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DEVELOPMENT OF CNC BENDING MACHINE USING PARALLEL KINEMATICS MECHANISM

Ken ICHIRYU, Zenkoh YAMAGUCHI and KOGA
Faculty of Engineering
Tokyo University of Engineering
1404-1 Katakura-cho, Hachiohji-shi, Tokyo, Japan
(E-mail: zenkou@ichry.mech.teu.ac.jp)

ABSTRACT

Recently, aluminum pipe is needed by industrial world. Because it is high rigidity and light. There are many methods of processing pipe. But now bending method is ill-suited to high-mix low-volume production. And so we looked at the feed pressure (MOS) bending machines. But there are many problems in them. First of all, structure of processing part is complex, and object of bending is confirmed to circular pipe. We developed three dimensional pipe bending machine using PKM (parallel kinematics mechanism). In this paper, we will be able to show bending accuracy and proposal of new bending machine.

KEY WORDS

Parallel kinematics mechanism, Gradual curve part, Bending angle, Limit of bending,

NOMENCLATURE

R : Bending radius
u : Offset
V : Distance between dies
P_L : Pushing load
? : Angle of die
t : twisting rate
L_v : Length of work of distance between dies
$?_b$: bending angle

BACKGROUND

Recently, industry requires different production method best fitted for its purpose. Same situation is observed in bending manufacturing field. As conventional bending method, there are press bending, tension bending. Above methods require own dies according to their profiles. Therefore, these methods are difficult to apply for modern small number production. In order to solve this problem, push forward bending method (MOS bending method) was proposed, recently. In MOS bending method, any assigned bending profile is possible to make by using two dies. Work is driven by feeder and it is bent by two dies combination. By this MOS bending method, die cost reduction becomes possible, because there is no need to make die corresponding to bending radius. Also, three dimensional profile bending becomes possible

PRESENT MOS BENDING MACHINE

Let explain about present MOS bending machine. Structure of bending head is simple in the machine shown in Fig.1. But sectional working profile is limited to circular, due to deficiency of freedom of bending head motion. By conventional machine to achieve universal profile bending, bending head becomes complicated, as shown in Fig2.

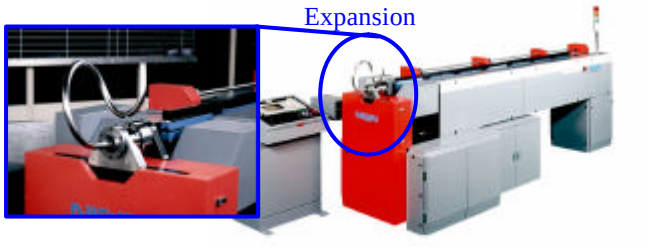


Figure 1 MOS bending machine example1

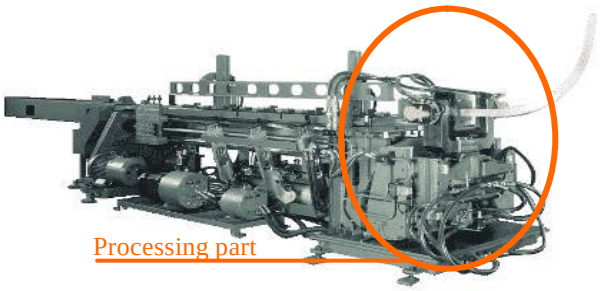


Figure 2 MOS bending machine example2

To solve this problem, we proposed new MOS bending machine using 6-axis parallel kinematics mechanism (PKM). Feature of PKM is high accuracy, high rigidity and simple structure. By using P KM as bending head, new universal compact machine is expected to realize.

PURPOSE

Purpose of this research is to develop MOS bending machine using 6-axis PKM working head. In this time, we announce effect of bending parameter on shape and quality.

PROPOSED BENDING MACHINE

In Fig.3, overall view of testing machine is shown. The machine is composed of working head and feeder, and controlled by simultaneous 7-axis motion controller.

Working head

Working head, driving part of movable die shown in Fig3, is composed of 6-axis extensible type PKM. Working head is controlled by 6 actuators semi-closed loop positioning.. Movable die is installed at the center of the end effecter. Fixed die is positioned at the center of foundation on base plate.

Feeder

Feeder, shown in Fig.3, is composed of electric motor and ball screw and guide rail supporting member. Guide rail prevents buckling of the work between guide die and pusher. Feeding actuator control is same with PKM actuator control.

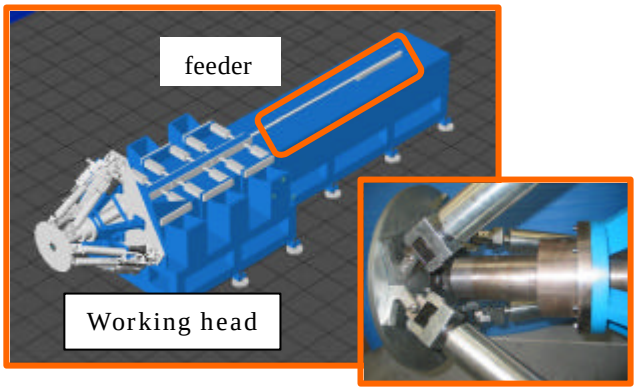
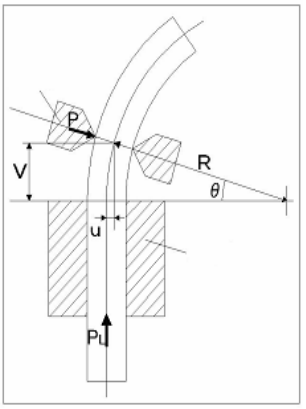


Figure 3 Proposal MOS bending machine

PRINCIPLE OF BENDING

Principle of simple bending

Principle of simple bending follows the MOS bending method. MOS principle is shown in Fig.4. Here, state of bending is schematically shown. Movable die is displaced U from the center of the **fixed** die axis. Here, there are two forces acting on this system, that is, pushing load PL and working load P which depends on offset u. Bending moment M=P×V is main factor of bending action, where V is distance of both dies. Each parameter is presented in the following.



$$u = R - \sqrt{u^2 - V^2} \quad (1)$$

$$q = \sin^{-1}\frac{V}{R} \quad (2)$$

Figure 4 simple bending

Principle of twist bending

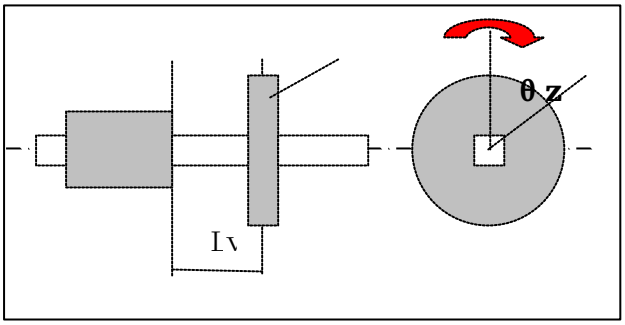


Figure 5 Principle of twist bending

Movable die is twisted by ?z. Twist bending moment $M_L = L_v \times P$ is main factor of twisting action.
Twisting rate is presented in the following.

$$t = \frac{q_z}{L_v} \tag{4}$$

Principle of spiral bending

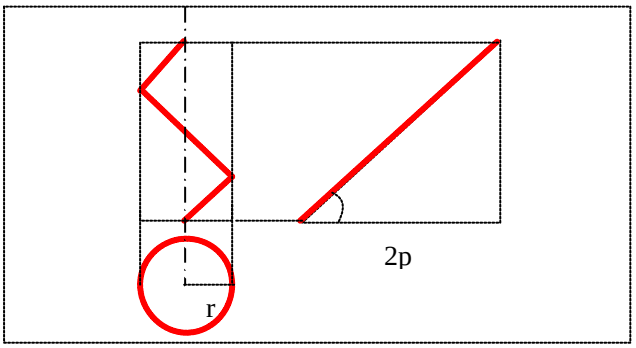


Figure6 Principle of spiral bending

Spiral bending can be achieved by the synthesis of simple bending and twist bending.
Spiral bending parameter is presented in the flowing. Steady-state spiral can be constructed with spiral pitch and spiral radius. Therefore, steady-state spiral is expressible by Frenet-serret formula.

$$r = \frac{k}{t^2 + k^2} \tag{5}$$

$$P = 2p\sqrt{r \cdot (\frac{1}{k} - r)} \tag{6}$$

Therefore, spiral bending is achieved by twist rate and curvature. Various spiral bending is achieved to replace twist rate and curvature by twist bending factor and simple bending factor.

PROGRESS IN DEVELOPMENT

Recently, we confirmed factor of simple, twist and spiral bending[1]. Bending angle of products and improvement of processing limit are researched.

Bending angle of products

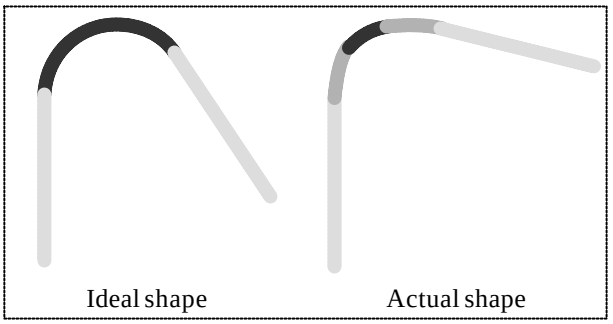


Figure7 Ideal and actual shape of pipe

Ideal shape is composed by straight part and defined curve. But It actually becomes as shown in Fig 7. It is because PKM is moved while the material is being pushed. As a result, the error margin is caused between the ideal value and the actual value. And a high accurate processing is impossible. And so, we tried to cut off gradual curve part. It is necessary to bring movable die close to fix die to that end. And, distance of gradual curve is shorten. In the experiment, we confirmed effect of distance of gradual curve part on bending angle.

Improvement of processing limit

Processing limit is related to V and u. But it is difficult to keep V and lengthen u. Because feature of PKM is which working area is narrow. And V is shorten like case2 of fig 8. Now, therefore, bending parameter is smaller[2]. V is related to bending shape as outline above.

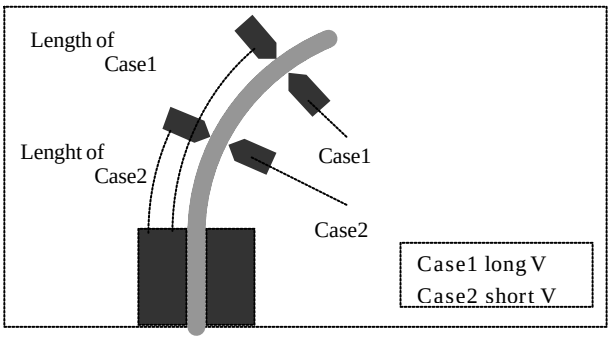


Figure 8 Effect of V on bending parameter

BENDING EXPERIMENT 1

Experiment purpose

This experiment purpose is to confirm the effect of Length of gradual curve part on bending angle.

Experiment procedure

Length of gradual curve part is shortened by 20 [mm] step from 100[mm]. And then, we measure bending angle.

Experiment result

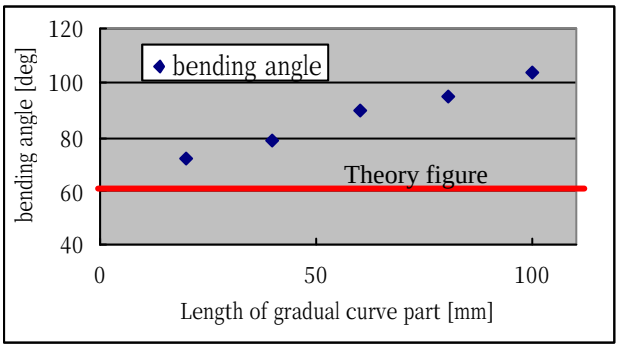


Figure9 Effect of L_g on $?_b$

As a result, gradual curve part is related to bending angle. And, if gradual curve part is loss, process of actual shape cannot be achieved. Therefore, it is necessary to propose new motion of movable die.

BENDING EXPERIMENT 2

Experiment purpose

This experiment purpose is to confirm the effect of distance between dies on shape of processing pipe.

Experiment procedure

Distance between dies is shortened by 35[mm] and 45[mm].

Experiment result

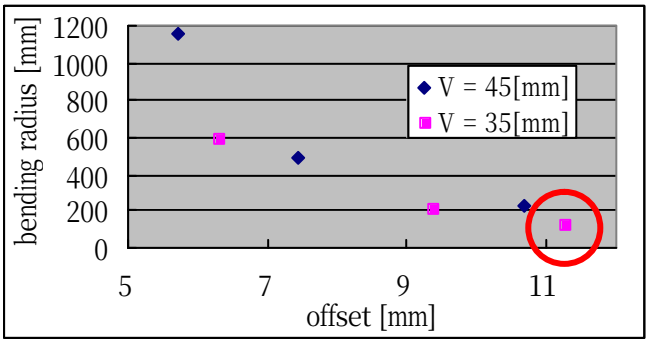


Figure 10 Effect of V on R

As a result, improvement of bending shapes was achieved by reduction of distance between dies. But, when movable die got up fix die, bending quality was poor. And, when offset is short, bending angle is large because of springback. And so, we will define appropriate balance between bending parameter and bending quality in future experiment.

SUMMARY

In this paper, we announced effect bending parameter on bending shape and quality. In the future, we construct new motion of movable die and new structure machine. For example, PKM is installed in vertical position. And this machine is miniaturized and made high power by using the hydraulic cylinder for actuator.

REFERENCE

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