EXTRUSION WITH CHANGING CROSS SECTION SHAPE OF TUBE

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ABSTRACT Demand for reducing industrial parts' weight will increase more and more in the future. Therefore, Aluminum tubes which are formed by extrusion are used for railway vehicle frame. But the shape and area of the cross section are constant now. If the shape of the tube would be changed corresponding to the magnitude of the actual load, the use of the tube can increase in many industrial fields. Therefore, the authors have designated and built a CNC extrusion prototype machine which can produce a changeable shaped tube. The extrusion force, the accuracy of the cross section and the distribution are experimentally examined. The characteristics of the CNC prototype extrusion machine and the changeable shape extrusion are made clear.

Keywords: ***metal forming, extrusion,***

1. INTRODUCTION

Circular and other various shaped tubes have high flexural rigidity and torsional rigidity as compared with their weight, therefore, tube consumption is increasing for many products and the weight of industrial parts is reduced. The shaped aluminum tube, which is formed by extrusion, is used not only in building frames but also railway vehicle frames for example the Shinkansen vehicle. The shaped aluminum tube will be used for automobile frames such as space frames, as automobile manufacturing companies are researching and developing to them for use in automobile frames, when the shaped frames are employed for automobile frames, it is useful for the shape of the cross section of the frames to be changed to reduced their weight. But the shape and area of the cross section are constant now. The shape of the cross section must be changed and manufactured in proportion to the magnitude of the moment which will act on the frame.

If the shape of the frame's cross section would be optionally changed corresponding to the magnitude of the actual load, the aluminum shape frames could will be used for various purposes such as the building, automobile and railway vehicle fields. Therefore, the CNC (Computer Numerical Control) extrusion prototype machine, which can change optionally the shape of the frame cross section, has been designed and built up by the authors. The tubes are made by the extrusion machine using the flouting mandrel method, and the extrusion force, the accuracy of the cross section and strain distribution are experimentally examined for the influence of the extrusion conditions, when the changeable outside shape of the frames are produced as a trial extrusion.

2. FUNCTION OF CNC EXTRUSION MACHINE

The main parts and functions of the prototype CNC extrusion machine are explained as follows; The extrusion machine is different from the conventional extrusion machine, as the dies can be controlled and moved as shown in Figure1. When the changeable shapes of the cross section are produced, the action of dies moving and the extrusion are carried out and repeated in a small section as shown in Figure2 after upsetting. Figure3 shows the movement and control parts of the extrusion machine. The positions of the dies and the punch are measured by the rotary encoders which exist in oil-pressure cylinders. After the positions are taken in the personal computer through the encoder counter and the computer checks the error between the setting position and actual position, the computer outputs the direction and speed signals through the A/D converter and can control the dies and punch positions. The computer can check the extrusion load through the A/D converter, from the load cell which exists at top of the punch cylinder.

Not only the shape of the cross section but also the length of the extrusion direction have been correctly controlled by the CNC extrusion machine, but the length of the extrusion direction is not directly measured. As both the billet volume before the extrusion and the volume after extrusion are calculated, and the relationship with the extrusion billet volume = the extrusion formed volume can be made up as shown in Figure4, the length of the extrusion direction can be indirectly calculated from the relationship between the position of the extrusion punch and the moving length of the punch. The billet workpiece is pure lead (JIS; Japanese Industrial Standard H2105) and the dimensions are the length =150mm, the height =20.8mm and the width =19.8mm. The workpiece is divided as two pieces and the ross

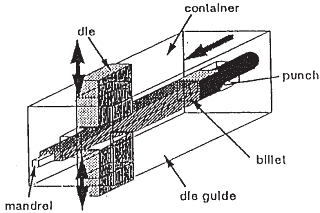

Fig.1 Extrusion principle of changeable cross section

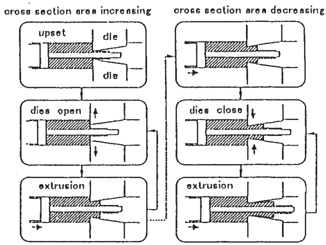

Fig.2 Model of extrusion process

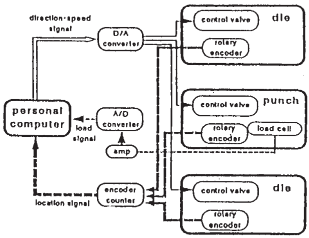

Fig.3 Measureing and control system

extrusion billet volime V_0 in = extrusion formed volume V_0 out

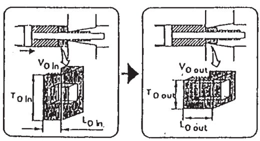

Fig.4 Estimation of extrusion length

points are written down on the inside of the pieces for measuring the strains as shown in Figure5. Molybdenite is employed in the experimental extrusion as the lubrication between the workpiece and the container or mandrel. Two kind mandrels are used and one cross section dimension (A) is 5.7mm×5.7mm and the another (B) is 7.7mm×7.7mm.

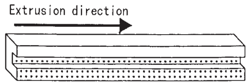

Fig. 5 Billet workpiece

3. EXPERIMENTS AND RESULTS

The extrusions are experimentally examined under the extrusion condition as shown in table1 in this report. The experimental extrusion are actually three types of extrusions; One has a constant cross section area with the outside dimensions T_0s= 11.0mm and 15.0mm. The other has an increasing cross section area with the outside dimensions at ending of extrusion T_0e = 15.0mm and 19.0mm. The another has a decreasing cross section area with the outside dimensions at beginning of extrusion T_0s = 15.0mm and 19.0mm.

3.1 Relationship between punch load and stroke.

The relationship between the punch load and the stroke of the extrusion are experimentally examined in three types extrusion, using A type mandrel as shown in Figure6. The starting point between the load and the stroke is the end of the upsetting. The extrusion loads become larger as the outside dimensions of extrusion become smaller in spite of the change in the cross section areas. The load decreases at constant cross section extrusion in the latter half extrusion process. Because, the friction between the container and the billet decreases. At cross section area increasing, the load decreases remarkably by reason of the

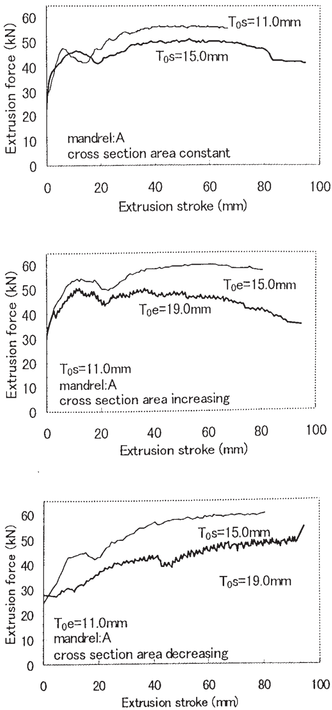

Fig6 Relationship between punch load and extrusion stroke

Table1 Extrusion condition

Hight change T_0e-T_0s (mm)	Starting hight T_0s (mm)	Ending hight T_0e (mm)	Mandrel	Forming step n (times)	Setting length L_0 (mm)
–	11.0	11.0	A	130	120
–	15.0	15.0	A	130	120
+4.0	11.0	15.0	A/B	80	120
+8.0	11.0	19.0	A/B	160	120
−4.0	15.0	11.0	A/B	80	120
−8.0	19.0	11.0	A/B	160	120

decrement of extrusion ratio. At cross section area decreasing, the load is increased from the beginning of the extrusion. The relationships between the load and stroke are made clear by the examination of three types extrusions.

3.2 Extrusion axial length and thickness

The cross section shapes are examined by measuring the typical positions as shown in Figure7, as the two types mandrels (A, B) are used at the extrusion. Figure8 shows the relationship between the extrusion axial length L and outside height T. The broken lines indicate the minimum permissible limits which were established for aluminum shaped tubes by JIS. The solid line indicates the setting values on the experimental extrusion. It is observed that the outside heights T_1 are smaller than the inside heights T_2 in Fig.8. The positions of the movable dies are checked and revived by measuring the height T_2 for which the values are taken from the constant area extrusion. Therefore, all values of T_2 are within the setting limit of JIS extrusion same as T_1. The extrusion can form the shaped tubes within the setting limits in spites of changes in cross section and thickness as shown in Fig.8.

Figure9 shows the relationship between the thickness t and the extrusion axial length L. All thickness values t are within the setting limits in spite of the dimensions of the mandrel

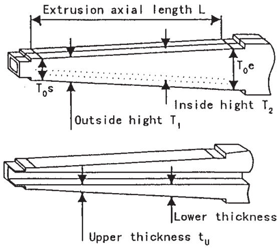

Fig. 7 Mesureing point of Formed tube

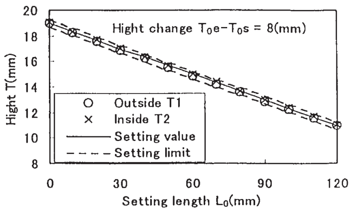

Fig.8 Relationship between setting length L_0 and height T

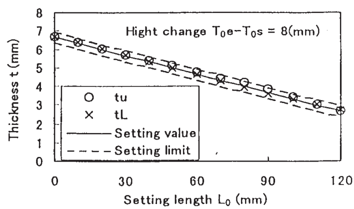

Fig.9 Relationship beween setting length L_0 and thickness t

and the change of the cross section. The extrusion axial length of the tube is taken from the relationship between the area of the cross section and the moving length of the punch. Therefore, the axial lengths are examined for the difference from the setting length as shown in Figure10. As the difference of outside dimensions between T_0c and T_0s become larger, the difference of extrusion length between the setting and actual values increases. As the extrusion is examined in Fig.2, the changeable extrusion shaped tubes are produced by repeating the very small movement of the punch and dies at the extrusion process. Therefore, the errors which occur each every stepof the at extrusion process, are saved up and the axial length difference is caused by the error saving. The extrusion steps are 80 or 160 at L_0 = 120mm as shown in Table 1. The error of 160 extrusion steps is larger than the error of 80 steps. But the error is little as shown in Fig.10.

3.3 Strain distribution

Figure11 shows the positions of strain measuringment. The strains are measured at the side wall and thickness direction of the extrusion tube as shown in Fig.11. The strain distributions are measured in the X (die moving

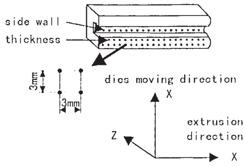

Fig. 11 Measuring point of extruded tube

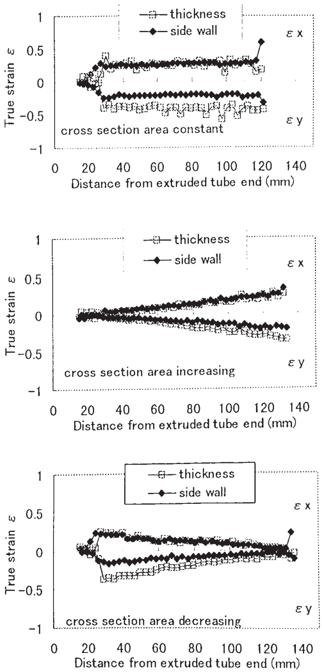

Fig.12 Strain distribution of extruded tube

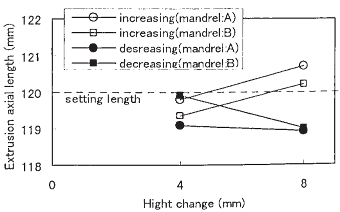

Fig10 Error of extrusion axial length

direction) and Y (extrusion direction) directions as shown in Figure12. When extrusion ratio is increasing or decreasing, the strain distributions change corresponding to the extrusion ratio. The sum of the X and Y axes strain is not equal to zero because the strain distribution is not plane strain state. Therefore the deformation in the Z direction which is vertical to X and Y directions, is caused at the extrusion. The above tendency is remarkable as corresponding to the increasing of the extrusion ratio and the strain distribution approaches the plane strain state at small extrusion ratio.

4 CONCLUSION

The new flexible prototype CNC extrusion machine has been built and the extrusion systems of the machine have been structured by the authors, and the extrusion of changeable cross section tube have been able to be manufactured. The possibility and characteristics of the extrusion are experimentally made clear by this study.

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