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TOOL DESIGN FOR SUPPRESSING FRACTURE AT THE TIP OF TUBE AFTER NOSING WITH DIE

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Summary. *The tool design concept is proposed for the suppression of the fractures at the inner surface of the nosed tube with a parallel portion, using finite element analysis. By the preliminary experiment and analysis, it is inferred that the main cause of fracture is the hoop stress during the process. A series of analyses was carried out for designing the tool geometry so as to reduce the hoop stress.*

1 INTRODUCTION

Nosing is a common metal forming process to manufacture tubes with a nosed portion. The nosed tubes are used as various parts, such as air bags and guides for shafts in automobiles. The suppression of defects on the surface and inside the products is one of the main concerns as well as the dimensional accuracy. The defects like fractures or wrinkles would cause the strength of products and the product life to deteriorate.

There are many research projects to carry out tool design using analysis so as to realise the desired final geometries[1]. Some research is also carried out for the suppression of defects in products by metal forming processes[2, 3]. Concerning tube nosing, fundamental studies on strain and forming limit are carried out experimentally and numerically[4, 5].

In the present paper, the tool design is carried out to suppress the fracture inside the surface of the nosed tube, focusing upon a transient phenomenon, which is unique to nosing of a tube with a parallel portion at the tip. By the preliminary experiment and analysis, it is inferred that the main cause of fracture is the hoop stress during the process. A series of analyses was carried out for designing the tool geometry so as to reduce the hoop stress.

2 INFLUENCE OF PARALELL PORTION ON FRACTRURE

An ordinary manufacturing process is shown in **Fig. 1**. A tube produced by a hot working process is supplied to a production line. The tube is subjected to pickling and machining so as to improve the surface integrity and precision before and after the metal forming process, i.e. drawing and nosing. Heat treatments are also carried out in order to secure the formability of tube and release residual stresses. The tube is drawn to a specified diameter before the nosing. The nosed tube is machined into the final geometry.

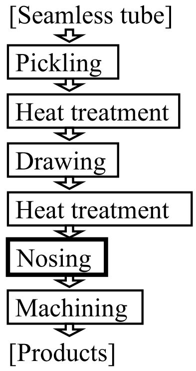
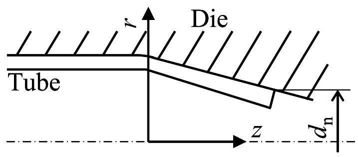


Fig. 1 Manufacturing process for nosed tube

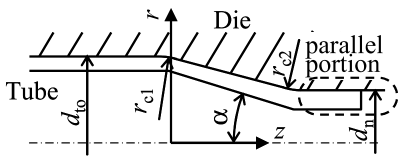
In the present paper, the target shape of the product is the nosed tube with the parallel portion. **Figure 2** shows the geometry of tubes without and with the parallel portion. With the knowledge from experience at the actual operation line, it was known that more fractures tend to occur for the nosed tube with the parallel portion than that without parallel portion qualitatively.

In order to clarify the influence of the parallel portion, a laboratory experiment was carried out under the condition shown in **Table 1** using medium carbon steel.

After nosing, wrinkles and fractures are counted for the whole circumferential direction at the cross-section vertical to the tube axis, changing the position along the axis. The defect of either wrinkles or fracture is defined as ditches with the depth more than 25 μm.



(a) Without parallel portion



(b) With parallel portion

Fig. 2 Geometry for nosing

The experimental results are shown in **Fig.3**. The larger the z value, i.e. the larger the outer diameter reduction, the more often the incidence of defects were observed. It is noteworthy that the existence of parallel portion accelerates the generation of wrinkle or fracture. The fractures with a deep edge were observed for the nosed tube with the parallel portion.

3 MECHANISM OF FRACTURE OCCURENCE

It is quite strange that the parallel part has some effect on the incidence of defects, even though the outer diameter reduction is almost the same to both the nosed tubes with and without the parallel portion. As it would be difficult to establish the cause experimentally, finite element analysis was carried out in order to clarify the mechanism. The commercial code ELFEN, which was developed by Rockfield Software Limited at

Die	Half angle α (degree) Nosed diameter d_n (mm) Corner radius at inlet of approach r_{c1} (mm) Approach radius r_{c2} (mm)	10 25 5 5
Tube	Outer diameter d_{to} (mm) Thickness t (mm)	40 3.5

Table 1 : Standard conditions for nosing

the University of Wales, Swansea was used.

The Coulomb friction rule was adopted and the friction coefficient was chosen as 0.05. This value was determined so that the analytical and experimental results have a good agreement concerning the deformed geometry.

Figure 4 shows the influence of parallel portion on the hoop stress. The hoop stress is very high at the tip of the tube as denoted by "A". Although the hoop stress at the boundary between the approach and the bearing is low at the end of nosing as denoted by "B", the stress rises acutely during the springback as denoted by "B*". These hoop stresses are much higher than those for tube without the parallel portion.

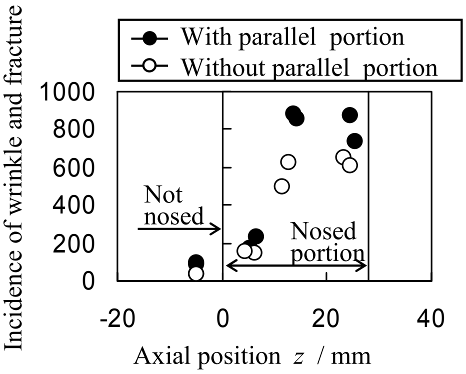


Fig. 3 Influence of parallel portion on the incidence of wrinkle and fracture (Experiment)

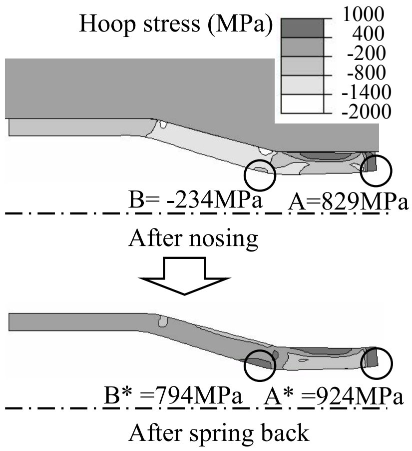


Fig. 4 Influence of parallel portion on hoop stress distribution

As the hoop stress is higher at the tip of tube "A" than at the boundary "B", the mechanism of the stress increase at "A" is studied numerically. **Figure 5** shows the axial position of the tube tip "A" according to the nosing progress. One of the characteristics is that the tip of the tube undershoots once, as A_1->A_2, and expands, as A_2->A_3 in the following movement. During this expansion *h*, the hoop stress rises. Hence it is necessary to reduce the undershooting and expansion *h* for suppression of the hoop stress.

4 TOOL DESIGN FOR SUPPRESSION OF FRACTURE

Two concepts of tool design are proposed for the suppression of the hoop stress by reducing the radial undershoot and expansion *h* of the tip of the tube. One is setting a plug inside. The other is applying large approach radius r_{c2} at the boundary between the approach and the bearing.

The plug is expected to constrict the movement of the inner surface of the tube so as to reduce the undershooting and expansion *h*. An example of the analytical result is shown in **Fig. 6**. Although the hoop stress at the tip "A" is drastically reduced as expected, it is still high at the boundary between approach and the bearing "B*".

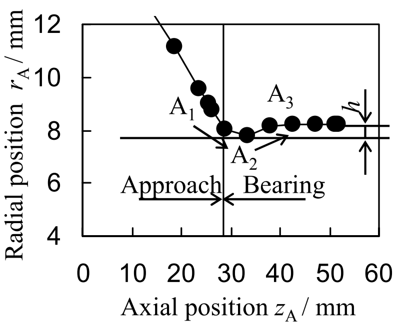


Fig. 5 Position change at the inner surface of tip during nosing

The large approach radius is expected to change the metal flow direction gradually so as to reduce the undershooting and expansion *h*. An example of analytical result is shown in Fig. 7. The hoop stress is still high at the tip of tube "A" against expectation. The hoop stress rises during springback, although it is suppressed well before springback. On the other hand, the hoop stress is reduced well at the boundary "B*".

The plug is effective for the suppression of the hoop stress at the tip of the tube and the large corner radius is effective at the boundary. The combination of the plug and the corner radius may bring the effect for suppression of the hoop stress for the whole inner surface.

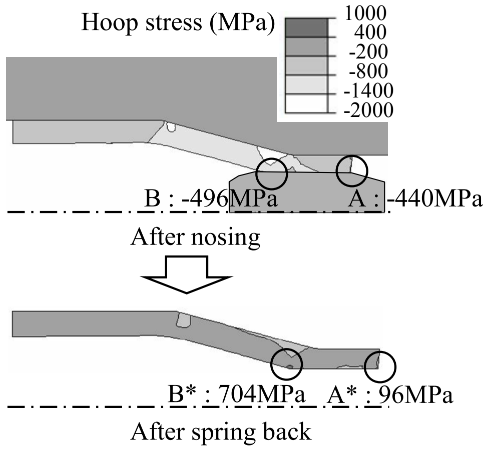


Fig. 6 Effect of plug on the hoop stress (Plug diameter = 8.6mm)

5 CONCLUSIONS

(1) It is clarified that the existence of parallel portion accelerates the generation of wrinkle or fracture.

(2) The mechanism of fracture is studied numerically and it is suggested that the main cause would be the hoop stress rises at the tip of the tube and the boundary between approach and bearing.

(3) The two concept of tool design were proposed. One is setting a plug inside. The other is applying large approach radius. The effect of them was investigated numerically.

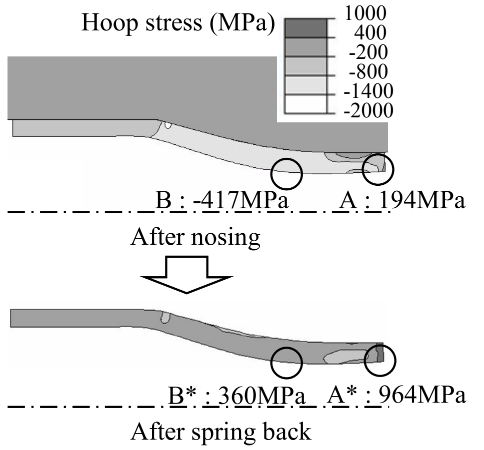


Fig. 7 Effect of approach radius on hoop stress (Approach radius r_{2c}=100mm)

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