Design and Fabrication of Automated Pipe Cutting and Bending Machine

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Abstract: This paper presents the design and fabrication of combined pipe bending and cutting machine in 3 dimensions. There is no single machine made to perform both bending and cutting operations for such a small diameter. This paper gives the brief description about the design and construction of the pipe bending machine which is used to bend and cut metal pipes. Our objective is to increase accuracy at low price without affecting the pipe bending productivity. Using this machine both bending and cutting of pipe of outer diameter 6.35 mm and thickness 2.1 mm is possible. The machine is capable of bending the pipe in 3D at various angles (2-180 degrees). Equipped with electric motor driven feed mechanism, the system offers high speed and high accuracy bending, with lower power usage. The innovation in this machine is its hydraulically operated rotatory cylinder and drawtube used to grip the work piece. This innovation in the machine design gives an opportunity to reduce cost and also to reduce the human efforts. The automated bending system provides consistent, high-quality parts and process reliability while eliminating time-intensive, manual handling of many operations.

***Index Terms* - Automation; Reliability; Complex; Productivity; Spindle; Collet chuck; Hydraulic rotary cylinder.**

I. INTRODUCTION

The 3D Automated Cutting Bending Machine provides the optimal bending solution for high-mix, low-volume production. The machine is an advanced system that achieves precise and economical bending results even in lot sizes of 6.35mm. The machine performs all operations quickly and precisely eliminating costly delays associated with manual tools.
As a result, you can triple or quadruple your number of bending setups per day. The machine is equipped with pulleys (for bending) providing the flexibility to accommodate rush jobs seamlessly. Now, complex bending operations can be done within minutes. This automated bending system provides consistent, high-quality parts and process reliability while eliminating time-intensive, manual handling of many operations.

The machine is a fully-integrated automatic bending system with a 3-axis rotation of chuck. The machine is designed specifically for high speed bending of small complex bends, the whole system is designed for unmanned production of any volume size or part mix for day long working hours. Equipped with electric motor lead screw driven mechanism, the system offers high speed and high accuracy bending, with lower power usage and a compact footprint. Features such as offline programming, all add to the systems impressive list of production capabilities. Hence, the machine with fully automated system is used to bend a pipe in 3 dimensions and cut which would be required in the manufacture of other vital components of the industry. For the automation part PLC (Programmable Logic Controller) is used. By designing and manufacturing a machine which requires lesser time than the regular machine and also the accuracy and precision is more than the average machine, this is more efficient than the other non-automated machines which are used for cutting and bending of tubes and pipes. Tube bending as a process starts with loading a tube into a collet, and clamping it into place between two dies, the clamping block and the forming die. The process of tube bending involves using mechanical force to push stock material pipe or tubing against a die, forcing the pipe or tube to conform to the shape of the die. Often, stock tubing is held firmly in place while the end is rotated and rolled around the die. Hydraulic force is used to bend the tube through two dies. This process will provide many solutions to the existing problems regarding time management, productivity and labor issues.

II. OBJECTIVES

a) Reduction in production time – Having a machine that is automated definitely speeds up the production time since no thinking is needed by the machine.
b) Increase in accuracy and repeatability – When an automated machine is programmed to perform a task over and over again, the accuracy is far greater.
c) Less human error – There are fewer chances of human errors.
d) Less employee costs – By adding automated machines to an operation, means less employees are needed to get the job done.

e) Increased safety – Having automated machines means having fewer employees who perform tasks that can be dangerous and prone to injury.
f) Higher volume production – Investing in automated equipment creates a valuable resource for large production volumes, which in turn will increase profitability.

III. METHODOLOGY

The Machine comprises of three sections a) bending mechanism (with pulleys) b) Work piece rotating mechanism (a hydraulic rotary cylinder and a spindle rotated by a servomotor) c) Feed Mechanism (with Electric motor driven lead screw) d) Clamping and Cutting accomplished by hydraulically driven cylinders. Tube bending is the umbrella term for metal forming processes used to permanently form pipes or tubing. A tube can be bent in multiple directions and angles. Common simple bends consist of forming elbows, which are bends that range from 2 to 90°, and U-bends, which are 180° bends. More complex geometries include multiple two-dimensional (2D) bends and three-dimensional (3D) bends. A 2D tube has the openings on the same plane; 3D has openings on different planes. Tube bending as a process starts with loading a tube into a tube or pipe bender and clamping it into place between two dies, the clamping block and the forming die. The process of tube bending involves using mechanical force to push stock material pipe or tubing against a die, forcing the pipe or tube to conform to the shape of the die. Often, stock tubing is held firmly in place while the end is rotated and rolled around the die. Pneumatic force which is the compressed air or hydraulic force is used to bend the tube through two dies.
There are three major parts:

1. Bending Mechanism –

a) A tube can be bent in multiple directions and angles. Common simple bends consist of forming elbows, which are bends that range from 2 to 90°, and U-bends, which are 180° bends. Formulae for Tube Bending:
1. $J = 1.41 + 0.42/k$
2. $W_b = \pi \times (D_3\text{-}d_3)/32$
3. $M = \sigma_{s\times} W_{b\times} J$

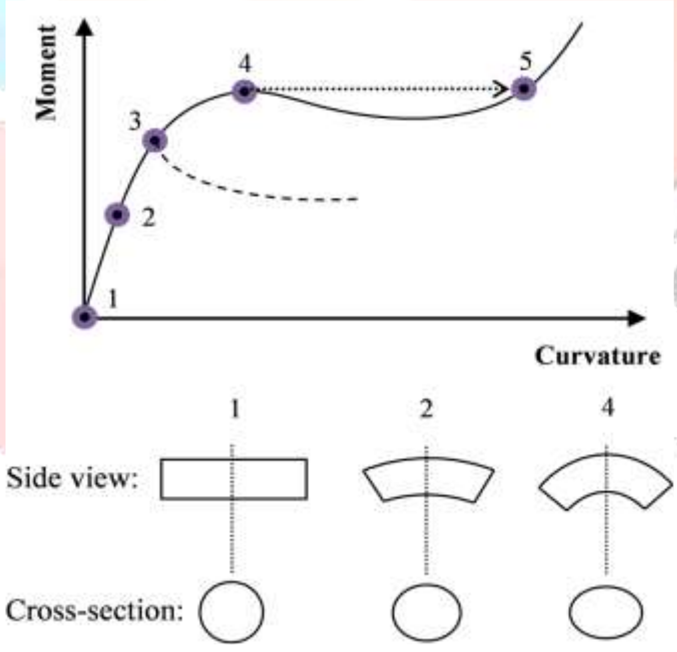

Fig -1: moment versus curvature

2. Work piece rotating mechanism:

a) More complex geometries include multiple two-dimensional (2D) bends and three-dimensional (3D) bends which are done by rotating the work piece by a collet chuck. b) Formulae for Spindle and Rotary Cylinder:
1. $T_{max} = 16T_e / [\pi \times d_o^3 (1 - k^4)]$
2. $P_b = 2T_{max} / (N\times D_1 \times D_2 \times L_b)$

3. Feed Mechanism (with Rack and Pinion & Guide rails for support):

a) Rack and Pinion driven mechanism helps in accurate feeding of tube in the bending pulley and hence to the cutter. The pinion is driven by a servomotor which reduces error if any at every stage.

b) Formulae for design of rack and pinion:

$Y = 0.484 – 2.87/Z$
$F_w = d_p \times b \times Q \times K$
$F_d = [21 V (bC + F_{tmax})]/ [21V +(bC + F_{tmax})]^{1/2}$

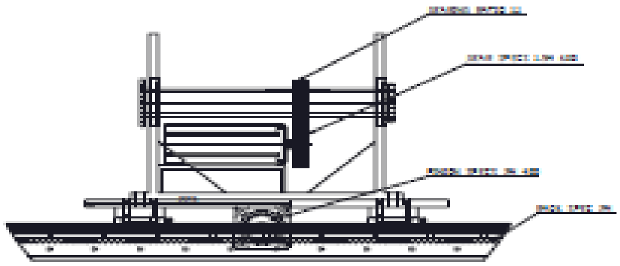

Fig -2: spindle drawing

4. Hydraulic Rotary Cylinder, Clamping Cylinder and Cutter:

a) Major part of the system is driven by the hydraulic power pack. The circuit is shown below.

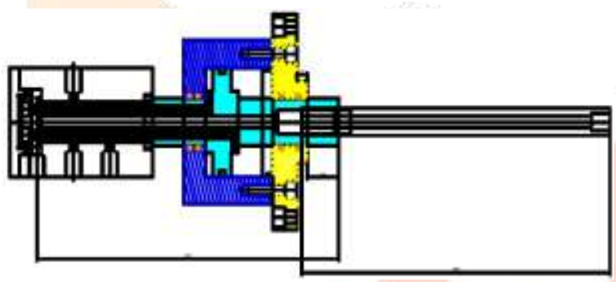

Fig-3: rotary cylinder and drawtube assembly

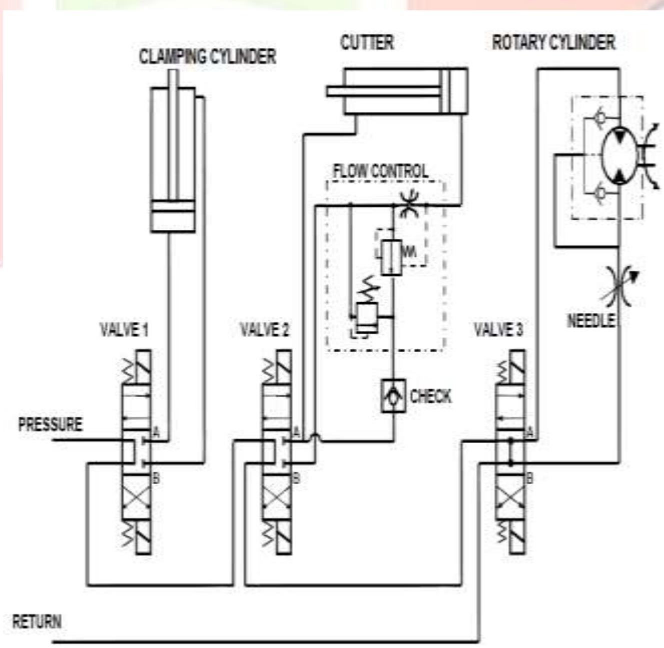

Fig-3: hydraulic circuit for the entire system

b) Formulae for Clamping of Pipe:

$\sigma= (r_{i2}\times P_i – r_{o2}\times P_o) / (r_{i2}–r_{o2}) + [(P_i - P_o)/ (r_{o2}-r_{i2}) \times (r_{i2}\times r_{o2}/r_2)]$

5. **Entire Machine Assembly:**

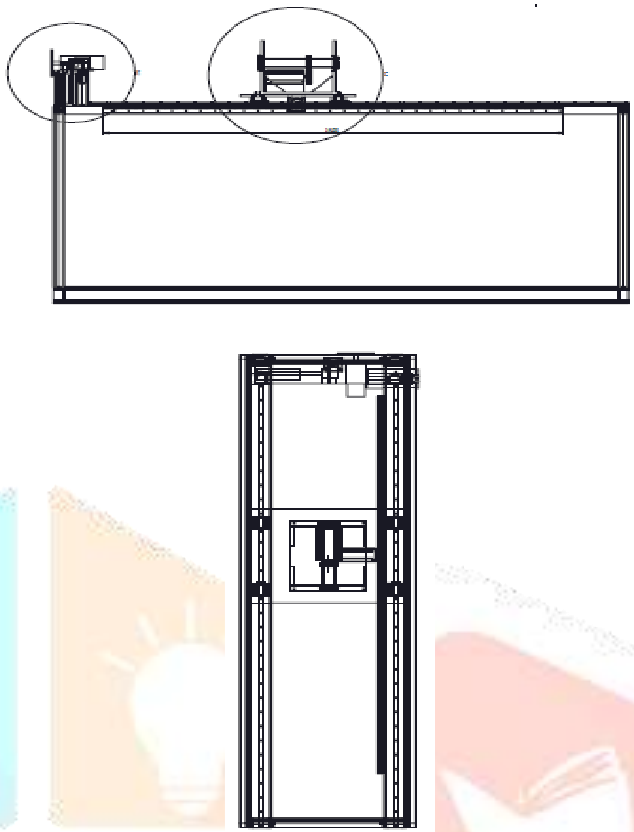

Fig-5: Front View and Top View of the Machine (Drawing on AutoCAD)

IV. CONCLUSIONS

The project design was completed and tested on various soft wares like ANSYS successfully. As per objectives the fabricated machine is able to perform the bending and cutting operations in 3 dimensions. Machine uses power source i.e. three phase motor and hydraulic power which reduced the capital cost of the machine. Machine also aims to reduce human efforts and to increase product quality and quantity. The machine is capable of bending and cutting of tubes of 6.35mm diameter without any damage to work piece. Furthermore, the machine could be easily and feasibly modified to handle tubes of even larger diameter up to 30mm. Hence, we believe that this machine is an example of automation at a very feasible price.

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REFERENCES

1. Nur Cholisa, Sugeng Ariyonob and Gigih Priyandokoc, “Design of single acting pulley actuator (SAPA) continuously variable transmission (CVT)” Elsevier Ltd, Energy Procedia 68, pp.389-397,2014.
2. Dimitar Dimitrova, Tamas Szecsib on “Machining accuracy on CNC lathes under the lack of unity of the process and design data”, Esevier B.V., Procedia CIRP 41, pp.824 – 828, 2016.
3. P.Ferro, M.Colussi, G.Meneghatti, F.Berto, M.Lachin, S.A.Castiglione, “On the use of the method stress method for the calculation of residual notch stress intensity factors: a preliminary investigation,” Elsevier B.V., Procedia Structural Integrity 3, pp. 271-350, 2017.
4. Ju Yi, Yingping Qian, Zhiqiang Shang, Zhihong Yan, Yang Jiao, “Structure analysis of planetary pipe cutting machine based on ANSYS,” Elsevier Ltd., Procedia Engineering 174, pp 1283 – 1288,2017.