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DIE DESIGN FOR REDUCING TUBE OUTSIDE DIAMETER BY COLD PRESS AND MECHANISM OF THINNING AND BENDING PHENOMENA

Masayoshi Akiyama*, Tatsuya Okui* and Kouichi Kuroda*

*†Sumitomo Metal Industries, Ltd.
Fuso-cho 1-8, Amagasaki, Hyogo, 660-0891, Japan
e-mail:akiyama-msy@sumitomometals.co.jp, Okui-tty@sumitomometals.co.jp, Kuroda-kui@sumitomometals.co.jp, web page: http://www.sumitomometals.co.jp

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Summary. *Outside diameter of tube becomes smaller than the inside diameter of die when a steel tube is reduced by cold press through a die with conventional geometry, and a reduced tube with smaller outside diameter is often accompanied by a bending phenomenon in the axial direction. Estimation of mechanism through which this phenomenon appears was investigated by elastic-plastic FEM and laboratory experiment. The key to the suppression of this phenomenon was a new geometrical design of die. The new design was determined by carrying out numerical analysis and laboratory experiment was carried out to verify the predicted effect of the new die design.*

1 INTRODUCTION

Round hollow parts having changing diameter in the axial direction are widely used for automobiles. One of the simple methods for manufacturing these parts is a cold reduction of tube outside diameter through a die by using a press machine. However, the reduced portion of tube manufactured through this method is not necessarily straight [1], and this bending phenomenon causes problems in the following processing process of reduced parts. Although this method is simple and good for installing in a manufacturing line, occurrence of bending phenomenon must be suppressed prior to the installation.

The first thing to do is clarifying the mechanism through which this bending phenomenon appears. For this purpose, elastic-plastic finite element analysis was carried out to estimate the phenomenon occurring on a tube in the die, and a series of laboratory experiments was carried out to check the validity of the numerical analysis. The code used for the numerical analysis was ELFEN [2], and the discrepancy between the outside diameter of reduced tube and the inside diameter of die was predicted. The intensity of this predicted discrepancy was checked by the experimental data, and the mechanism of bending phenomenon was estimated.

Taking this result into consideration, a die having a new geometry was designed in order to suppress this discrepancy to the least minimum. Laboratory experiment using this new die showed that both the discrepancy and bending phenomenon disappears when it is used.

2 PHENOMENON AND MECHANISM

The material is a typical carbon steel and the parent tube is reduced its outside diameter by being pressed through a die using a press. The overview of experiment and an example of reduced tube is shown in Fig 1. The original tube was processed by machining and the parent tube was perfectly straight in the axial direction, but a clear bending phenomenon is observed on the reduced tube. All the experimental results showed that the thin portion in the circumferential direction was always lies on the outside portion of the bent tube. The estimated mechanism of bending is illustrated in Fig. 2.

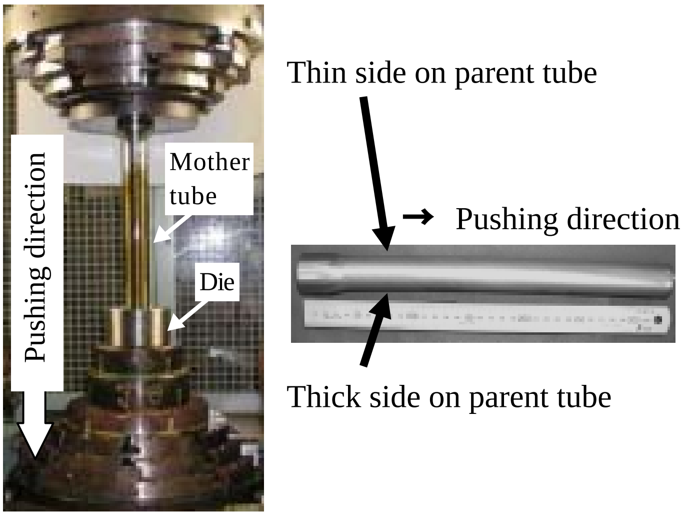


Fig. 1 Overview of experiment and example of bending phenomenon of reduced tube

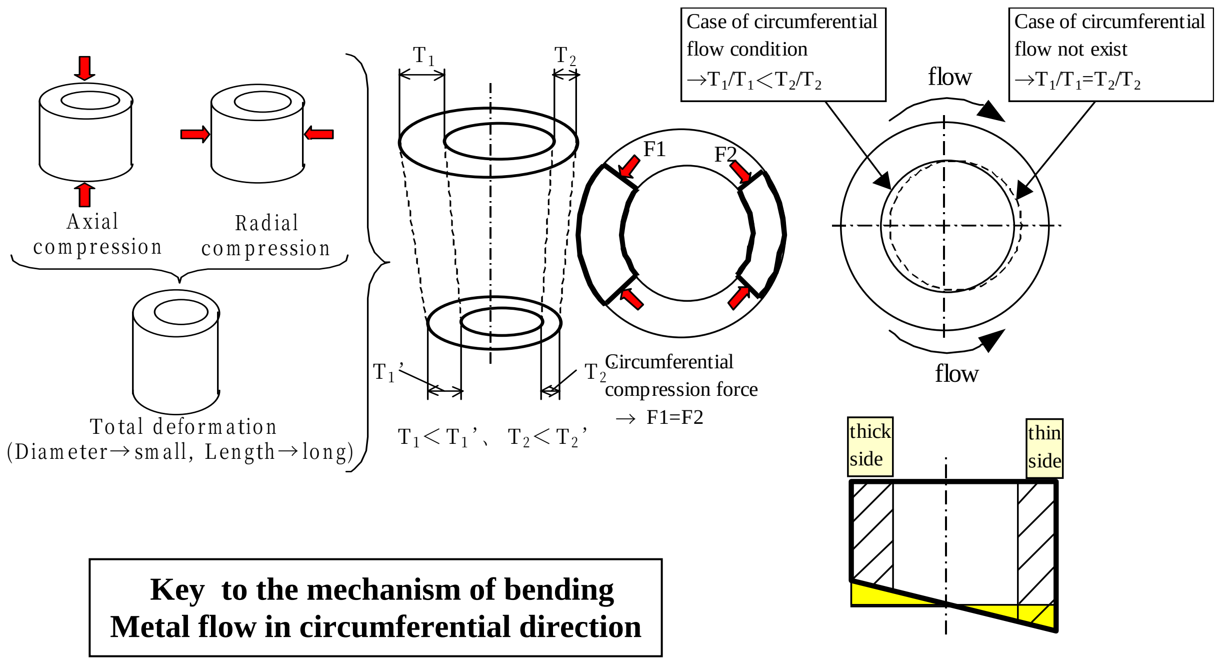


Fig. 2 Assumed mechanism of bending phenomenon

3 INITIATION OF BENDING

Axi-symmetric elastic-plastic FEA was carried out to estimate numerically the mechanism of bending. The code was ELFEN developed at University of Wales Swansea. The used die was a simple single-taper die and Coulomb friction rule was assumed on the contac surface between the inside surface of die and the outside surface of tube.

An example of results is shown in Fig. 3. It is curious to note that the outside surface of reduced tube is not in contact with the bearing portion of the die. The authors put a name to this phenomenon “undershooting”. It was assumed that due to this undershooting the constraint of tube outside surface in the radial direction became unstable and it lead to the bending phenomenon.

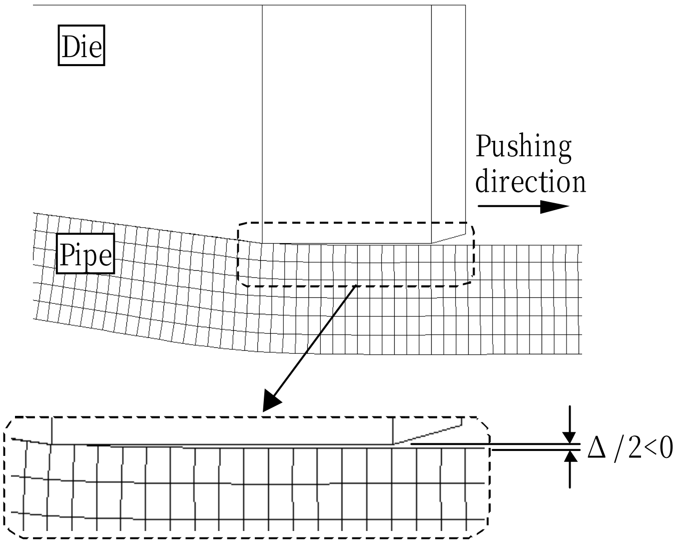


Fig. 3 Undershooting phenomenon of reduced tube

In order to prevent this undershooting phenomenon from occurring, a double-taper die of which geometry and image are given in Table 1 and in Fig. 4 was adopted. The second taper is taken very small so that the reduced tube smoothly contacts the bearing portion of die. The effect is shown in Fig. 5. It is clear that double taper die suppresses undershooting.

Table 1 Geometry of double taper die

Die angle θ_1 °	15
Die angle θ_2 °	2
Inside diameter D_d'mm	32.55
Inside diameter D_d mm	31.90
No2 zone length	18.6
Bearing length B mm	3.5, 10.5, 20.0, 30.0

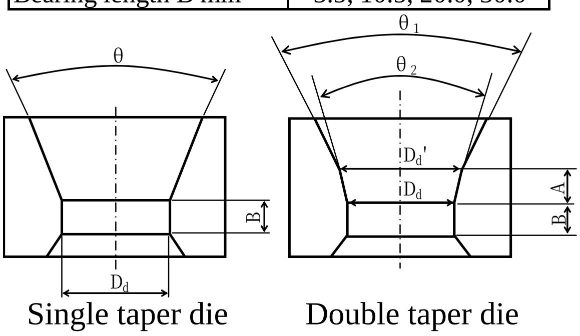


Fig. 4 Comparison of die geometry

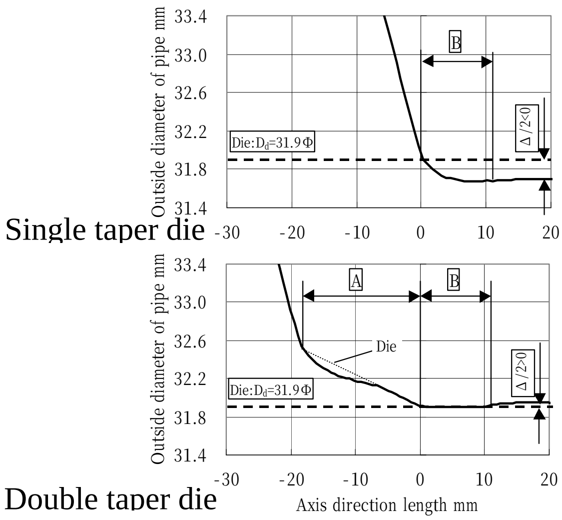
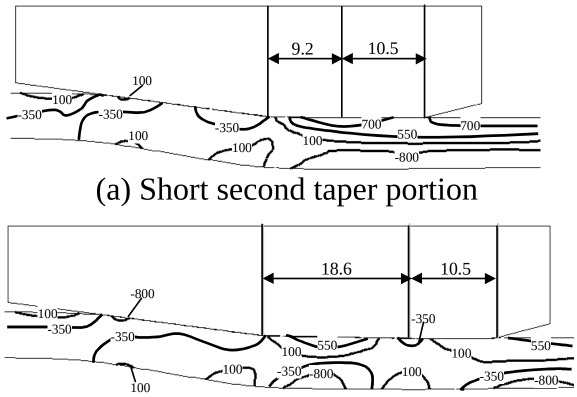


Fig. 5 Effect of new die geometry

Fig. 6 shows the influence of the length of the second taper portion on the distribution of axial stress during cold press. It is shown that milder distribution of axial stress is observed for the case of longer second taper portion, i.e. for the case of the second taper portion with 18.6mm. Milder stress distribution suggests smoother contact of tube outside surface on the inside surface of die, especially on the bearing portion.

Influences of the length of second taper portion and length of bearing portion on the intensity of bending are shown in Fig. 7. It is clearly shown that adoption of longer second taper portion and longer bearing length prevent the bending phenomenon from occurring.



(a) Short second taper portion

(b) Long second taper portion

Fig. 6 Influence of die geometry on axial stress

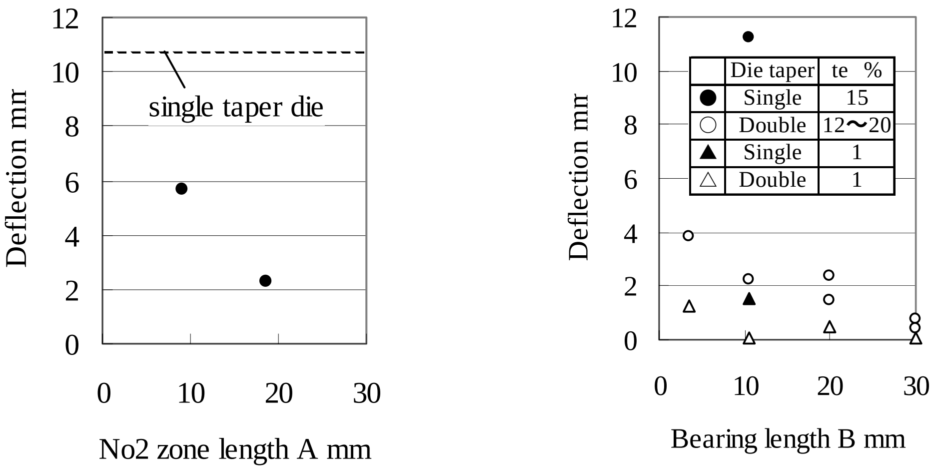


Fig. 7 Influences of second taper portion length A and bearing length B on bending

4 CONCLUSIONS

Bending phenomenon occurring on a tube cold-reduced in its outside diameter through a die was investigated. There is a strong correlation between the eccentricity of parent tube and the direction of bending, as thin portion elongates more than thick portion . A double-taper die was proposed and the effect was demonstrated for the prevention of bending phenomenon.

REFERENCES

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