or it may move along with tube. The pressure die provides a boost (pushes the material at the extrados of the tube) to reduce the thinning of the tube and can be very helpful when the bending angle is large and the bending radius is small.

### Types of Bending:

1. Push Bending.
2. Compression Bending.

## II. DESIGN AND ANALYSIS OF ROTARY DRAW TUBE BENDING MACHINE

Over the last decade bending technology has been a sensation in the field of engineering because this area can be continually improving, resulting in higher quality with less troubleshooting and manufacturing defects. Rotary draw bending is presented alongside machinery parts with their function and effects on bending moment and failure types along with their reasons. Also shown is deformation in tube bending and the effect of tools, parameters.



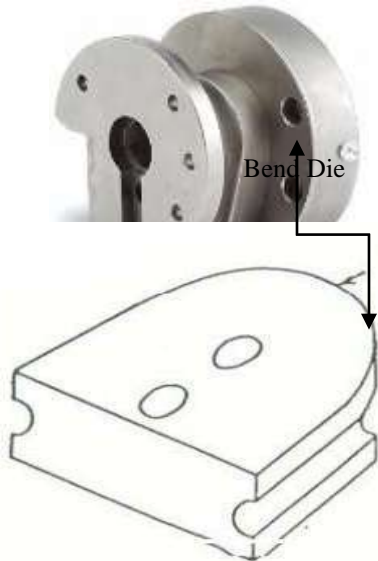
### III. MACHINERY PARTS & MATERIALS

1. Pressure Die
2. Clamp Die
3. Bend Die
4. Wiper Die
5. Gear Teeth
6. A.C Motor (Input power)

### IV. FUNCTION OF MACHINERY PARTS

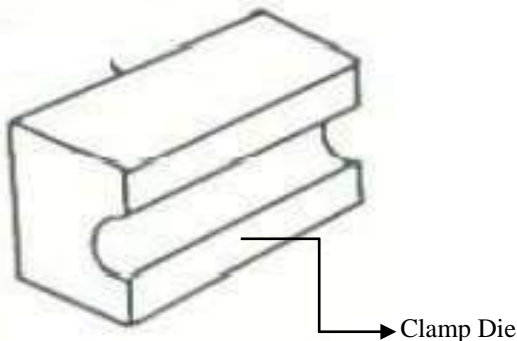
#### A. Bend Die

The forming tool which is used to make a specific radius of bend is called a bend die. The bend usually consists of two separate pieces called the insert and bend radius.



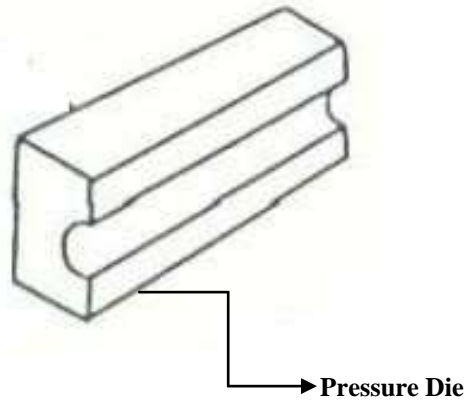
#### B. Clamp Die

The clamp die works in conjunction with the bend die to ensure it clamps the tube to the bend die. The clamp die will move in and out to allow feeding of the tube. Thus, this die holds the tube or pipe in bending axis with helping of bend die.



#### C. Support (Pressure) Die

The pressure die is used to press the tube into the bend die and to provide the reaction force for the bending moment. The pressure die will travel with the tube as it is being formed.



#### ADVANTAGES

- Compared to many other styles of standard bending, draw bending is a process that often more closely controls the material flow during bending.
- The reason is because it is drawing (or pulling) the material through bend die.
- It does not have the potential twisting weakness of compression bending. It can create much smaller CLR (center line radius) bends than push bending.
- There are several methods of analysis of Rotary tube bending machine, such as finite element methods (FEM) and theoretical approaches

#### D. Working Principle of Rotary Draw Bending Machine Tools

The pressure die is used to press the tube into the bend die and to provide the reaction force for the bending moment. The pressure die will travel with the tube as it is being formed. The pressure die boost cylinder is attached to the pressure die. Thus, it covers the tube from outside and travel along bend axis and force effect on tube helps to bending process.

#### E. Plastic Deformation in Tube bending and Parameters of Tools of Rotary Draw Bending

In this part present the base of theory's formula and additive tools effects. In fact, theory of plastic deformation tube bending was observed many articles but most of them are used common formulas. Actually, some of the formulas were really complicated. Due to lack of time, engineers prefer to use simplified calculations and it is also valid for this thesis.

#### F. Notation

|            |  |
|------------|--|
| r          | Average radius of the tube cross-section |
| D          | Outside diameter of the tube             |
| d          | Inside diameter of the tube              |
| k          | Geometry parameter                       |
| R          | Bending radius                           |
| $\sigma_s$ | Material yield strength                  |

- $\alpha$  Angle between circumferential point, center point and the topmost point in tube section
- I The moment of inertia
- J The moment of inertia (Simplified)
- $W_b$  Section modulus
- M Bending moment
- $N_o$  Integral parameter of moment of inertia formula
- T Wall thickness

**G. Formulas for Tube Bending**

According to Tang (2000), introducing geometry parameter of the tube is:

$$k = \frac{R}{2r}$$

According to Tang (2000), integral parameter of moment of inertia formula:

$$N_o = \int_0^{90} \left( \frac{2k+1}{2k+2-\cos\alpha} \right) x \left( 1 - \frac{2k+\cos\alpha}{4k+3-\cos\alpha} x \frac{\cos\alpha}{2k} \right)$$

According to Tang (2000), formulation of moment of inertia:

$$I = \frac{5rD}{D^2 + d^2} x \left( 0.636 + \frac{0.42}{k} \right) N_o$$

Solution of the integral  $N_o$  is difficult, even by using some computer mathematics programs such as Matlab. Tang used simplified formula and this figure show comparison of derived and simplified bending moment function and results of these two formulas are approximately same according to Tang (2000).

According to Tang(2000), The simplified moment of inertia is shown as J:

$$J = 1.41 + \frac{0.42}{k}$$

According to Johansson (2010), section modulus ‘ $W_b$ ’ is given by:

$$W_b = \frac{\pi}{32} (D^3 - d^3)$$

After all these formulations, according to Tang (2000), bending moment is given by:

$$M = \sigma_s W_t J$$

Bending moment of booster formulation is given by:

$$M_b = F_b x R$$

Bending moment of pressure die formulation is given by:

$$M_p = F_p x D$$

As a result, total bending moment with all factors is given by:

$$Total\ Bending\ Moment = M \pm M_b \pm M_p + M_w + M_m$$

**V. ANALYSIS USING ANSYS**

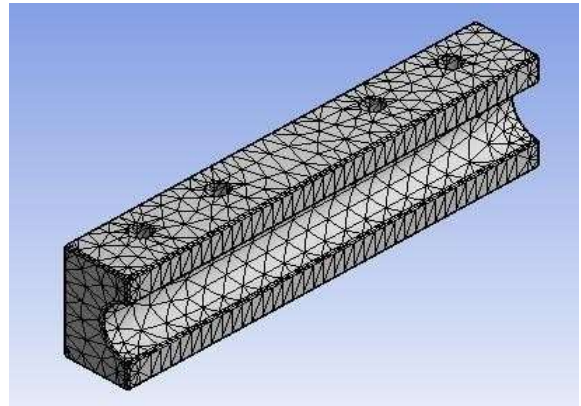


Fig: Pressure Die

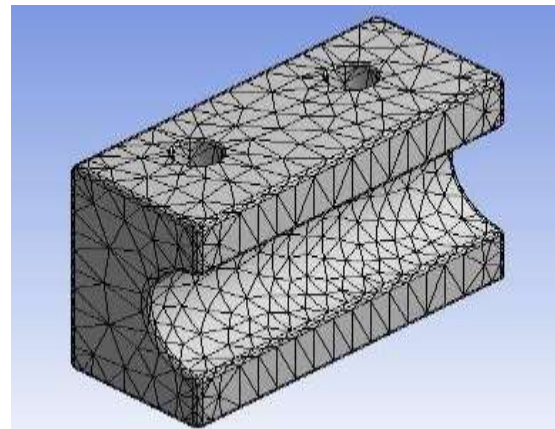


Fig: Clamp Die

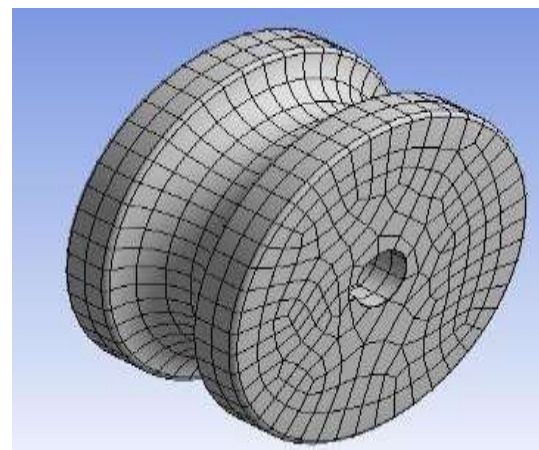


Fig: Bend Die

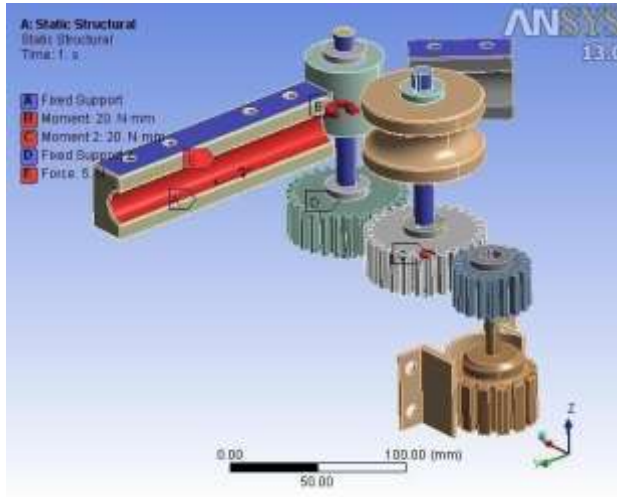


Fig: Boundary Conditions for the Assembly

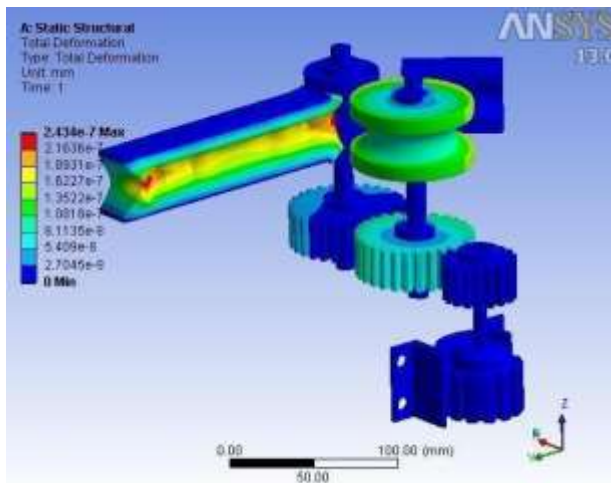


Fig: Total Deformation

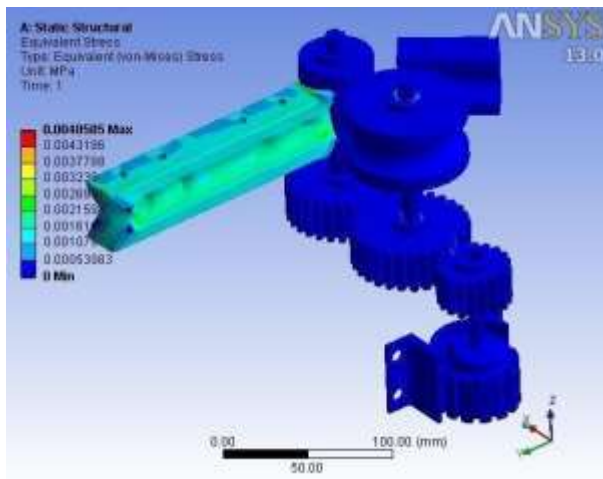


Fig: Von Mises Stress

**Finite element model**

|          |       |
|----------|-------|
| Nodes    | 52786 |
| Elements | 19220 |

**Total Deformation (in mm)**

|         |          |
|---------|----------|
| Minimum | 0        |
| Maximum | 2.434e-7 |

**Von-Mises Stress (in MPa)**

|         |          |
|---------|----------|
| Minimum | 0        |
| Maximum | .0048585 |

**Material Properties**

|                     |                               |
|---------------------|-------------------------------|
| Young's Modulus MPa | 2.e+005                       |
| Poisson's Ratio     | 0.3                           |
| Bulk Modulus MPa    | 1.6667e+005                   |
| Shear Modulus MPa   | 76923                         |
| Density             | 7.85e-006 kg mm <sup>-3</sup> |

**VI. CONCLUSION**

In the thesis, the rotary draw tube bending theory with all parameters performed on a form application program. And also Finite Element Analysis (FEA) has been carried out and simulation results are obtained using ANSYS software.

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