Chip-less cutting process of the tube in radial direction with the rotary tool

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Abstract. In Japan, some of the nuclear power plant must to be decommissioned. We focused on the cooling tubes used for the reactor condenser. For decontamination of cooling tubes, it is necessary to cut them to short length and to axially split them. In our method, end of the tube is griped by a small chuck fixed in the small engine lathe and rotated. The rotary tool is pressed against the rotating tube by the electrical controlled cylinder. The cutting time should be shorter. However, the increment of tool pressing force may cause the high tool wear. It is assumed that the even without increasing the cutting force, the material yields by applying a tensile force at the cutting part according to the Tresca's yield criterion. In order to generate a tensile force in the tube axial direction at the cut part, a bending moment was applied to the end of the rotating tube. We investigated the relationships among the tool pressing force, bending moment and the cutting time. It was revealed that the pressing force and bending moment reduces the cutting time. Especially, the bending moment reduced the cutting time for brass and titanium tubes effectively.

Introduction

The prototype advanced thermal reactor FUGEN nuclear power station has completed the operation on March 29, 2003. As far as possible, we have to remove the radioactivity from a radioactive waste in the nuclear facility and to dismantle it. The decommissioning of FUGEN must to be dismantled the facility according to the Reactor Regulation Law safely and rationally. The radioactive waste will be solidification, etc. depending on the property and radioactivity level after the process of volume reduction. They are stored in the temporary storage area provided in the building in a solid waste storage warehouse or under an appropriate management and they will be discarded or reused depending on the radioactivity level in the disposal facility of waste operators[1,2]. There are many kinds of radioactive waste. We focused on the cooling tubes used in reactor condenser. They had been used quite a lot and have already been removed from the reactor condenser. They have been cut and stored about 1 m length, because of

Fig. 1 Cooling tubes after used

manual cutting, the cut part is very rough as shown in Fig.1. For the next processing (measuring the radioactivity level or cleaning), it is necessary to cut it short and cut the edge cleanly. During cutting, the small sized powder type chips which will become secondary contaminants should be avoided. Therefore, we tried to develop the new method to cut tubes quickly without discharging cutting chips[3].

Experimental setup

The tube specimen is gripped by the three-jaws chuck that is fixed to the small sized engine lathe and is rotated. The lathe is equipped with two electrical actuators are equipped as shown in Fig.2. The rotary circular cutting tool we used is also shown in Fig.2. It is commercially parts and used for manually operated type tube cutter. The tool diameter is 30mm and the cutting edge angle is almost 50 degrees. One actuator is for pressing the rotary cutting tool against to the tube specimen. The other is for adding the bending moment to the tube specimen. The tool pressing device is shown in Fig.3. The tube specimen is supported by two cam followers and the pressing force is measured by the load cell.

Figure 4 shows the tube bending unit. In order to generate a tensile force in the tube axial direction at the cut part, a bending moment was applied to the end of the rotating

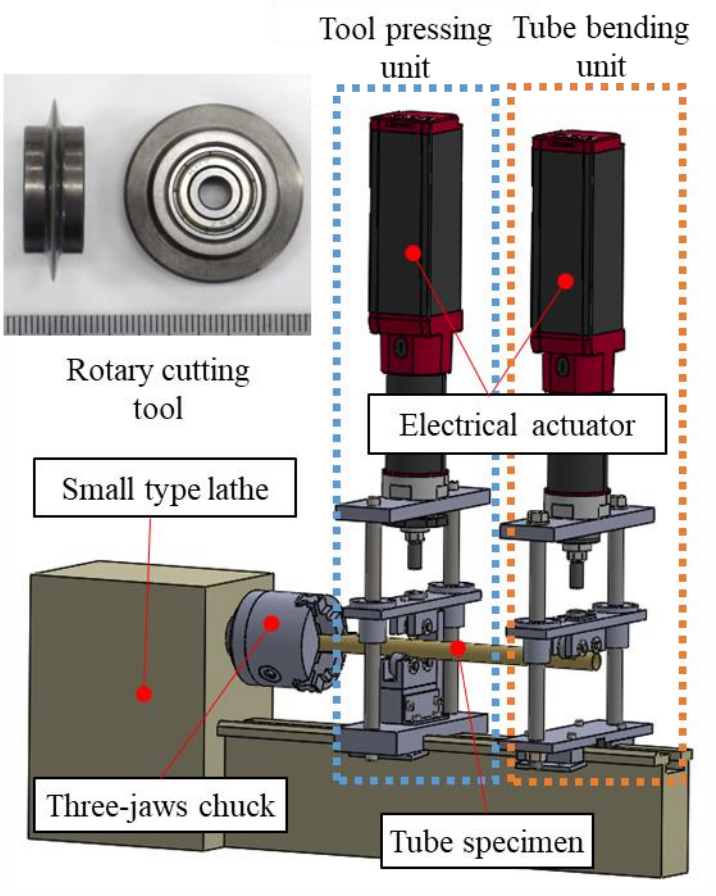


Fig. 2 Experimentl setup for cut-off tube

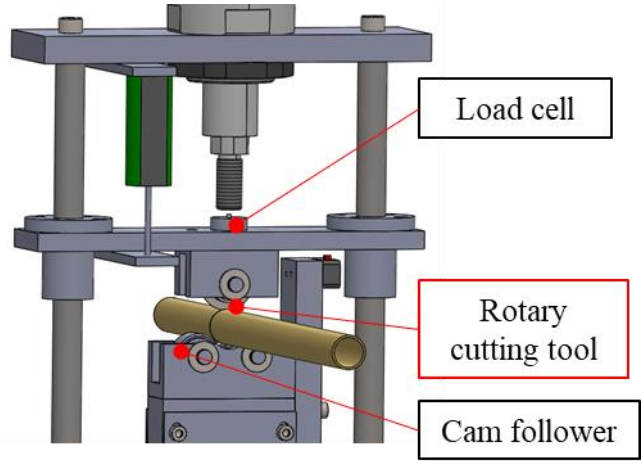


Fig. 3 Tool pressing unit

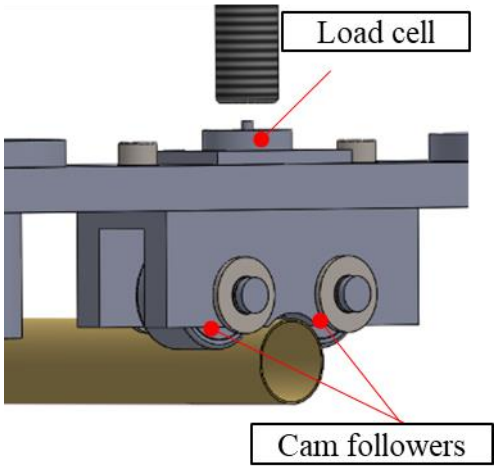


Fig. 4 Tube bending unit

tube. The bending force is applied to the tube through the cam followers and its force is measured by the load cell. It is expected that the even without increasing the tool pressing force, the material yields by applying a tensile force at the cutting part according to the Tresca's yield criterion as shown in Fig.5[3]. As the load on the tool is reduced, the tool wear progress is thought to be slower.

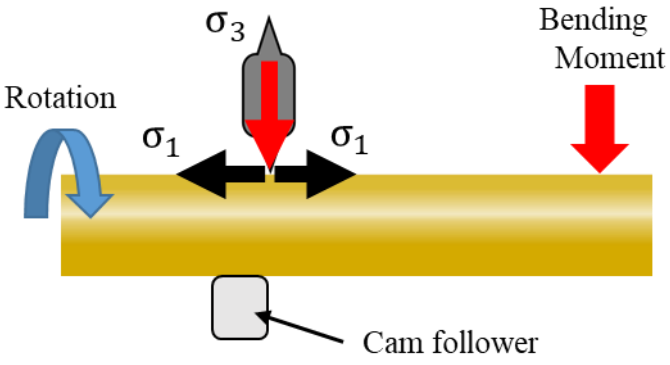


Fig. 5 Trescca's yield criterion

Two kinds of tubes are chosen as specimen. One is the brass tube C6871 and its outer diameter is 19 mm and the 1.2 mm in wall thickness. The other is Titanium tube TTH340W and its outer diameter is 19 mm and the 0.5 mm in wall thickness. Although it is slightly different in size, both tubes are actually used in nuclear power plant in JAPAN.

Experimental result and discussion

Fundamental cutting tests of C6871 and TTH340W tubes were carried out with the tool pressing load of 300N and the rotational speed of 500 rpm as shown in Fig.6 without adding the bending moment. Relationships between the rotating numbers required for cut-off a tube and the numbers of cut tubes is investigated. The wall thickness of the TTH340W tube is almost half of the C6871 tube. The numbers of cut TTH340W tubes was set as twice as much as the C6871 tubes. At the initial stage, rotating numbers increases rapidly. After that, it becomes almost constant in both tubes as shown in Fig.7. The vertical axis indicates the number of rotations required to cut-off the tube once. It seems that very small chipping occurs at the cutting edge. Therefore, a new blade was used for experiment after 5 test cuts.

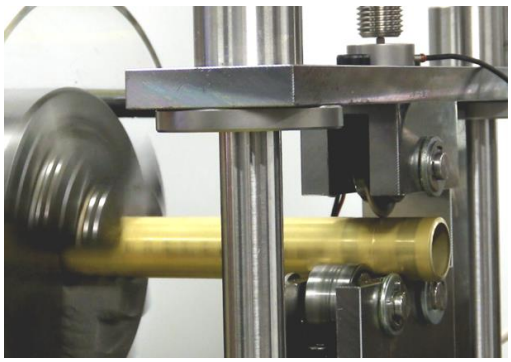


Fig. 6 Cut-off the tube specimen

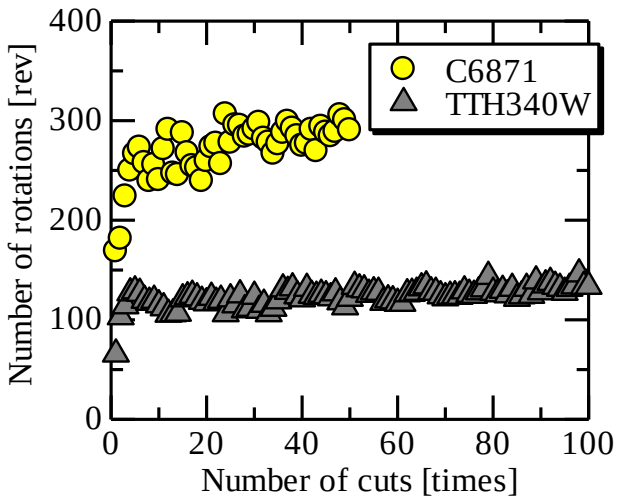


Fig. 7 Number of rotations for cut-off the tube

Rotational speed

The relationships between the rotating numbers required for cut-off a tube and the rotational speed of the tubes is investigated. The rotating speed was changed from 100 to 1000 rpm. In the experimental range, the rotational speed hardly affected the rotation numbers for cut-off the tube as shown in Fig.8. In consideration of the safety during experiment, the later experiments were carried out at a rotational speed of 500 rpm.

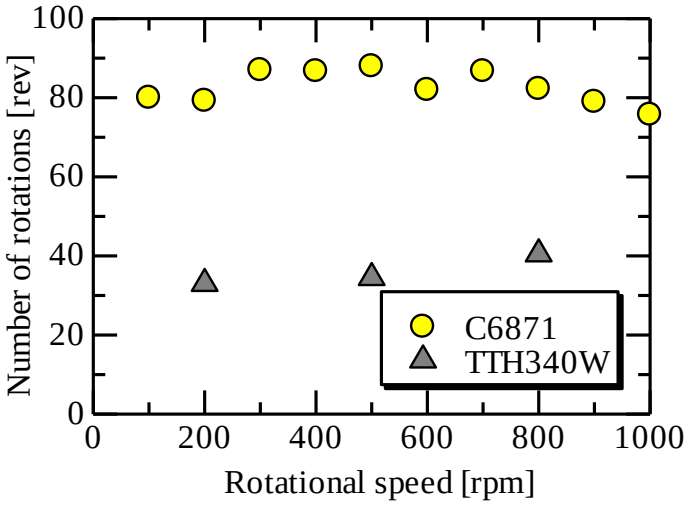
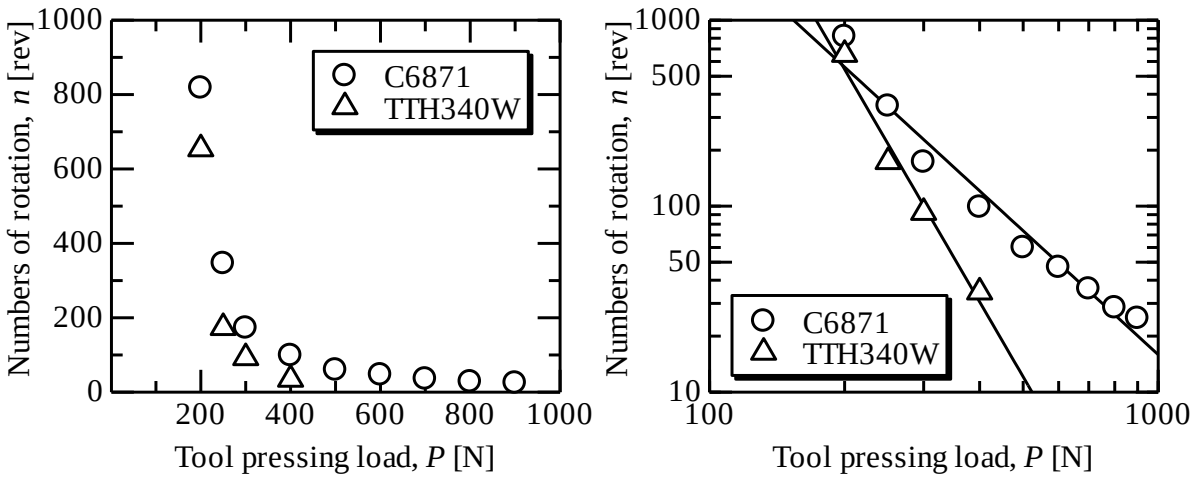


Fig. 8 Effect of rotational speed on number of rotations

Tool pressing load

Relationships between the rotating numbers required for cut-off a tube and the tool pressing force was investigated. The tool pressing load was changed from 200 to 900 N. The number of rotations decreases rapidly with tool pressing force as shown in Fig.9(a). The result of the above re-plotted by the log-log plot is shown in Fig.9(b). The obtained data can be approximated with a straight line on the log-log plot. The gradient of approximate straight line of TTH340W is much larger than that of C6871. It has been shown that the tool pressing load has a large effect on the number of rotations for cut-off. However, as the load of the tool increases, the tool life is thought to be shortened.

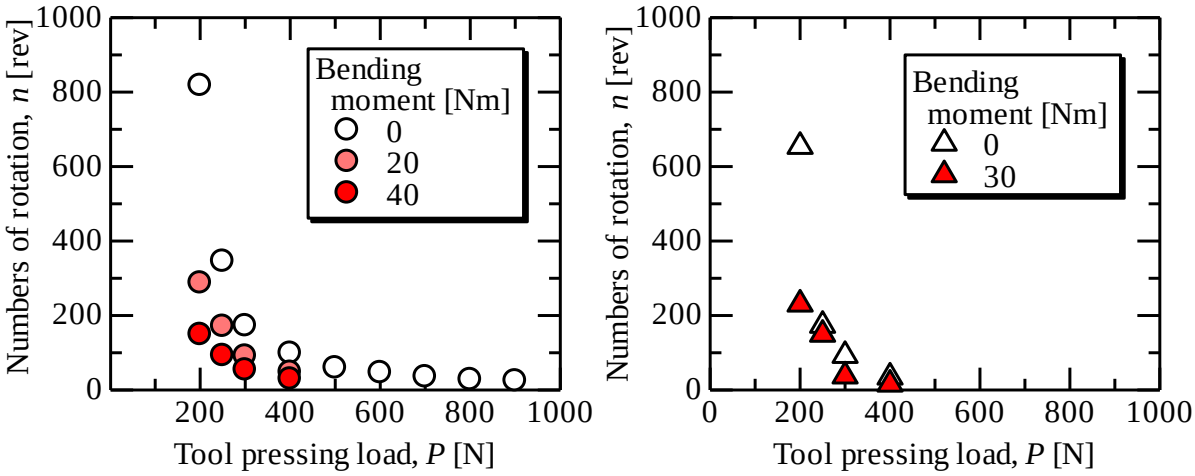


(a) Normal plot (b) Log-log plot

Fig. 9 Relationship between tool pressing load and numbers of rotation

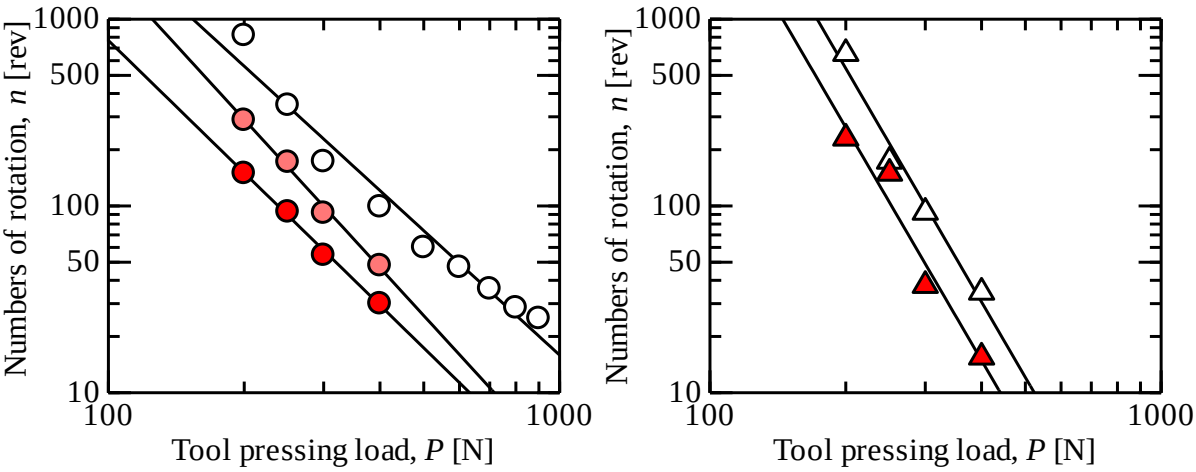
Bending moment

We devised cutting the tube in a short time with a small tool pressing force by applying a bending moment to the tube during cutting it. The bending moment was applied to a position 100 mm away from the cutting part. The tool pressing force was changed from 100 to 900 N and the applying moment was changed from 20 to 40 Nm. The numbers of rotations for cut-off the tube were much decreased with bending moment as shown in Fig.10(a) and (b). In particular, when the pressing force is small, it becomes about 20 to 30 % in both tubes. The results of the above re-plotted by the log-log plot are shown in Fig.11(a) and (b). In the both tube, all data can be approximated with a straight line on the log-log plot. The Y-intercept were affected by the applied moment and the gradient were not so affected. And the gradient of the approximation straight line is thought to be depended on the material of tubes.



(a) Brass tube : C6871 (b) Titanium tube : TTH340W

Fig. 10 Relationship between bending moment and numbers of rotation



(a) Brass tube : C6871 (b) Titanium tube : TTH340W

Fig. 11 Log-log graphs for each tubes

Concluding remarks

In the present study, we tried to develop the new method to cut tubes quickly without discharging fine chips. The rotary cutting tool was applied to the brass tube and titanium tube they are turned by small engine lathe. Further, considering the long tool life, in order to decrease the tool pressing load, the bending moment was added to the tube. The conclusions based on the experimental results are as follows.

- The tube made of brass and titanium could be cut-off with a rotary cutting tool without creating any fine chip.
- In our condition range, the rotational speed or cutting speed hardly affect the tube cutting-off time.
- The tool pressing load decreases the cutting time of tube made of brass and titanium.
- The bending moment has large effect on the cutting time of tube made of brass and titanium.
- In the log-log plot of the relationship between the cutting time and the tool pressing load, the gradient is affected by the kind of material, and the Y-intercept is affected by the bending moment.

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