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ISSN: 0976-3031

International Journal of Recent Scientific Research
Vol. 6, Issue, 6, pp.4472-4476, June, 2015

International Journal of Recent Scientific Research

RESEARCH ARTICLE

DESIGN AND MANUFACTURING OF PNEUMATIC PIPE BENDING MACHINE

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ARTICLE INFO

Article History:

Received 5th, May, 2015
Received in revised form 12th, May, 2015
Accepted 6th, June, 2015
Published online 28th, June, 2015

Key words:

Drosophila, Diversity, Occurrence constancy method, Simpson index

ABSTRACT

In line with the growth in the recent technologies, there is large opportunity present in the piping sector. As the part of the piping industry the demand of the customer being changes day by day. The manual pipe bending machines are not able to fulfill the raising demands of the market in quality, quantity as well as cost prospective.

Particularly in this machine, we have used the compressed air to perform the bending operation. This makes the machine or the process much more efficient over the manual operated bending machine. Radius of the bend can be obtained within the limits of this machine. The machine is very useful for the Aluminum & copper pipes.

The name of the machine explains the concept of the machine. The rollers of the radius equal to the radius of the pipe are placed at the location suitable to the radius of the bend to be obtained. The horn which having the radius equal to the radius of the bend is connected to the piston of the pneumatic cylinder. The required force is applied on the horn by the compressed air through the cylinder.

The machine is designed to bend a pipe of aluminum, MS and copper type of metallurgical grade.
The aluminium and copper pipe upto 22 mm OD and 1.5 mm thickness and MS pipe upto 20 mm OD and 0.5mm thickness has ben designed by this machine.

INTRODUCTION

Pipe bends are critical components in piping systems. In the manufacturing process of pipe bends it is difficult to avoid thickening on the intrados and thinning on the extrados. The cross section of the bend also becomes non circular due to bending process. The acceptability of pipe bends is based on the induced level of these shape imperfections.

Ovality and thinning are the shape imperfections considered for the analysis. It is observed that thinning and ovality are to be taken into account together to decide the acceptability of these bends. The possible flexibility that can be introduced in the selection of ovality and thinning limits of pipe bends to reduce rejection has been suggested.

Pipe bends are used extensively in power plants to convey fluids and to change the direction of the fluids flowing inside the pipes. Bending of pipes with circular cross section is of considerable importance in the manufacture of boilers and the construction of pipe lines. Although the selection of a pipe bend manufacturing process for a specific case is influenced by several factors the most frequent methods of bending of pipes are bending with a mandrel and without a mandrel. During forming process of pipe bends, the outer fibre of the pipe bends thin down, which leads to a phenomenon known as thinning

Pipe Bend cross section

The following assumptions are made in the analysis: Linear behavior, homogeneous isotropic material, and steady static state loading. The effects of the following are not considered in the present evaluation: Bourdon's effect, external pressure, external forces, external moments, centrifugal forces due to change of fluid flow direction, effects of friction between the pipe inside fluid and the pipe bend inner surface, fluid turbulence, interfaces between the straight pipe and pipe bend, tolerances and deviations of the straight pipe before fabricating into pipe bend and pipe bend surface roughness.

The cross section of a pipe bend is assumed to become a perfect ellipse after bending as shown in the figure.

Design Methodology

Design consists of application of scientific principles, technical information and imagination for development of new or improvised machine or mechanism to perform a specific function with maximum economy & efficiency.

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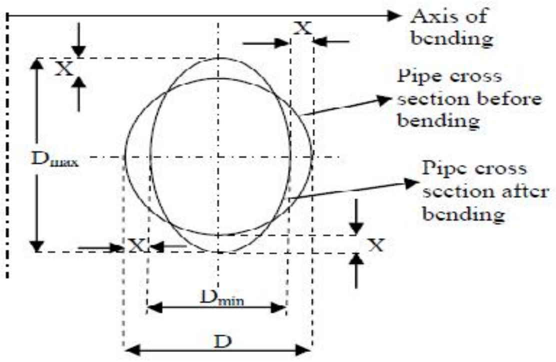


Figure 1 Pipe bend cross section before and after bending

Hence a careful design approach has to be adopted. The total design work, has been split up into two parts

- System design
- Mechanical Design.

System design mainly concerns the various physical constraints and ergonomics, space requirements, arrangement of various components on main frame at system, man + machine interactions, No. of controls, position of controls, working environment of machine, chances of failure, safety measures to be provided, servicing aids, ease of maintenance, scope of improvement, weight of machine from ground level, total weight of machine and a lot more.

In mechanical design the components are listed down and stored on the basis of their procurement, design in two categories namely,

- Designed Parts
- Parts to be purchased

Calculations for Plastic and Elastic deformation

Calculations within Elastic Limit

By using Flexural formula:

$$\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$$

Poisson's ratio= 0.27-0.30 , E=210 GPa

y= distance of center to pt. of maximum stress.
Outer diameter of pipe= 20 mm, Inner diameter of pipe= 19 mm

Thickness of pipe= 0.5 mm
$M_b = w/2*l/2$

And also, $I_{xx} = \pi/64 *(d_o^4 - d_i^4)$. Therefore , $I_{xx} = 1456.864\ mm^4$
Thus putting above values in flexural formula,
We get value of w = 699.294 N

Calculations for plastic deformation

Factor required by pipe to bend from static to plastic region is given by $K_{sp} = (F_p /w)$

Assuming, $K_{sp} = 1.58$

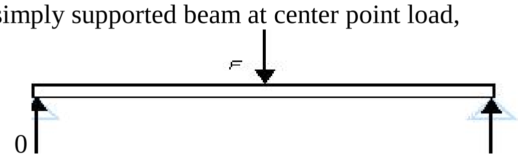
This means that 1.583 times the static force is required to bend a pipe in plastic zone.

Therefore, force required = $K_{sp} * w = 1.58 * 699.29$
$F_p = 1107.216$ N

Now, let us find the deflection of pipe under static condition for load w=699.294 N

Deflection of pipe

For simply supported beam at center point load,



Simply supported beam

Deflection at center is given by, $y = wl^3 /48 EI$
$y = (699.294*(300)^3)/(48 * 210000*1456.864)$ mm
y = 1.2850 mm
Now, roller and pipe will be in contact.

Therefore, friction will occur between them, coefficient of friction is 0.16
$F_r = 0.16* F_p$ i.e. $F_r = 177.154$ N

Also, the friction will occur between piston and inner surface of cylinder.

Rubber O ring and UPVC are in contact
Therefore $F_p' = 0.15* 1107.216$ i.e. $F_p' = 166.082$ N
Thus, total frictional force, $F_f = F_r + F_p'$
Therefore, $F_f = 343.236$ N
Total force required along with frictional force to bend a pipe of mild steel (OD= 20 mm and t= 0.5 mm)
Total force required, $F_T = F_f + F_p$
$F_T = 343.236+1107.216=1450.452$ N
Thus, total force required to bend a pipe is 1450.452 N

Design of pneumatic cylinder

$P= F_T / A$, $d_i = ((4* F_T)/p\pi)^{1/2}$

Selecting pressure not exceeding than 12 kg f/cm^2
Nominal diameter= 40 mm
Outer Diameter= 50 mm

Theoretical Displacement to be travelled by Horn

The displacement travelled by the horn from roller center line up to bend angle of various angles of various degrees without considering spring back effect can be calculated as follows

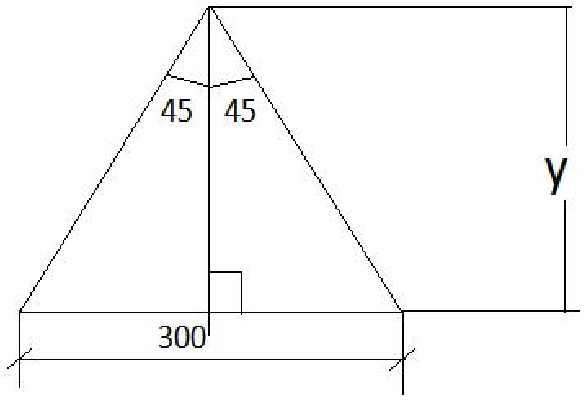


Figure 2 Theoretical distance travelled by the horn
tan45= y/150   i.e. y= 150 mm

Table 1 Theoretical displacement travelled by the horn

Angle (θ)	Displacement (y) , mm
90	150
95	137.44
100	125.86
105	115.09
110	105.03
115	95.56
120	86.60
125	78.08
130	69.94
135	62.13
140	54.59
145	47.29
150	40.192
155	33.254
160	26.449
165	19.747
170	13.123

Spring back effect

In bending after the applied force is withdrawn the metal tries to resume its original position causing a decrease in bend angle. Such a metal movement is called as spring back phenomenon.

It is caused by the elastic stresses remaining in the bend area. After the bending pressure on metal is released the elastic stresses are also released and causes metal movement. Spring back varies from ½ to 5 degree in steel and ½ to 3 degrees in aluminium.

The elastic stresses remaining in the bend area after bending pressure is released will cause a slight decrease in the bend angle.

Metal movement in this type is known as spring back, as shown in figure 1. The magnitude of the movement will vary according to the material type, thickness and hardness. A larger bend radius will also cause grater spring back.

The spring back increases with increase in tensile strength, bend radius, bend angle.

Spring back is calculated for mild steel as:
$\theta_U = \theta_L * (1- (R_L M_L / E I))$
where ,

θ_U = bend angle after the occurrence of spring back.
θ_L = bend angle before spring back has occurred
R_L & M_L = bend radius and bending moment
E & I = Modulus of elasticity and area moment of inertia.

Spring back for Aluminium is calculated using following formula:

Spring back angle(dθ) = (0.00791*θ) + 0.4664
Where θ = bend angle required

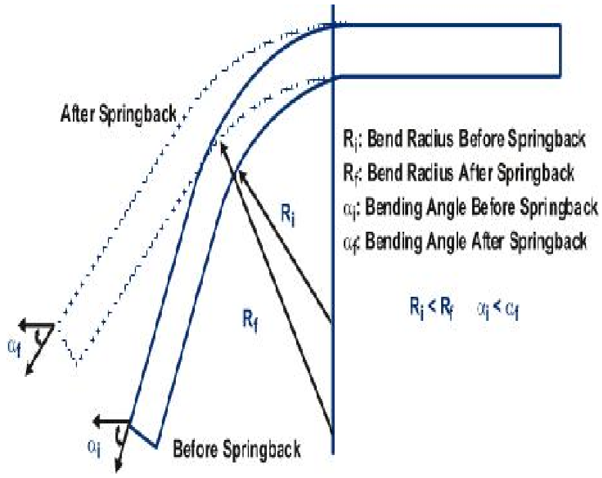


Figure 2 Spring back before and after bending

Table 2 Spring back angle for Al

Angle (θ)		Spring back angle
90		1.178
95		1.217
100		1.257
105		1.296
110		1.336
115		1.376
120		1.415
125		1.455
130	1	1.494
135		1.534
140		1.573
145		1.613
150		1.652
155		1.692

Table 3 spring back angle for MS

Angle (θ)	Actual bend angle obtained	Spring back angle
90	91.23	1.23
95	96.29	1.29
100	101.36	1.36
105	106.43	1.43
110	111.49	1.49
115	116.56	1.56
120	121.63	1.63
125	126.70	1.7
130	131.76	1.76
135	136.83	1.83
140	141.90	1.9
145	146.97	1.97
150	152.04	2.04
155	157.10	2.1

From the above graph it is clear that as bending angle increases spring back angle also increases irrespective of material.

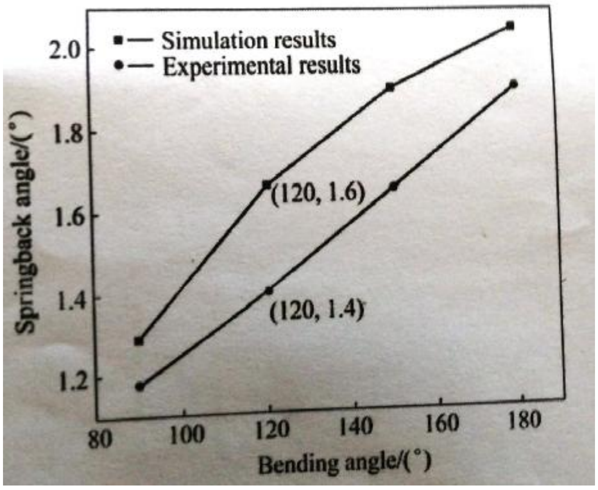


Figure 3 Comparison between spring back angle and bending angle

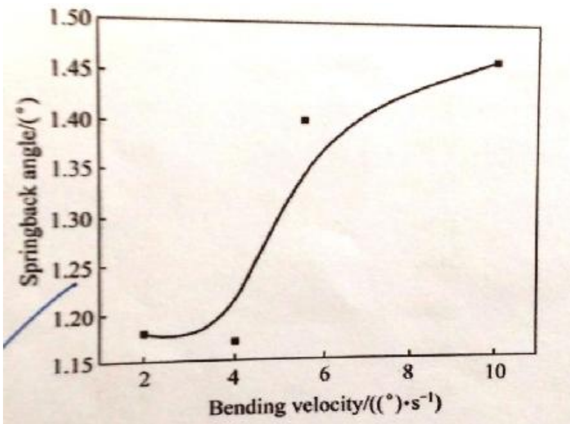


Figure 4 Comparison between spring back angle and bending velocity

From the above graph it is also clear that as bending velocity increases spring back angle increases gradually and then becomes lesser as compare to earlier.

ANSYS RESULTS

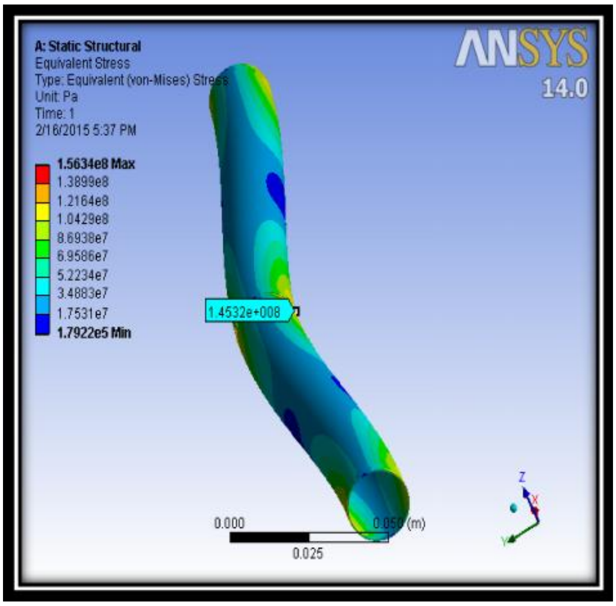


Figure 5 Stresses in pipe upto yield point for MS

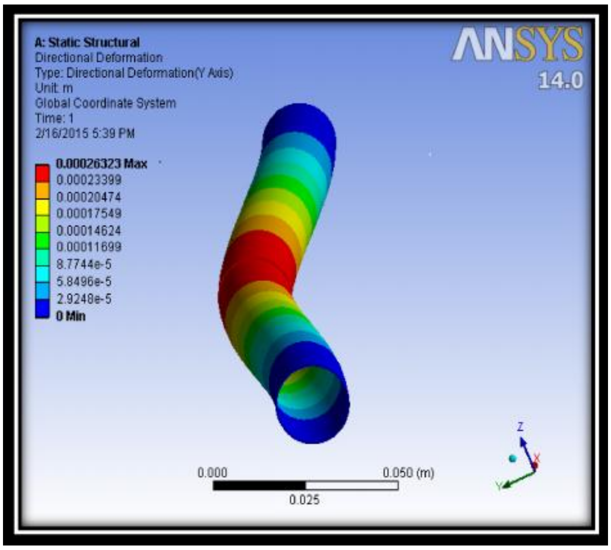


Figure 6 Deflection in pipe upto yield poin for MS

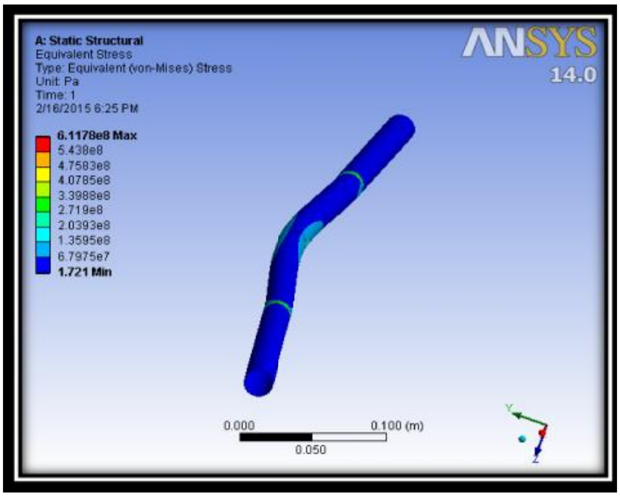


Figure 7 Stresses in pipe under working condition

CONCLUSION

1. The testing was done on aluminium pipe of 20mm OD and 1.5mm thickness and MS pipe pipe of 1 inch(25.4mm) and 0.5mm thickness.
2. The trial for aluminium pipe was done by filling fine sand to reduce the pipe thickness at bent portion.
3. The aluminium pipe of 20mm OD and 1.5mm thickness was made bend successfully upto 70 degress by application of 7 bar pressure and control of compressed air by flow control valve.
4. Similarly MS pipe of 1 inch (25.4 mm OD) and 0.5mm thickness was bend upto 60 degress by application of 5 bar pressure and control of compressed air by flow control valve.
5. During the testing the sand was filled in both the metallurgical grade of pipes to prevent fracture of pipe and reduces the induced stesses beyond the ultimate point and testing was performed.
6. Also during the testing the effect of spring back angle was considered for both the metallurgical grades of pipe.

7. It was observed that as bending angle increases spring back angle also increases for a particular metallurgical grade of pipe.
8. It was also observed that as brittleness of material increases spring back angle also increases that is spring back angle for MS was observed more as compare to aluminium for a particular bend angle.

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How to cite this article:

Vikash Patial *et al*., Design And Manufacturing Of Pneumatic Pipe Bending Machine. *International Journal of Recent Scientific Research Vol. 6, Issue, 6, pp.4472-4476, June, 2015*

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