A New Model in Design and Manufacturing of Mobile Hydraulic Pipe Bending Machine in Industry

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Abstract

In recent years pipe bending machine is used in both industry and domestic purpose for bending the pipe under the required angles and dimensions. Sometimes Heat treatment is used for pipe bending but the heat treatment technique is not safe and have problems are produced in the pipes, such as wrinkling, curve forming, reduced thickness, whole forming, reduced strength, easy breakable.

In the hydraulic pipe bending machine having an good advantage compared to heat treatment methods, the advantages are accurate degree and radius, no crack formed in the pipe, easy handling, does not change in thickness and also a time consuming is very less.

The required dimensions for the profile cutting, bending angle are choosing from the industry and creating a design using CATIA software for the profile modules. After that, the hydraulic pipe bending machine will be prime for the required pipe bending purpose under various required dimensions and angles.

Keywords: wrinkling, forming, profile modules, dimensions, CATIA.

1. Introduction

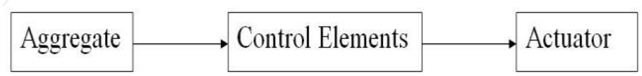
1.1 Fluid power

Fluid power is energy transmitted and controlled by means of a pressurized fluid, either liquid or gas. The term fluid power applies to both hydraulics and pneumatics. Hydraulics uses pressurized liquid, for example, oil or water; pneumatics uses compressed air or other neutral gases. Fluid power can be effectively combined with other technologies through the use of sensors, transducers and microprocessors.

1.2 Hydraulics

Hydraulics is the transmission and control of forces and motions through the medium of fluids. Short and simple. Hydraulic systems and equipment have wide-spread application throughout industry. For example: machine tool manufacturing, press manufacturing, plant construction, vehicle manufacturing, aircraft manufacturing, shipbuilding, injection molding machines [8].

1.3 Conversion of Energy in Hydraulics

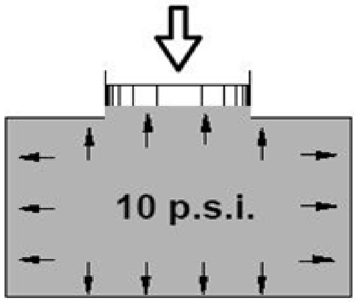


“Figure 1. Energy Conversions”

Various forms of energy are converted to accomplish mechanical movement in the injection molding machine. Electrical energy is converted to mechanical energy, which in turn is converted to hydraulic energy to operate and control the moving components of the machine. The hydraulic energy is converted to mechanical energy to achieve the final desired result, which may be “mold clamping pressure” or “material injection". The terms of Pump, motor, Fluid reservoir, Pressure relief valve, Filter, Piping are the aggregate; Valves, determining the path, pressure, flow rate of the working fluid are the control elements and Linear, Rotational, Swinging are the actuators. The “Figure 1” above summarizes the energy conversions for an injection molding machine.

1.4 Pascal's Law

Pascal's Law states that pressure acting on a confined fluid is transmitted equally and undiminished in all directions. In the figure below, a 10 pound force acting on a 1 square inch area generates a pressure of 10 pounds per square inch (psi) throughout the container acting equally on all surfaces [9].



"Figure 2. Working of Pascal's Law"

The principle is that the pressure in any portion of a hydraulic system is equal throughout that system. This statement is valid with the omission of the force of gravity, which would have to be added, according to the fluid level. "Figure 2" shows the application of Pascal's Law.

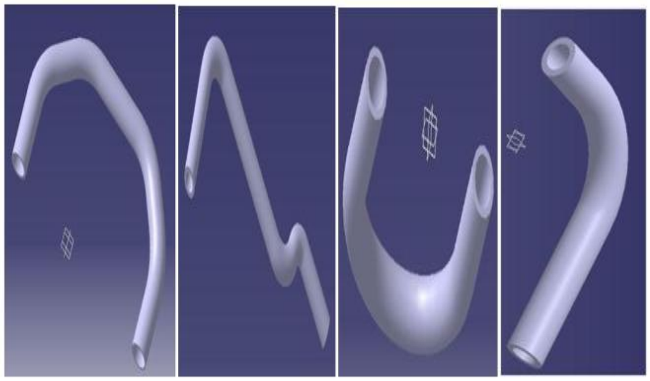
1.5 Mobile

Mobile: Fluid power is used to transport, excavate and lift materials as well as control or power mobile equipment. End use industries include construction, agriculture, marine and the military. Applications include backhoes, graders, tractors, truck brakes and suspensions, spreaders and highway maintenance vehicles.

1.6 Pipe Bending Machine

Bending is a manufacturing process that produces a V-shape, U-shape, or channel shape along a straight axis in ductile materials, most commonly sheet metal **[10]**. Commonly used equipment includes box and pan brakes, brake presses, and other specialized machine presses. Typical products that are made like this are boxes such as electrical enclosures and rectangular ductwork.

Pipe bending is the umbrella term for 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 pipe 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. These processes can be used to form complex shapes out of different types of ductile metal tubing [7]. Freeform-bending processes, like three-roll-push bending, shape the work piece kinematically, thus the bending contour is not dependent on the tool geometry. "Figure 3" shows the application of Pipe or Pipe Bending.



"Figure 3. Applications of Pipe Bending Machine"

2. Problem Identification

2.1 Heat-Treatment

The various types of heat-treating processes are similar because they all involve the heating and cooling of metals; they differ in the heating temperatures and the cooling rates used and the final results. The usual methods of heat-treating ferrous metals (metals with iron) are annealing, normalizing, hardening, and tempering.

Most nonferrous metals can be annealed, but never tempered, normalized, or case-hardened. Successful heat treatment requires close control over all factors affecting the heating and cooling of a metal. This control is possible only when the proper equipment is available. The furnace must be of the proper size and type and controlled, so the temperatures are kept within the prescribed limits for each operation. Even the furnace atmosphere affects the condition of the metal being heat-treated. The furnace atmosphere consists of the gases that circulate throughout the heating chamber and surround the metal, as it is being heated. In an electric furnace, the atmosphere is either air or a controlled mixture of gases. In a fuel-fired furnace, the atmosphere is the mixture of gases that comes from the combination of the air and the gases released by the fuel during combustion. These gases contain various proportions of carbon monoxide, carbon dioxide, hydrogen, nitrogen, oxygen, water vapor, and other various hydrocarbons. Fuel-fired furnaces can provide three distinct atmospheres when you vary the proportions of air and fuel. They are called oxidizing, reducing, and neutral.

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2.2 Stages of Heat Treatment

Heat treating is accomplished in three major stages:
Stage l—heating the metal slowly to ensure a uniform temperature
Stage 2—Soaking (holding) the metal at a given temperature for a given time and cooling the metal to room temperature
Stage 3—cooling the metal to room temperature

2.3 Types of Heat Treatment

Four basic types of heat treatment are used today. They are annealing, normalizing, hardening, and tempering. Annealing, Normalizing, Hardening, Carburizing, Cyaniding, Nitriding, Tempering

2.4 Problem Description

The sides of tube are subjected to various kinds of tools' strict contacting effects including bend die, clamp die, pressure die, wiper die and mandrel (with multiple flexible balls). The tube is clamped against the bend die by the clamp die and pressure die; then the clamp die and bend die rotate simultaneously, and the tube is drawn past the tangent point and rotates along the bend die groove to obtain the desired bending angle and bending radius. Thus the bending deformation is finished and then the mandrel is withdrawn and the tube is unloaded. Among these dies, the wiper die is used to fit the gap between the bend die and the back tangent of the tube to prevent possible wrinkling; the mandrel with multiple flexible balls is used to support the tube inner side to avoid wrinkling and cross section distortion. To ensure high quality bent tube components, the bending process needs precise coordination of various dies. The contact conditions may change the stress and strain distributions in local field or the whole forming zones. In summary, there are altogether five kinds contact interfaces including tube-wiper die, tube-mandrel, tube-pressure die, tube-bend die and tube-clamp die. Both the groove dimensions of dies and the tooling setup determine the clearance value of various interfaces. Generally, the geometry specifications of dies are determined by pre-design process [5].

"Figure 4. Problem Descriptions in Pipe Bending Machine"

In practice, the tool setup is conducted to make the best fit (appropriate clearance) for the facility at hand. When the tube diameter becomes smaller due to the tube thickness variation or the larger groove diameter of bend die/pressure die, the wrinkling may occur at both sides of tube near the neutral layer. Figure 4 shows various locations where the wrinkling frequently occurs in thin-walled tube bending. The multiform and asymmetric local distribution features of the wrinkling due to inappropriate setup of tools are thus observed. Figures 4(a)-4(c) show that, the wrinkling could occur at straight or curved portion of tube, and sometimes it may happen at the whole portion of tube. The wrinkling may happen at front portion of tube near clamp die due to relative slip between tube and clamp die. Figures 4(e)-4(f) show that, if the wiper die and pressure die are not installed at the same horizontal level, the ripples may happen at upper or lower curved portion of tube. From the experiment, it is thus concluded that the clearance can affect whether or where the wrinkling occurs, also it is thought that, the clearance may have an influence on the bend ability of tube with respect to other defects such as wall thinning and cross-section deformation.

3. Methodology

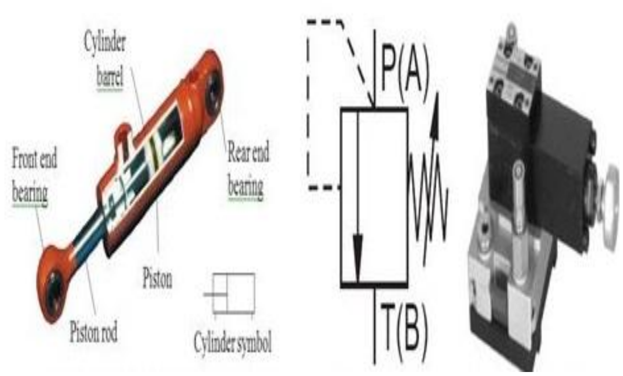
3.1 Components used for Pipe Bending Machine

3.1.1 Double Acting Cylinder

A double-acting cylinder is a cylinder in which the working fluid acts alternately on both sides of the piston. It has a port at each end, supplied with hydraulic fluid for both the retraction and extension of the piston. “Figure 5” shows the Double Acting Cylinder.

3.1.2 Pressure Relief Valve

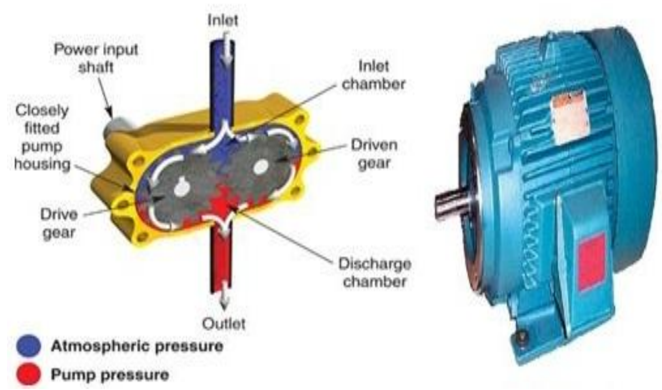
The relief valve (RV) is a type of valve used to control or limit the pressure in a system or vessel which can build up by a process upset, instrument or equipment failure, or fire. The pressure is relieved by allowing the pressurized fluid to flow from an auxiliary passage out of the system. “Figure 5” shows the Pressure Relief Valve.



“Figure 5. Hydraulic Cylinder and Pressure Relief Valve”

3.1.3 Hydraulic Pump

Hydraulic pumps are used in hydraulic drive system and can be hydrostatic or hydrodynamic. **Gear pumps** (fixed displacement) having swept volume for hydraulics will be between bout 1 cm^3 (0.001 litre) and 200 cm^3 (0.2 litre). “Figure 6” shows the Gear type Hydraulic Pump.



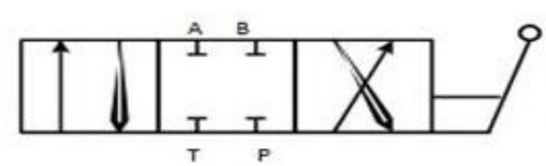
“Figure 6. Hydraulic Pump and Motor”

3.1.4 Hydraulic Motor

A hydraulic motor is a mechanical actuator that converts hydraulic pressure and flow into torque and angular displacement (rotation). The hydraulic motor is the rotary counterpart of the cylinder. A gear motor (external gear) consists of two gears, the driven gear (attached to the output shaft by way of a key, etc.) and the idler gear. “Figure 6” shows the Hydraulic motor.

3.1.5 Manually Operating 4/3 Directional Control Valve (DCV)

Directional control valves they allow fluid flow into different paths from one or more sources. **Manually operated valves** work with simple levers or paddles where the operator applies force to operate the valve. A **hydraulically operated 4/3 DCV** works at much higher pressure. “Figure 7” shows the Manually operated 4/3 Directional control valves.



“Figure 7. Manually Operating DCV”

3.2 Overall View of Mobile Hydraulic Pipe Bending Machine

"Figure 8" shows the Overall View of Mobile Hydraulic Pipe Bending Machine

"Figure 8. Layout of Mobile Hydraulic Pipe Bending Machine "

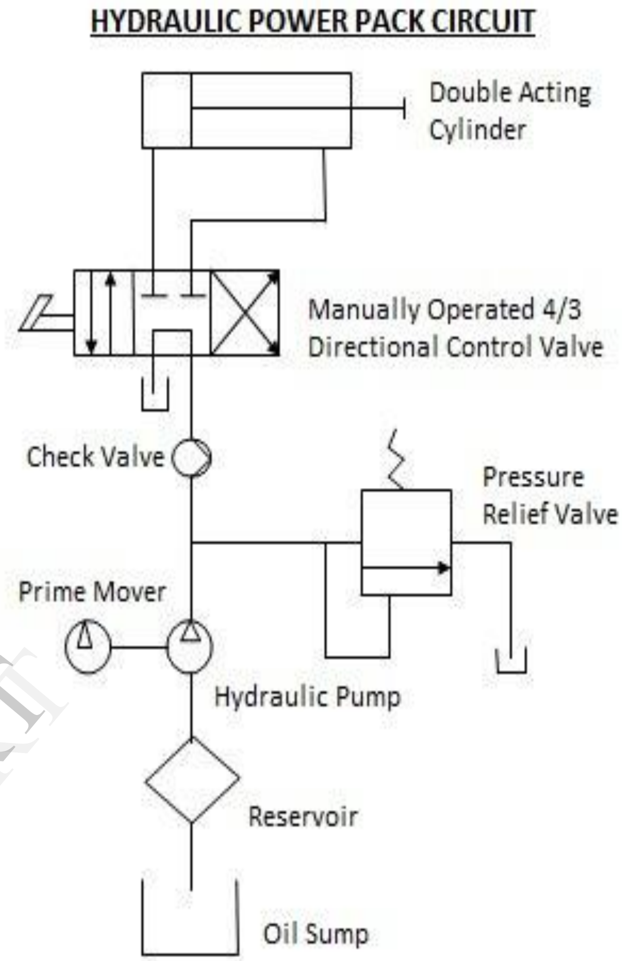
4. Working, Assembly and Design

4.1 Working

4.1.1 Hydraulic Power Pack

Hydraulic Power Units are the main driving components of hydraulic systems. Consistently mainly of a motor, a reservoir and a hydraulic pump, these units can generate a tremendous amount of power to drive most any kind of hydraulic ram. Hydraulic Power Units are based on Pascal's law of physics, drawing their power from ratios of area and pressure. "Figure 9" shows the Mobile Hydraulic Pipe Bending Machine- Power Pack Circuit.

4.1.2 Hydraulic Power Pack Circuit



"Figure 9. Hydraulic Power Pack Circuit"

4.2 Assembly

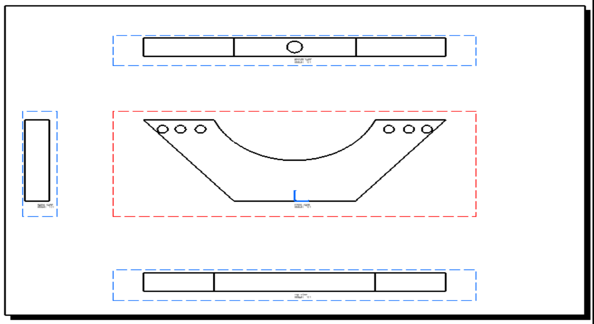
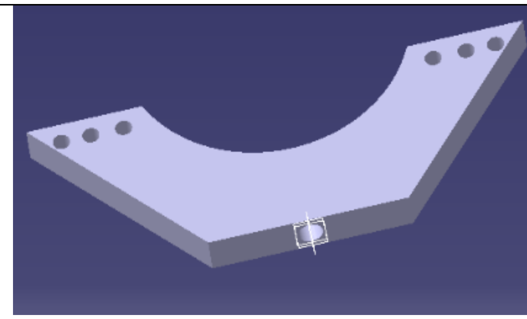
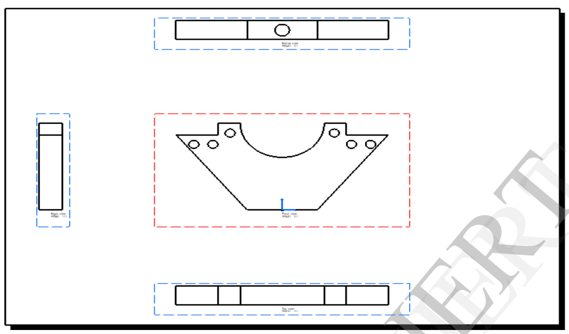
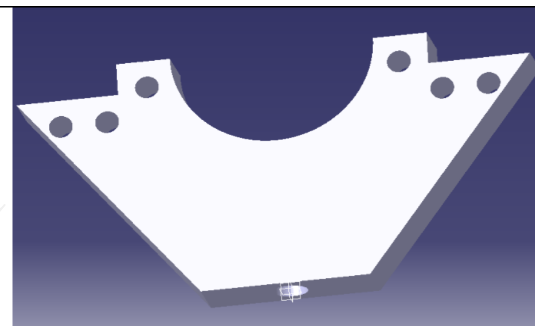
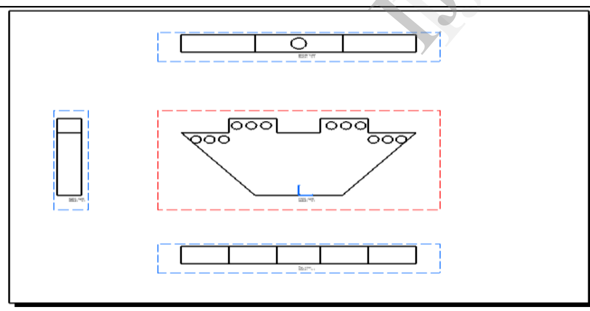
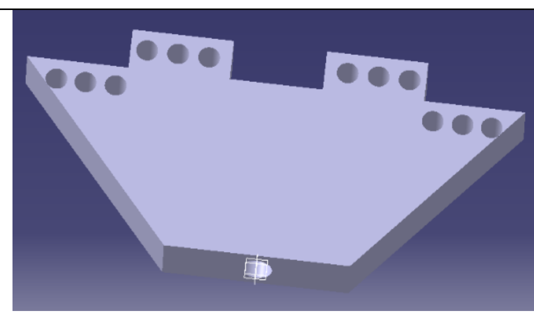
Assembly of Profiles with Cylinder,

Assembly of the lower plate: First turn over the cylinder and remove the hex bolts on the base of the cylinder. Align the holes of the lower plate with the holes of the cylinder base, and affix with the hex bolts taken from the cylinder base.

Assembly of the upper plate: When the lower plate is assembled, turn the cylinder over and insert swaging blocks in the hole of the lower plate. Place the upper plate over the swaging blocks and use the die cover shaft to secure the swaging block and the back oil cylinder seat.

4.3 Design

Software : CATIA V5

Profile	2D View	3D View
1.		
2.		
3.		

Profile Cuttings

"Table 1. shows the Profile cutting in 2D and 3D views"

Table 1. Profile Modules

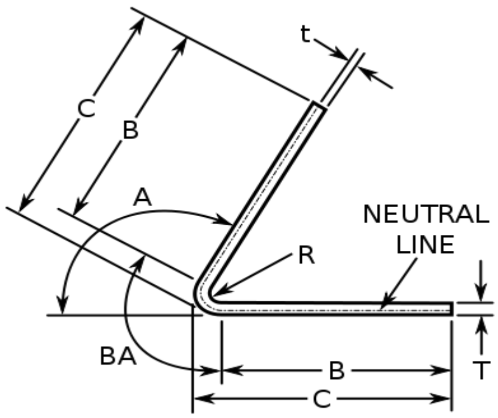
5. Calculation

5.1 Bend Allowance

The bend allowance (BA) is the length of the arc of the neutral line between the tangent points of a bend in any material. Adding the length of each flange taken between the center of the radius to the BA gives the Flat Pattern length. This bend allowance formula is used to determine the flat pattern length when a bend is dimensioned from 1) the center of the radius, 2) a tangent point of te radius or 3) the outside tangent point of the radius on an acute angle bend [4]. "Figure 10" shows thhe Bending Allowance diagram.

The BA can be calculated using the following formula:

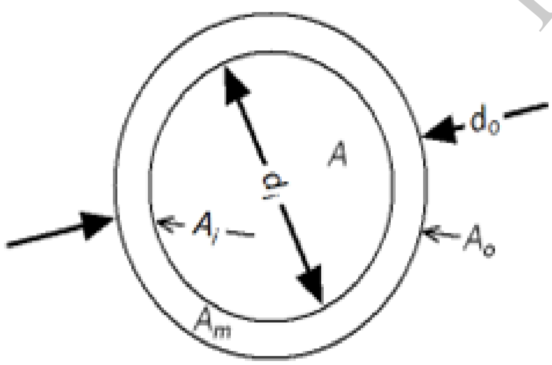
$$BA = A\left(\frac{\pi}{180}\right)(R + K \times T)$$



"Figure 10. Bending Allowance"

Where, t = distance from inside face to the neutral line [3], A = bend angle in degrees (the angle through which the material is bent), T = material thickness, R = inside bend radius, BA = bend allowance, K = K-Factor, which is t / T.

5.2 Cross Sectional Area



"Figure 11. Cross Sectional Area of a Pipe"

"Figure 11" shows the Cross Sectional Area and other Calculations diagram.

1. Cross-sectional Area of a Steel Pipe can be calculated as $A = 0.785\ di^2$
2. Moment of inertia can be expressed as $I = 0.0491\ (do^4 - di^4)$
3. Outside surface area of steel pipes can be calculated as $Ao = 0.2618\ do$
4. Area of the metal can be calculated as $Am = 0.785\ (do^2 - di^2)$
5. Section modulus can be expressed as $Z = 0.0982\ (do^4 - di^4) / do$

Where, Am = area of the metal (Square inches), A = cross-sectional area of pipe (Square Inches), Ao = outside area of pipe - per foot (Square Feet), I = moment of inertia (inches), do = outside diameter (inches), di = inside diameter (inches), Z = section modulus (inches).

6. Conclusion

The current urgent demands for high efficiency and precision production are vitally related to the accurate prediction and effective controlling of the various failures or instabilities in pipe bending. This depends on the insight into the occurring mechanisms and influences rules of different defects or instabilities. Thus, advances on the studies of these common topics in pipe bending are summarized including wrinkling instability, wall thinning (cracking), spring back phenomenon, cross-section deformation and process/tooling design/optimization. With the increasing needs for better performance, the more complex three-dimensional spatial tubular bent components with more lightweight materials are required. These components are characterized with the thin wall thickness, large diameter, small bending radius, and the tubular materials are generally hard to- deform ones with limited ductility and high strength.

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Reference

1. M.S.J. Hashmi, "Aspects of tube and pipe manufacturing processes: Meter to nanometer diameter" *Journal of Materials Processing Technology*; Vol. 179, No. 1-3, pp. 5-10, 2006.
2. How to Calculate Bend Allowance for Your Press Brake, archived from the original on 2010-02-24, retrieved 2010-02-24.
3. http://www.ciri.org.nz/bendworks/bending.pdf

4. Li Heng, and Yang He, "A Study on Multi-defect Constrained Bendability of Thin-walled Tube NC Bending Under Different Clearance", Chinese Journal of Aeronautics, Vol. 24, pp. 102-112, 2011.
5. G.H. Lim, P.S.K. Chua, Y.B. He, "Modern water hydraulics—the new energy-transmission technology in fluid power", Elsevier, Vol. 76, No. 1-3, pp. 239-246, 2003.
6. Manufacturing Processes Reference Guide, Industrial Press Inc., 1994.
7. D. Merkle, B. Schrader, and M. Thomes, *Hydraulics Basic Level*', Edition: 2nd, revised edition 1, 1998.
8. Peter Nachtwey, 'Fluid Power Basics', Delta Computer Systems, Inc., 2009.
9. Todd, H. Robert, Allen, K. Dell, Alting, Leo, *Manufacturing Processes Reference Guide (1st ed.)*, Industrial Press Inc., ISBN 0-8311-3049-0, 1994.
10. H. Yang, Z. C. Sun, Y. Lin, "Advanced plastic processing technology and research progress on tube forming", Journal of Plasticity Engineering; Vol. 8, No. 2, pp. 83-85, 2001.