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SOME OBSERVATIONS ON COANDA SPIRAL NOZZLE FOR EXHAUST VENTILATION

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SUMMARY

A "Coanda spiral nozzle" is designed for the artificial formation of a free spiral flow. The main focus of the present study is to observe the aerodynamic characteristics of the nozzle and discuss its possible utilization in exhaust ventilation.

By using the Coanda spiral nozzle a large amount of air containing indoor contaminants can be exhausted even though only a small amount of primary air is supplied to the nozzle. Due to the "Coanda spiral flow" formed inside the nozzle, air contaminants contained in exhaust air can be prevented from attaching to the internal surface.

A free spiral flow is generated at the blowoff side by using a prototype of the Coanda spiral nozzle, but it is not clearly confirmed through this preliminary test whether a spiral flow is formed at the suction side of the nozzle. At present the study is in the prototype test stage and has yet to look at practical application.

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INTRODUCTION

One of the features of a spiral vortex flow is that it concentrates air contaminants into the vortex core generated at the center of the rotational flow and quickly transports them to the exhaust opening along the core axis. The author has already introduced the main findings of a study on application of spiral vortex flow to indoor air quality control [1]. The study dealt with a forced spiral flow which was produced by artificially adding an angular momentum to the fluid.

The current investigation, however, examines a free spiral flow. The free spiral flow utilizes the phenomema whereby fluids spontaneously initiate rotational movements by adding a large radial momentum toward the central axis of an axial flow. The main focus of the present study is to observe the aerodynamic characteristics of the "Coanda spiral nozzle", which is designed for the artificial formation of a free spiral flow, and discuss its possible utilization in exhaust ventilation.

PRINCIPLE OF COANDA SPIRAL NOZZLE

Figures 1 and 2 show a prototype of the Coanda spiral nozzle. An annular slit is formed on the conical part of the nozzle to blow primary air into the nozzle. Due to the Coanda effect, the airflow is attached to the converging surface, and negative pressure is created inside the nozzle. This negative pressure causes ambient air to be sucked into the nozzle and form an axial airflow. Through the combination of these two axisymmetric flows a rotational air movement is spontaneously generated in the nozzle. This rotational flow does not diverge outwards from the central axis, as observed in a cyclone, but converges into the axis [2].

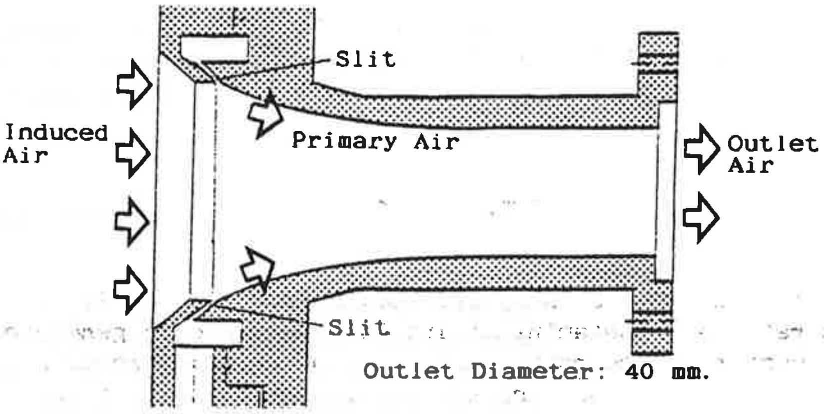


Fig. 1. Longitudinal section of a Coanda spiral nozzle.

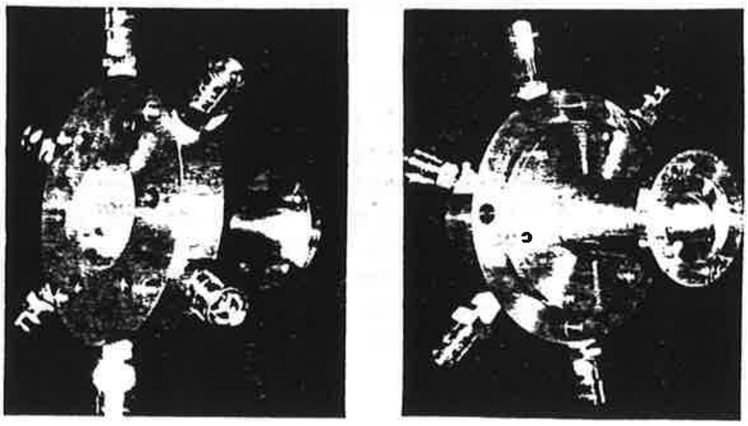


Fig. 2. Prototype of Coanda spiral nozzle.

VELOCITY DISTRIBUTIONS AT OUTLET APERTURE

Figure 3 shows the outlet velocity distributions when changing the slit width. In the case of a 0.1 mm slit width, the higher velocity appears in the outer part of the flow near the nozzle surface, and lower velocity appears in the central part of the nozzle. This results because the curvature of the converging surface is not sharp enough to give sufficient radial momentum for creating a rotational movement to the axial flow.

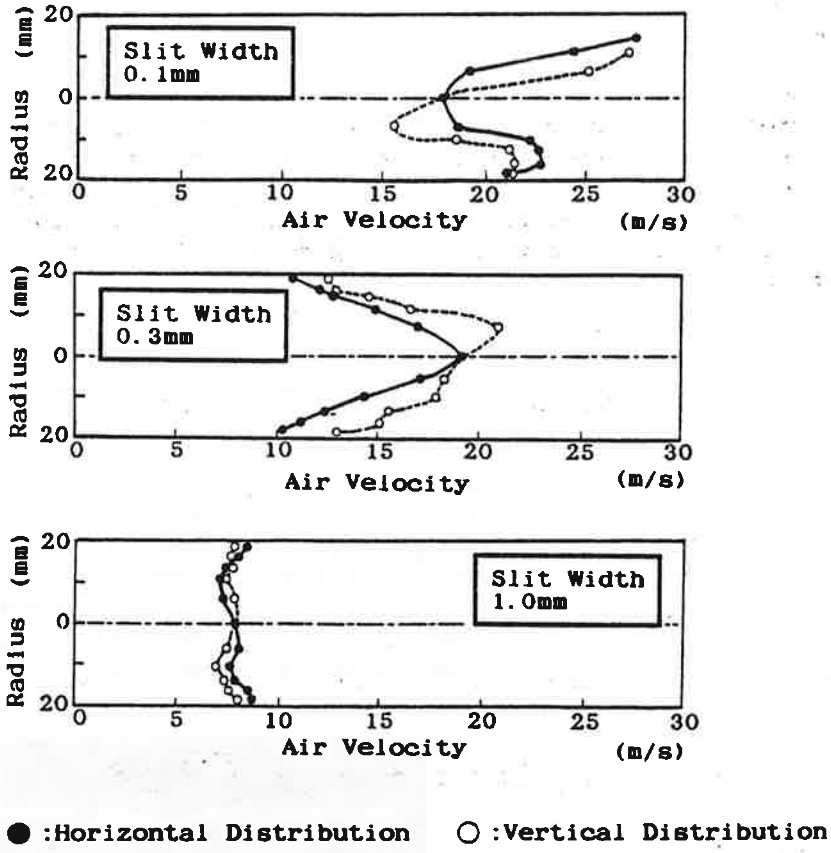


Fig. 3. Air velocity distributions at the outlet aperture.

When the slit width is set to 0.3 and 0.5 mm, the velocitiy in the central part is much higher compared to the velocity in the outer part, and the maximum velocity occurs at the central axis. This velocity profile is similar to that observed in laminar flow, although the Reynolds number at the outlet is in a turbulent region (Re=38,900), which implies that the flow is a free spiral flow in which the air rotationally converges to the central axis.

When the slit width exceeds 1.0 mm, the velocity distribution becomes flat, as observed in common turbulent flow. In this case, it is thought that the air supplied from the slit is not attached to the nozzle surface, but is detached from it. Thus, when using the Coanda spiral nozzle, it is necessary to arrange the conditions related to the nozzle configuration and the slit width in order to generate a stable free spiral flow.

In the case of a slit width of less than 0.5 mm, the features of the Coanda flow and that of the Coanda spiral flow strikingly appear as the Reynolds number increases. However, when the slit width is more than 1.0 mm and the flow of primary air is detached from the nozzle surface, the velocity profile is always flat regardless of the Reynolds number.

CHARACTERISTICS OF COANDA SPIRAL JET

To confirm how a jet airflow rotates, a qualitative observation was performed using a lightweight cloth tape and smoke. Figure 4 shows an example using a tape with a slit width of 0.3 mm, in which the velocity profile shows a typical free spiral flow. Based on the helical form of the tape, the flow is confirmed to be counterclockwise. In order to better understand the characteristics of Coanda

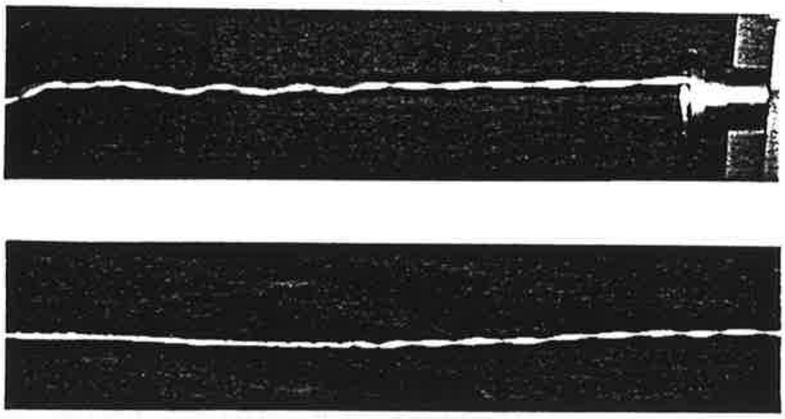


Fig.4. Helical form of a tape in the spiral jet denotes a counterclockwise flow.

spiral flow, it will be necessary to measure vector components in future studies.

For the slit width of 0.3 mm, measurements of jet velocity distributions were carried out at different distances from the nozzle outlet. Results revealed ittle difference between the measured profiles and that of a circular turbulent jet.

Figure 5 shows the centerline velocity decay. When the converging airflow into the central axis is enhanced and spontaneouse rotational flow is strong, it is believed that the diffusion angle of the jet decreases and the potential core length increases. The core length obtained through the above measurements is 6.5 times as large as the nozzle outlet diameter.

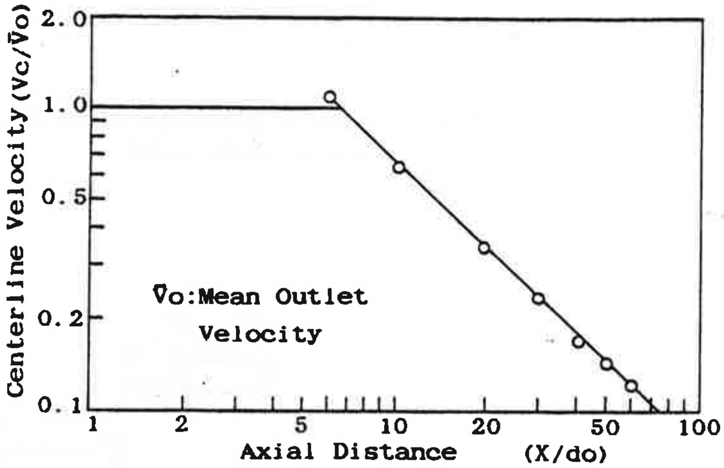


Fig. 5. Centerline velocity decay for the nozzle of a 0.3 mm slit width.

PRESSURE AND VELOCITY DISTRIBUTIONS INSIDE THE NOZZLE

Figure 6 shows the static pressure distributions on the central axis inside the nozzle. In the cases of 0.1 and 0.3 mm slit width, the pressure is negative and decreases in value as the slit width decreases. As a result, the induced air volume increases as the slit width decreases. The

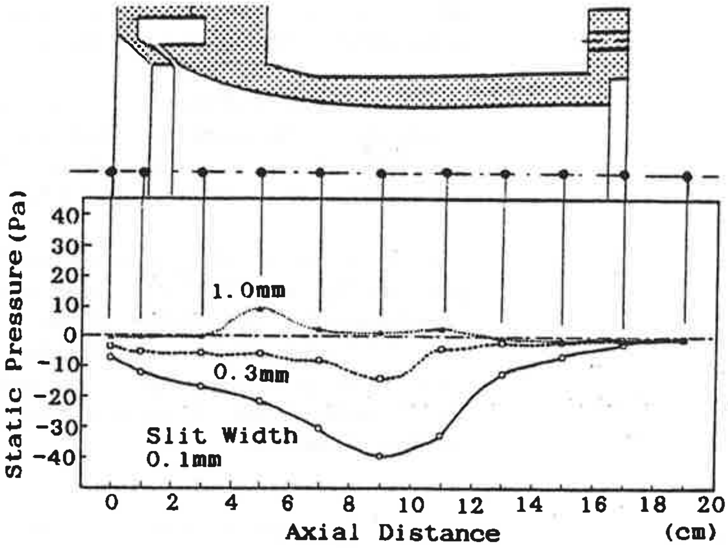


Fig. 6. Static pressure distributions inside the nozzle along the central axis.

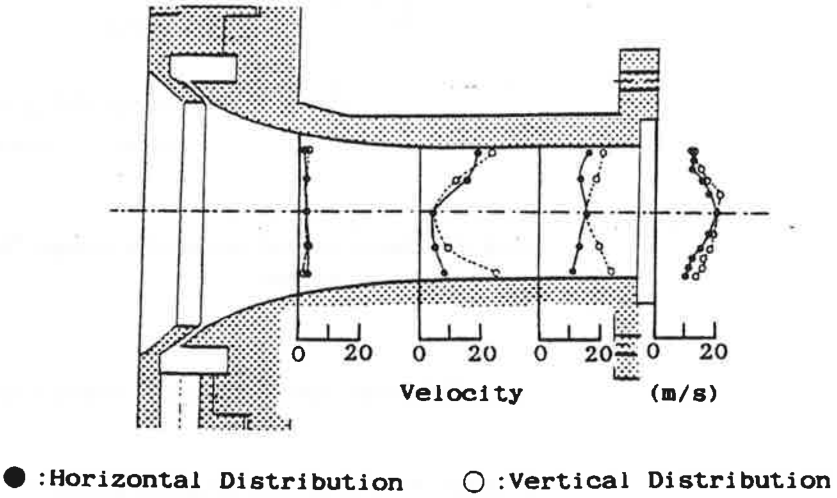
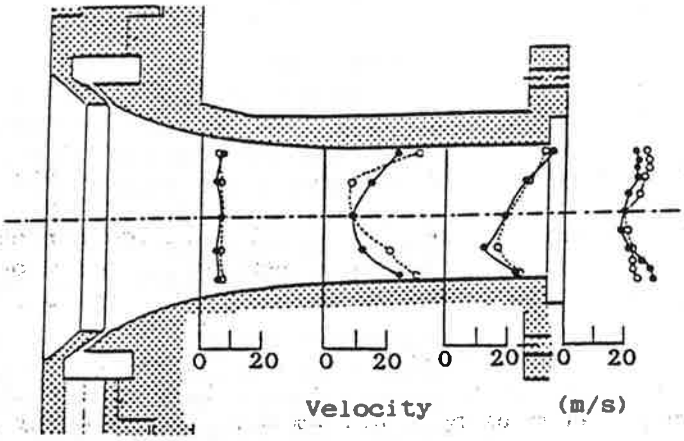
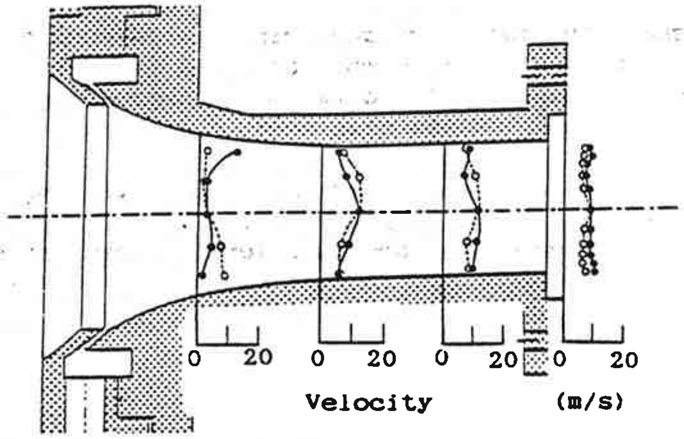


Fig. 7. Air velocity distributions inside the nozzle in the case of a 0.3 mm slit width.



● :Horizontal Distribution ○ :Vertical Distribution

Fig. 8. Air velocity distributions inside the nozzle in the case of a 0.1 mm slit width.



● :Horizontal Distribution ○ :Vertical Distribution

Fig. 9. Air velocity distributions inside the nozzle in the case of a 1.0 mm slit width.

pressure is minimized at the central portion along the axis of the nozzle and slowly increases toward the suction side, and relativly steeply increases toward the blowoff side.

Figure 7 shows the state in which primary air supplied from a slit at a high speed (63.2 m/s) forms a Coanda flow. An induced flow through the suction aperture joins the Coanda flow, and the combined flow gradually grows to a spirally converging flow, Coanda spiral flow, having maximum velocity at the central axis of the nozzle. The inside surface of the nozzle is thus protected by the clean primary airflow from the air contaminamts contained mainly in the induced airflow.

Figures 8 and 9 show the velocity distributions inside the nozzle in the case of a 0.1 mm and a 1.0 mm slit width respectively. When using a 0.1 mm slit the velocity in the outer zone is always higher than in the central zone. This is the feature of a Coanda flow but not a Coanda spiral flow. In the case of a 1.0 mm slit width the primary air does not attach to the nozzle surface and forms a kind of turbulent pipe flow.

INDUCED AIR VOLUME VS. PRIMARY AIR VOLUME

Figure 10 shows the result of measuring the primary air volume and induced air volume when changing the slit width. The ratio of the induced air volume to the primary air volume was found to increase as the slit width decreases. In the case of a 0.1 mm slit width, a maximum ratio of ten-fold reached, depending on the pressure applied to the nozzle. When the slit width is 0.3 mm, the ratio is maintained at approximately 3.5 under any pressure level. When the slit width further increases, the induced air volume decreases. In the case of a 1.0 mm slit width, the induced air volume approximately equals the primary air volume.

VELOCITY DISTRIBUTIONS AT SUCTION APERTURE

Figure 11 shows the velocity distributions around the suction opening when the slit width is 0.3 mm. Although the flow pattern is similar to a commonly observed potential

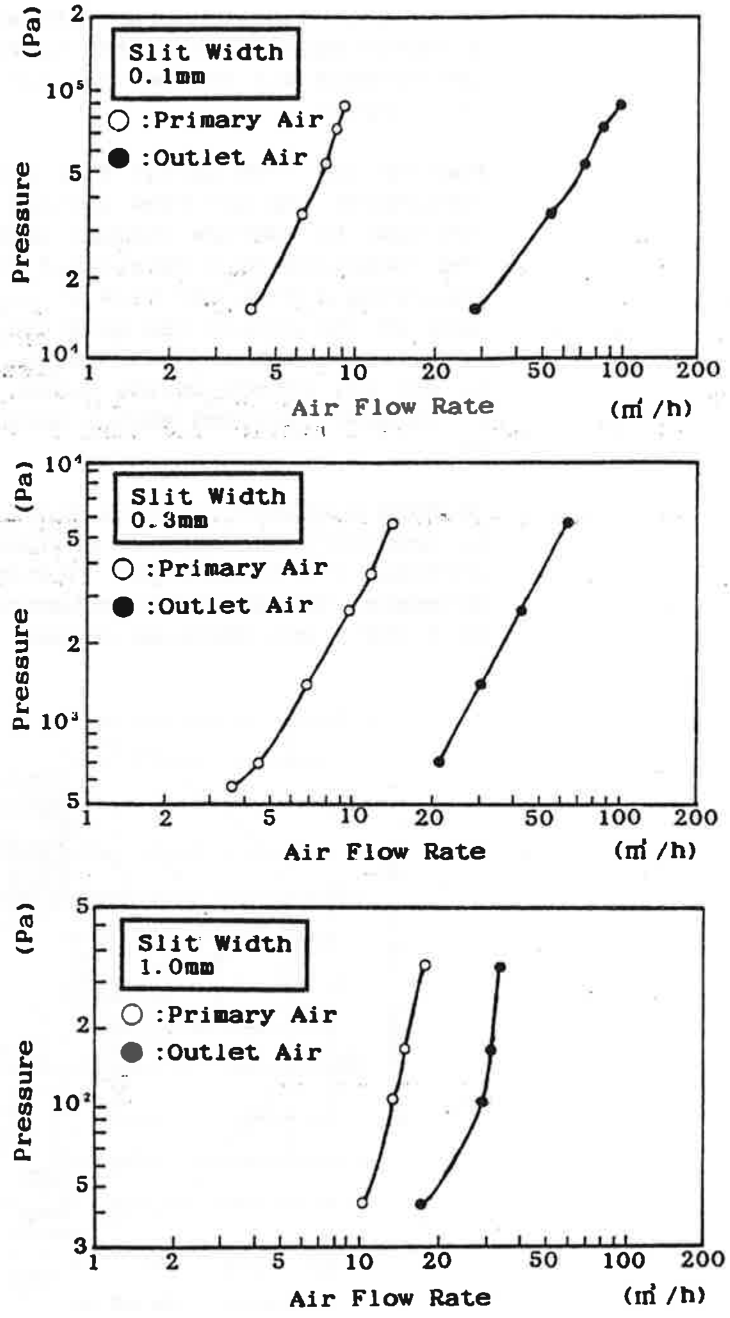
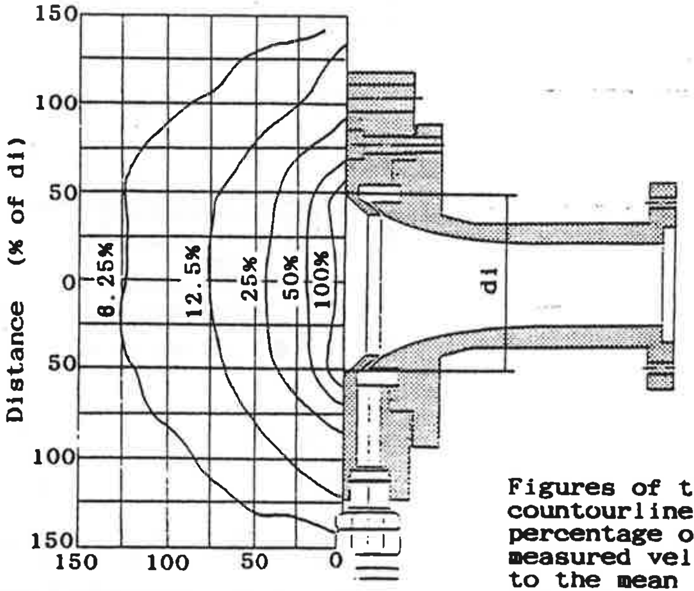


Fig. 10. Primary air volume and outlet air volume. The difference between primary air and outlet air volume is induced air volume.

flow, the velocity around the suction aperture increases by a factor equivalent to the ratio of the induced air volume to the primary air volume, and consequently the exhaust capacity is improved.

Whether the free spiral flow produced in the nozzle influences the air flow pattern at the suction aperture is not easy to confirm through this preliminary experiment. The formation of a rotational flow at the suction side by supplying a weak air flow at a certain angle to the central axis of the nozzle was confirmed only qualitatively through flow visualization using smoke. However, this phenomenon may be not the effect of the Coanda spiral nozzle itself, because it is also observed when a normal suction aperture is used [3].

To form a stable rotating flow around a suction aperture, it is necessary not only to produce an additional airflow serving as a trigger for rotational movement but also to determine the specific influences of the nozzle shape, the slit width and Reynolds number.



Figures of the countourlines are percentage of the measured velocity to the mean induced velocity at the suction aperture.

Fig. 11. Velocity distribution around the suction aperture.

CONCLUSIONS

By using the Coanda spiral nozzle a large amount of air containing indoor contaminants can be exhausted even though only a small amount of primary air is supplied into the nozzle.

The Coanda spiral nozzle prevents air contaminants from attaching on the internal surface because most air contaminants are converged to the central axis and transported along it.

It is not clearly confirmed whether a rotational flow is formed at the suction side of the nozzle, though it is confirmed that a rotational flow is genereted at the blowoff side.

The shape of the nozzle, the slit width and the Reynolds number are considered as factors contributing a stable rotational flow. The author will conduct further tests on these factors in the future.

ACKNOWLEDGMENTS

The author expresses his gratitude to Professor Dr. K. Horii for his guidance on the design of the prototype nozzle and his valuable advice on the experiment.

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