CONTROL OF OVALITY IN PIPE BENDING: A NEW APPROACH

A. V. Kale[1*], H. T. Thorat[2]

1. Department of Mechanical Engineering, Yeshwantrao Chavan College of Engineering, Hingna road, Nagpur, Maharashtra, India, Pin. 441110, svssngp@gmail.com

2..Director, NIT Srinagar, Uttarakhand,India.Pin 246174, htthorat@yahoo.com

Abstract

This paper formulates and analyses results of experimentation of pipe bending process on a new modified pipe bending mechanism. Ovality or flattening of pipe in the bent portion is a major defect and contributes to poor quality of the bend, deforms the cross section and reduces the strength of the bend to cause easy buckling of the pipe. Several other defects in addition to this drawback of the bending process necessitated corrective action and modification in the existing equipment to bend pipe with minimum defects. Hence, this work targets at design, development, fabrication and use of equipment, which will produce pipe bends with better quality without sacrificing simplicity of existing equipment. Analysis of experimental data is presented here

Key Words: Tube/Pipe Bending, Rotary Compression Bending, Ovality

1. Introduction

Considerable progress is made in all aspects of equipment involved in pipe bending processes. The machines, dies, mandrels, tooling and automatic controls have undergone substantial development in recent years. Existing tools and equipments do not give the output to the required standards. Bending process of the pipe is accompanied by various defects such as wrinkles, bumps, scratches and excessive ovality. These defects contribute to poor quality of the bend[1]. Ovality or flattening of pipe in the bent portion is a major defect. Ovality in the bent portion deforms the cross section and reduces the strength of the bend, so it buckles easily[2]. The flattening of elastic tubes under pure bending has been a focus of much attention over many decades since Brazier first studied this problem in 1927[3]. Buckling of pipes during bending is studied by Belke L.[4]. Gerber[5] studied flattening effect by taking the plastic properties into consideration, although his investigation was relatively elementary. An oval cross-section is assumed for the deformed pipe after bending. Equation for radius of a point at any circumferential angle is established for this cross-section by Pan K. and Stelson K.A.[6]. Numerous contributors have reported their experiments on this phenomenon and provided some elementary analyses to fit the experimental results. These results form the basis for the further theoretical studies of the problem[7-12].

Drawbacks of the bending process necessitated corrective action and modification in the existing equipment to bend pipe with minimum defects. Hence, this work targets at design, development, fabrication and use of equipment, which will produce pipe bends with better quality without sacrificing simplicity of existing equipment.

Existing compression bending mechanism is modified and used for the experimentation. Pipes of constant diameter but different thicknesses are bent for various positions of top support plate i.e. with or without pre-compression of pipe. Experimentation is carried out using 80 pipes. All pipes are bent for total bend angle of 85^0. Dimensions of each pipe are measured before and after bending. Experimental results are tabulated. Tables contain diameters before and after bending at thirteen discrete positions along the length of the pipe. From this data, ovality before and after bending are calculated.

2. Proposed Concept for Control of Ovality

In the existing bending mechanisms, a circular pipe is loaded in the fixed form die as shown in Fig. 1 in which points A, B, C, and D are equidistant from the centre. Arrows in the figure indicate the direction of reaction by fixed forming die against the force applied for bending.

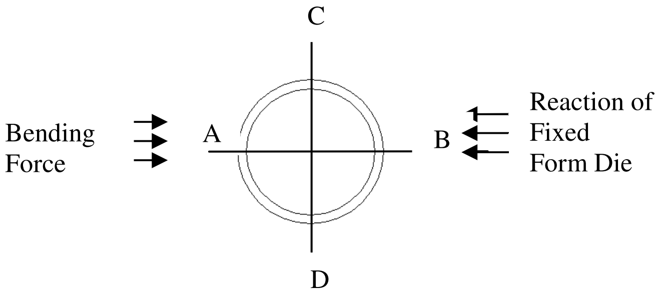

Figure 1 Pipe Fixed in Form Die Before Bending

Pipe bends when the force is applied through wiping die. In this process, the point B remains at the same position but point A is shifted towards the centre due to compression of the pipe. As there is no support at points C and D, therefore, these points are shifted vertically outwards, as shown in Fig. 2, to form an elliptical cross section having major and minor axes resulting in oval cross section at the bend.

From the observations, it is concluded that the pipe must be supported for maximum of its periphery and it is also necessary to provide the support to the pipe during bending to avoid the deformation of the pipe vertically.

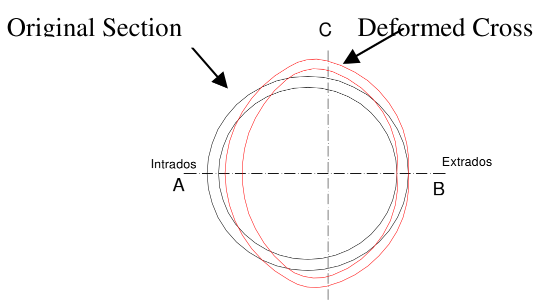

Figure 2 Deformation of the Pipe without Vertical Support

In the proposed method, an attempt is made to restrict outward movement of points C and D by using top and bottom support as shown in Figure 3. If increase in diameter while bending is restricted, deformed cross-section cannot flatten easily. The roller support should not overlap the pipe for larger area. Each roller envelops for 130º on the pipe diameter.

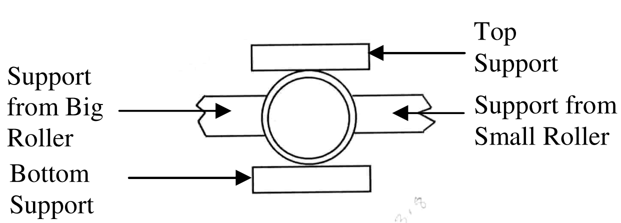

Figure 3 Proposed Concept

3. Operation of the Mechanism

A schematic of the new rotary compression bending mechanism is as shown in Fig. 4. The mechanism is manually operated and similar to the compression bender, which consists of two rollers. One roller is large in size and having the radius equal to the bend radius. Angular movement is locked by using dowel pins, but it can move up and down due to springs, which are placed beneath this roller. Another roller, which is smaller in size, is mounted on the separate bolt and is in the same horizontal plane with the big roller. The small roller is fastened to the link by a nut through an oval hole. This oval hole permits the horizontal adjustment of the small roller, for bending the pipes of different diameters.

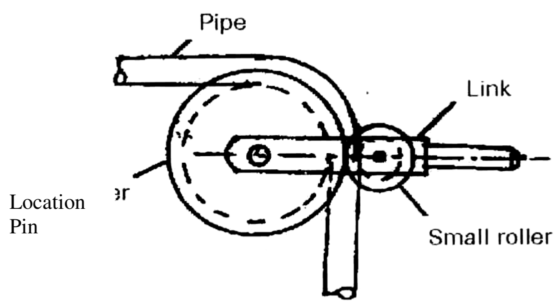

Fig. 4 Bending action in Modified Mechanism

4. Experimentation

The aim of experimentation is to use modified bending mechanism to bend the pipes. Experimentation is planned for the pipes with constant diameter of 22 mm but of varying thicknesses. Tubular blanks of length 350 mm are used for experimentation. Pipes used are of thickness 1.2, 1.25, 1.5 and 2.0 mm. Pipes are procured accordingly. These are grouped according to thickness and colour coated. Pipes are marked with the grid pattern as shown in figure 5 and made ready for experimentation. Dimensions are measured before bending. Based on these dimensions, the pipes are classified into sub groups having approximately same dimensions. Five pipes are used from each group and

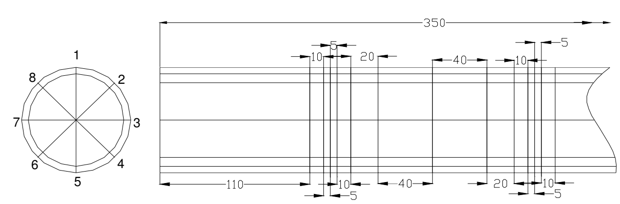

Figure 5 Grid Pattern on the Pipe

5. Description of Pipe Bending Process on Modified Bending Mechanism

Bending operation of the pipe on the mechanism is done in the following sequence:

i. A tubular blank of the pipe is located in the pin provided at rear end. It is located in such a way that the starting point of the bend goes towards the pin side and the seam is at the top. As there is an excessive clearance between inside diameter of the pipe and outside diameter of the pin, therefore, it is easy to locate the pipes of various inside diameters.

ii. Initially, when the pipe is inserted on the location pin, outside diameter of the pipe is not guided in the groove of floating big roller. Central roller is spring-loaded. Rotation of this roller is restricted by providing three dowel pins of diameter 12 mm. It is always touching to the bottom of the top support plate due to the spring force. Top support plate, which has threads on its inside diameter, can be moved up and down. Central roller moves with the top support plate to adjust the required bending condition. Thus, pipe is located exactly at the centre and at high points of the diameter.

iii. Bending is performed in four conditions of the top support plate as mentioned below:

- Keeping the gap between the pipe and bottom of the top support plate. This is called as open condition.
- Keeping the bottom surface of the top support plate touching to extreme periphery of the pipe. This is called as touching condition.
- Compressing the pipe by 0.25 mm by lowering the bottom surface of the top support plate by 0.25 mm compared to the touching condition. This is called as load 1 condition.
- Compressing the pipe by 0.5 mm by lowering the bottom surface of the top support plate by 0.5 mm compared to the touching condition. This is called as load 2 condition.

iv. When the force is applied at the end of lever, the small roller advances and locates itself on to the diameter of the pipe, gripping it against the central roller. Provision is made in the design for the vertical adjustment of the small roller also, if required.

v. The bending arm rotates about the fulcrum point of central bolt and the small roller wipes the pipe while rotating about itself.

vi. During the rotation of the bending arm, compressive force exerted by small roller is used to advance the pipe and bend to conform to the shape of the central roller.

vii. After bending, bending arm is brought back to its original position, the top support plate is moved up and pipe is removed.

6. Measurement of Dimensions before and after Bending

As the circular cross section is divided into eight parts as shown in figure 5, therefore, outside diameter is measured before bending of the pipe at four positions i.e. between points 1-5, 2-6, 3-7 and 4-8 with the help of digital Vernier Calliper. The data is recorded in the sheets similar to table1. Thickness is measured at each point on the orthogonal grid along 13 discrete places, corresponding to eight divisions, with the help of ultrasonic thickness tester. The instrument is calibrated for Mild Steel specimen of thickness 1.2, 1.25, 1.5 and 2.0 mm. After the measurements of diameter and thickness, mean diameter is calculated for each group of the pipe separately and recorded in the same table. There are 80 such data recording sheets for 80 pipes.

From each group, twenty pipes are selected. Five pipes are bent for each condition of top support plate. Diameters at four positions and thickness at each point of the grid along the length of the pipe are measured and recorded after bending. Moreover, change in length between the sectors as marked on the pipe along its axis is also measured for each pipe for 12 sectors and recorded in the same table. Values of maximum ovality increase in thickness on tension and compression side, increase in length between the markings along the length of the pipe before and after bending is computed in the same table.

7. Analysis of Experimental Data

From the values of diameters before bending from table 1, percentage ovality is calculated as:

% Ovality before bending =

$$\frac{D_{1B} - D_{3B}}{D_o} \times 100 \qquad (1)$$

From the values of diameters after bending, ovality is calculated as:

% Ovality after bending =

$$\frac{D_{max} - D_{min}}{D_o} \times 100 \qquad (2)$$

Values of percentage ovality of the pipes before bending are as shown in Ttable 1, for all thicknesses. These pipes are bent for different positions of top support plate during experimentation.

Table 1 Ovality before Bending at the Centre of the Bend

Group	t	ψ	Open	Touching	Load 1	Load 2
			% Ovality BB			
Group B	1.20	42.62	0.540	0.56	0.86	0.48
Group A	1.25	42.62	0.144	0.19	0.14	0.16
Group C	1.50	42.62	0.270	0.19	0.25	0.19
Group D	2.00	42.62	0.250	0.33	0.28	0.35

Values of percentage ovality after bending, at the center of the bend (at 42.62^0 bend angle), are as shown in Table 2 for all thicknesses and different positions of top support plate.

In the Table 2, percentage ovality for thickness 1.2 mm, ranges from 46% to 6.93 % for open to load 2 condition. For 1.25 mm, it is 42% to 5 % depending upon pre-compression of the pipe. Increase in the percentage ovality after bending is very high for bend angles ranging from 14.21^0 - 71.03^0. It is also observed that, as the thickness increases, the value of ovality decreases at the center of the bend.

The basic objective is to reduce the ovality in pipe after bending with the help of new concept. This reduction in ovality is achieved by bending the pipes with different conditions of top support plate i.e. with pre-compression. Values of ovality after bending at various cross sections of pipe are as shown in table 3. For all thicknesses, ovality is large for open condition i.e. without the constraint on deformation in vertical direction. If the top compression plate is kept touching with the pipe diameter and the pipe is bent, ovality reduces to half of its values in open condition. If the pipe is pre-compressed by 0.25 mm, ovality further reduces to half of its values than in touching condition for smaller thickness i.e. 1.2 and 1.25 mm. It is marginally reduced in higher thicknesses. If the pipe is pre-compressed by 0.5 mm, ovality reduces considerably irrespective of the thickness and value of ovality remains more or less same for all thicknesses.

The comparison of experimental percentage ovality after bending for different positions of top support plate is as shown in Figure 6.

Table 2 Ovality at the Centre of the Bend after Bending

Maximum Ovality after Bending at the Centre of the Bend										
Group	t	ψ	Open		Touching		Load 1		Load 2	
			Ovality mm	% Ovality	Ovality mm	% Ovality	Ovality mm	% Ovality	Ovality mm	% Ovality
Group B	1.20	42.62	10.86	46.43	4.81	22.32	2.31	10.4	1.54	6.93
Group A	1.25	42.62	10.77	42.03	4.47	20.12	2.11	9.5	1.13	5.55
Group C	1.50	42.62	4.19	18.86	1.76	7.91	1.67	7.52	1.24	5.51
Group D	2.00	42.62	2.7	11.81	2.46	6.87	1.89	6.41	1.05	4.88

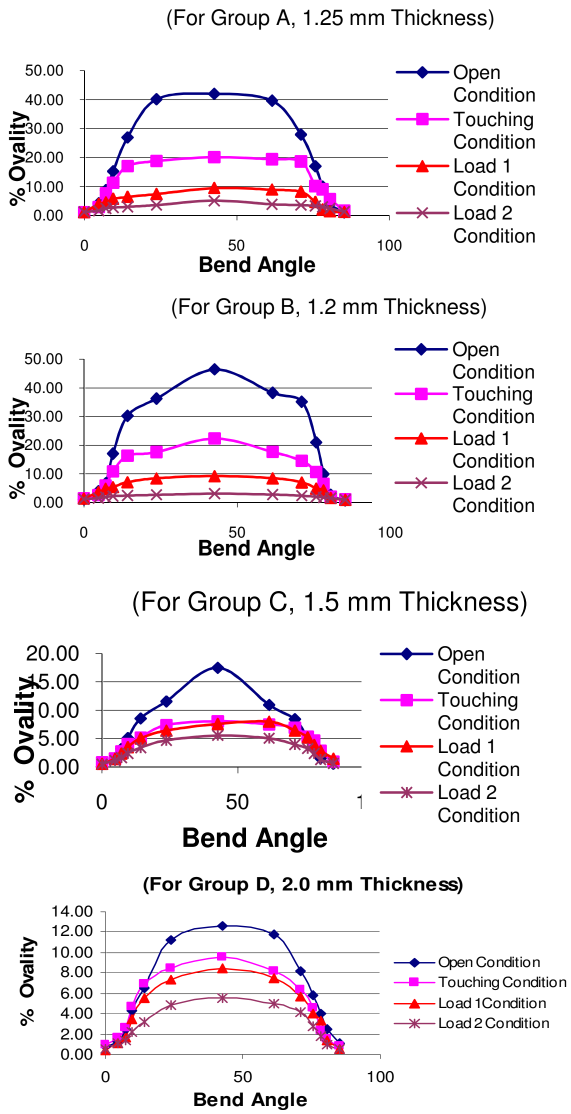

Figure 6 Variation of Ovality for Four Positions of Top Support Plate.

In figure 6, highest value of maximum ovality is for open condition and it decreases as pre-compression is increased by lowering the position of top support plate. Its value is lowest for load 2 condition i.e. when the pipe is pre-compressed to 0.5 mm. It is clear from figure that ovality decreases as the thickness increases.

8. Conclusion

From the experimental data, percentage ovality is computed at thirteen discrete places along the length of the pipe. Graphs are plotted to check its variation with respect to bend angle. It is observed that percentage ovality at the centre of the bent pipe decreases with increase in wall thickness and pre-compression of the pipe. This is because the larger thickness pipe resists buckling during bending and moreover, neutral axis is shifted to tension side avoiding flattening of the pipe thus reducing ovality.

Percentage ovality range for open to fully pre-compressed condition of the pipe is as follows.

46.43% - 6.93 % for 1.2 mm thickness
42.03% - 5.55 % for 1.25 mm thickness
18.96% - 5.10 % for 1.5 mm thickness
11.81% - 4.88 % for 2.0 mm thickness

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