Design of Multi Bend Radius Bending Die for CNC Tube Bending Machine

Sachin Kamble

BE Mechanical Engineer, Department of Mechanical Engineering, Dr. D. Y. Patil Institute of Engineering, Management and Research, Akurdi, Pune – 411044

Abstract: ***Tube bending and pipe bending services produce finished parts from tubes and pipes. Plastic deformation of tubes can be achieved in numerous ways. One of the most useful types is CNC tube bending machines which is used in many industries such as aerospace, automotive, HVAC systems and so on. Bending die on the numerically controlled (NC) tube benders or other benders can bend tubes with only one kind of bend radius formed on the die. It is difficult for such a situation to meet the requirement of modern manufacturing with characters of much varieties and small batch. In present CNC tube bending machines the only one die used for forming same bend radius for product. It slower the production rate and increase requirement of the trained manpower. The present study proposed a new concept of rotary draw bending die called Multi bend radius bending die, on which tubes with different bend radius within a definite range can be bent using the same die by only adjusting the Diameter of bend die.***

Keywords: Bend die, Bending radius, pipe bending

1. Introduction

As important lightweight structures and liquid conveying or heat exchanging components, metallic tubular parts are widely used in the fields of aeronautics and aerospace, automobile, oil and chemical industries, etc. It has great advantages of efficiency, cost, and quality when tubular productions are made by plastic forming technologies. Among them, bending is most commonly used, and till date, numerous tube bending approaches, such as rotary draw bending, press bending, drawing bending, and pushing bending have been developed in response to the diverse demands of tube specification, shapes, materials and forming tolerance. Due to the characters of high efficiency, stable quality, and ability to form tubular parts with complex shapes, rotary draw bending is the dominant approach and is used on most of the tube benders, especially the numerically controlled tube benders. Rotary - draw - bending is widely used for bending. The application spectrum of the process covers a wide variety of geometries with constant bending radii. These products can be used in a wide range of industrial and private applications. During the rotary draw bending process, complex uneven tension and compression stress distributions are induced, which may cause multiple defects or instabilities such as cross - section distortion, wall thinning (even cracking), wrinkling, and spring back. Till date many studies have been conducted on tube bending, and most of them are concentrated on optimization of the forming parameters, and tooling to promote the development of tube bending science and technology by using experimental, analytical, and numerical methods. In present tube bending machine from evaluation of machine to till date for formation of bent on the tube regular specific dies used for same bend radius. For forming different bend radius on the same tube it required to change the bend die for that radius. During this changeover the machine stops also production stop. For this operation the skilled worker required due to production rate reduces. For overcoming this problem we will design the multi bend radius bending die for various bend radius obtain neither stopping the machine nor changing dies.

2. Literature Reviews

1) "On a new concept of rotary draw bend - die adaptable for bending tubes with multiple outer diameters under non - mandrel condition" T. Wen
   Conclusion - Wrinkling at the intrados of tube bent on MDB - Die did not occur as long as the critical value of the relative bending radius r/d did not exceed. On the whole, the bending quality in terms of section distortion and wall thinning of tubes bent on MDB - Die did not decrease irrespective of whether d is less than D or not. With the utilization of MDB - Die in tube bending process, higher efficiency and even higher quality can be obtained, and the cost can be cut down.
2) "Bending capacity calculator for rotary tube" Jatoth Ramachander
   Conclusion - 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.

3. Problem Definition

In current situation the productivity required for the machine is higher for mass production in minimum time hence our project is specifies the time consumed by the machine for operation of multi radius bend takes excessive time for changeover. To overcome from this problem we implant the new concepts contained in the project and gain the higher efficiency in CNC tube bending machine and hand operated machine by reducing manpower effort. The present study proposed a new concept of rotary draw bending die called Multi bend radius bending die, which tubes with different bend radius within a definite range can be bent using the same die by only adjusting the Diameter of bend die.

4. Problem in Tube Bending

1) Important Features

Appearance: It is considered important where aesthetical appearance becomes one of the major concerns where the tube itself is mounted on an area visible to the human eye, or simply where the tube itself is a part of an ornamental structure. Flattening should be prevented in order to maintain good appearance.

Wall thickness: In some applications, where any pressured fluid passes inside the tube, wall thickness is reckoned to be important, since thinner the walls, smaller the force that it can withstand without being damaged.

Geometry**:** Different tube geometries may require different parameters when forming. For instance, substantial care must take when forming square tube profiles, since it is much more difficult to sustain the sharp edges of the profile in the bending processes.

2) Factors Causing Difficulties

Low wall thickness compared to tube diameter: When the ratio of wall thickness to tube diameter is small to a considerable amount, fracture and wrinkling may occur on the tube walls. There is a limit to the ratio in question for every end tube material.

Low bending radius: Change in the bend die diameter changes the bending radius. Bending with low bending radiuses may be critical, since there will be too much tension on the outer side and too much compression on the inner side of the tube which can cause tearing or collapse from the outer side and wrinkling on the inner sides. Weld: Care must be taken when bending tubes preformed with welding. The bending should not be made through the welded area since the welded face may not withstand the tensile forces and may result in failure through its weld seam.

3) Bending Problems

Section changes: Due to the tensile and compressive stresses in the outer and inner sections respectively, outer thinning and inner thickening occur on the cross - section of the tube in the bending area.

Wrinkling: When working with low bending radius and low wall thickness compared to tube diameter conditions, wrinkling can occur (Figure 10). To prevent this, proper wiper element should be used.

Hump on outside of pull off end: There is a clearance of 1mm between bend die and clamp die when holding the tube to bend. This clearance is used so as to better hold the part to bend and prevent it from sliding. Nevertheless, if the bend die and clamp die are to hold the part too tight, humps can be generated through the clearance and it is undesirable.

Scratches in clamp area: Scratches in the clamp area can occur if the clamp holds the part too tight.

Ball segment bumps in bend area: If the mandrel used had balls and if the size and material of the mandrel was noted properly, there may be ball prints in the bend area that can be seen from the outside.

Scratches on inside of bend area: Mandrel used can make scratches on the inside of the bended area of the tube. Therefore, to overcome that problem, appropriate mandrel radius and material must bend.

Tooling marks on centerline: Pressure die serves the purpose of receiving the radial stress and supports the straight tube from outside. While doing this, it should permit the tube to slip inside it. Because of this, if the pressure die material is noted properly, tooling marks on centerline can occur. For instance, ductile cast iron can be used as the material which has spherical grains in the microstructure range. That way, tooling marks can be prevented.

Spring back: When the bending process will be over, the remained stresses in the body of the bended tube will cause to a relaxation in the part that will decrease the degree of bending. To solve the problem, the initial degree of bending might be increased to a certain degree driven by the simulation results. Another solution relies on increasing the elastic modulus (E) of the tube material. Increasing the E means making the part more rigid which will result less loosening of the part after the forces are removed.

5. Die Design Methodology

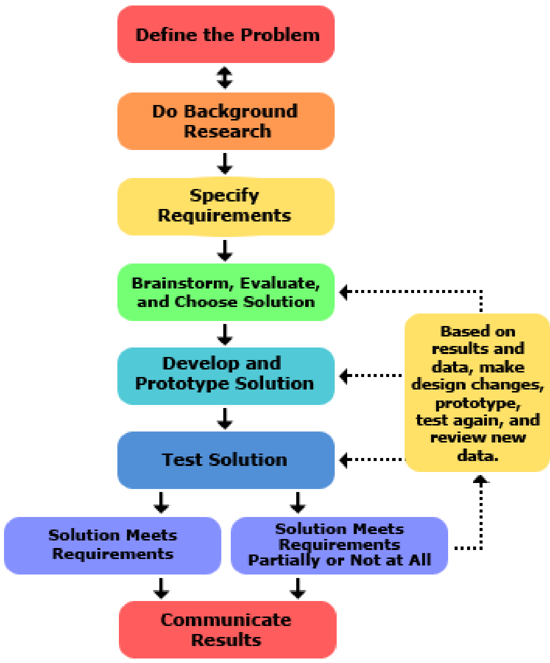

Figure 1: Die design methodology

6. Component of Proposed Die

- Self - expanding die
- Expanding metal ring
- Variable Screw

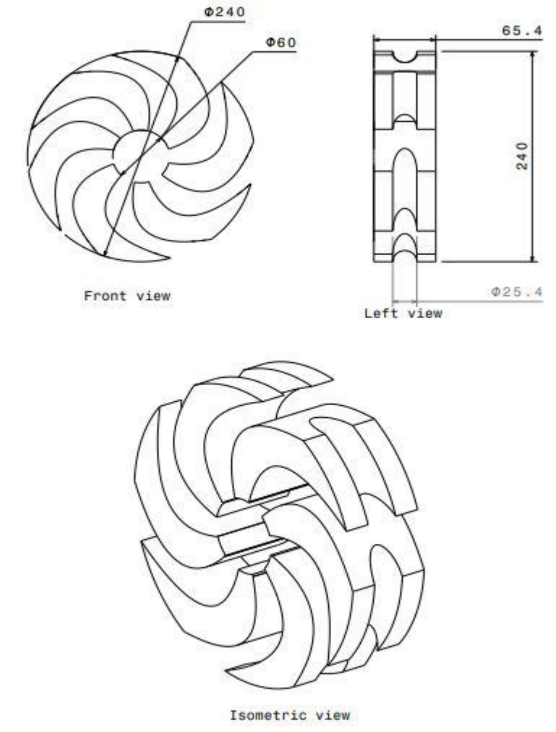

Figure 2: Sketch of Die set with component

7. Working of Bend Die

Traditionally a rotary draw bending die is an assemblage composed of bend die and die insert, a clamp die and pressure die. Sometimes a so called wiper die and a mandrel are also used to improve the bending quality.

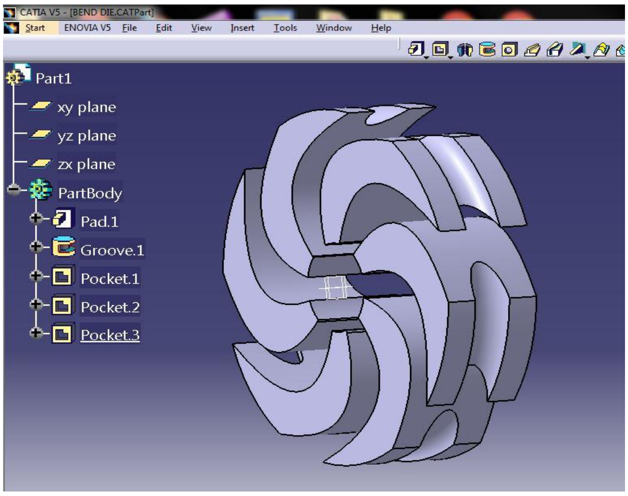

Figure 3: CAD model

During the operation after each part of the die set is settled on the corresponding position of the bender, in newly formed bend die is adjusted to required bend radius by rotating the variable diameter screw relative to the circular scale to obtained exact radius of bent. After this the clamp dies adjust the position of clamping outer radius of tube for fixed surface. The pads provides in between the gap forming in the flanges of the die for even surface contact of the bend. The tube is held tightly between the bend die insert and the clamp die then the bend die, die insert and clamp die rotate together around the axis of bend die forming a bent shape. The required bend radius obtained by using die.

8. Design Calculations

Plastic Deformation in tube bending and parameter of tools of rotary draw bending:

Notation:
R – Bending Radius
r – Avg. Radius of the tube cross section
D – Outside diameter of the tube
d – Inside diameter of the tube
I – Moment of inertia
T – Wall Thickness
α – Angle between circumference point
Center point and the topmost point in tube section
J – Moment of inertia (simplified)
N – Integral parameter of moment of inertia
Assuming 1 inch tube with thickness 2.5mm
Yield strength = 1793 MPA
Young's modulus = 210 GPA
C = 1.7mm
Bending strength = (Sy×I) /C
$= (1793\times I\times 〖10〗^5)/12.7$
But,
$I = \pi/(64\times (D^4 - d^4))$
$= \pi/(64\times (〖25〗^4 - 22.4))$
$= 6826.96mm^4$
F = (B. S) / (Distance of center from bending point)
$=962.34/((120+25.4)\times 〖10〗^3)$
F=6636.82N
Pmax = F/A
$A = \pi/(4\times 〖220〗^2)$
$= 22.30\times 〖10〗^3 〖mm〗^2$
$Pmax = 6636.82/(22.30\times 〖10〗^3)$
$= 0.5873 N/m^2$
$= 0.5873\times 〖10〗^6 N/〖mm〗^2$
T = p×d/2
$= 587.83\times 〖10〗^3\times 120/2$
$=35.238\times 〖10〗^3 N/m^2$
Shear stress induced in flanges of die (τ) =F/A =66
Thickness of flanges of bend dies (t)
$F = K. L \times Tensile\ strength \times t^2/D$
Where,
F = Bending Force
K = Constant (1.33)
L = Length of bend in inch
St = tensile strength of material
St = 1882 MPA
From above equation
$F = K\times L \times Tensile\ strength \times t^2/D$
$6636.82= 1.33\times 14.84\times 1882\times 〖10〗^6\times t^2/D$
I = F/A
=6636.82/85.4
$I = 77.71 N/〖mm〗^2$
$\sigma c = Pc/A$
$= (587.3\times 〖10〗^3)/(d\times t)$
$= (587.3\times 〖10〗^3)/(25.4\times 30)$
$\sigma c = 770.73 N/〖mm〗^2$
$\sigma_1 = \sigma c/2+\sqrt{((7770.73/2) + (77.71)^2)}\ \sigma$
$\sigma_1 = 778.48$

σ _2 = σc/2 - √ ((7770.73/2) + (77.71) ^2) σ
σ _1 = 775.0
σ max= Sut/FOS
Tensile strength = Sult/2
Sult= 2 ×Tensile strength
Sult= 2 × 1882 = 3764 N/ 〖mm〗 ^2
σ max= 3764/FOS
FOS = 4.88

9. Conclusion

The current work proposed a new concept of rotary draw bend die called multi radius bend die presented different bend radius with using only one die which resulted in a different tubes bending operations. By reducing the changeover time of dies on machine when machine is ideal. The concept approach the physical work required for the operation and match the requirement.

References

[1] Paper: 1. Manjunathan. R1*, Mohanraj. R1, Moshay. M1, Natchimuthu. N1, "Design and Manufacturing of U - Bending Tool to Overcome Spring Back Effect by Ironing Impact" Department of Mechanical Engineering, Jayalakshmi Institute of Technology, Thoppur, Tamilnadu, India 2Asst. Professor, Department of Mechanical Engineering, Jayalakshmi Institute of Technology, Thoppur, Tamilnadu, India
[2] T. Wen∗ "On a new concept of rotary draw bend - die adaptable for bending tubes with multiple outer diameters under non - mandrel condition" College of Materials Science and Engineering, Chongqing University, Chongqing 400044, China
[3] P. Vikram1, P. Vijayanand2, V. Suresh3 1 "Capacity Calculator for Rotary Draw Tube Bending" M. Tech (CAD/CAM) Student, Department of Mechanical Engineering, Holy Mary Institute of Technology & Science, Hyderabad - 501301.2 Assistant Professor, Department of Mechanical Engineering, Holy Mary Institute of Technology & Science, Hyderabad - 501301 3 Professor, Department of Mechanical Engineering, Holy Mary Institute of Technology & Science, Hyderabad - 501301.
[4] LI Heng*, YANG "A Study on Multi - defect Constrained Bendability of Thin - walled Tube NC Bending Under Different Clearance" He State Key Laboratory of Solidification Processing, School of Materials Science and Engineering, Northwestern Polytechnical University, Xi'an 710072, China Received 12 April 2010; revised 5 August 2010; accepted 22 October 2010

Books
[1] Design of machine element – By V BBhandari (Fourth edition) [5]
[2] Tool Design - Cyrll Donaldson (Third edition) [6]

Conference:
[1] PaoloAlbertellia, *, MatteoStranoa "Experimental investigation of energy saving opportunities in tube bending machines ", Michele Monnoa a Politecnico di Milano, via La Masa 1, 20156 Milan, Italy [7]
[2] ChristopherHeftrich, Rainer Steinheimer, Bernd Engel. "Rotary - draw - bending using tools with reduced geometries" 17th International Conference on Metal Forming, Metal Forming 2018, 16 - 19 September 2018, Toyohashi, Japan [8]
[3] Jatoth Ramachander1 "Bending capacity calculator for rotary tube" HOD & Sr. Assistant Professor of Mechanical Engineering, S. V. Engg. College Suryapet [9]