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EXAMINATION OF THE GUIDE FIN SHAPE FOR THE CYCLONE TYPE DRAIN SEPARATOR

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Abstract. The drain separator is a device for separating drain which cause trouble in the pneumatic system. Among them, the cyclone type drain separator is currently widely used as a device that generates rotational flow inside and separates by centrifugal force. In this research, we focused attention on a rotational flow generator which is a main component for generating a rotational flow in a cyclone type drain separator. We aimed at performance corresponding to a wide flow rate range by changing the shape of rotational flow guide fin and examined from the viewpoint of biomimetics on shape.

Keywords: Drain separator, Cyclone, Biomimetics, Dragonfly

INTRODUCTION

Today, many of the common pneumatic devices are using air pressure at room temperature. Moisture "drain" in the tube often causes operational problems [1]. Drain removal is indispensable for air-supply lines and such problem can be resolved by installing a drain separator to separate airs and liquids.

This research focuses on the cyclone-type drain separator that uses centrifugal force generated by rotational flow. The purposes of this research are to realize performance of handling wide range of flow rates and reduce internal pressure loss by changing the shape of the guide fins within the rotational-flow generator. From the point of view of biomimetics, dragonflies fly within the range of Reynolds numbers of the actual device. So we applied the shape of dragonfly wings to the shape of the guide fins. and examined the shape of the fin.

CYCLONE TYPE DRAIN SEPARATOR

FIGURE 1. shows the cyclone-type drain separator internal flow. The cyclone type drain separator is a device which separates gas and liquid by centrifugal force. The advantage of this equipment is that it is smaller in size than other types of drain separator and that it is maintenance free because it does not use filters and elements.

The mechanism of separating the drain using centrifugal force employs the use of a rotational-flow generator with multiple guide fins as shown in ② of FIGURE 1. to generate internal rotational flow.

One of the issues at hand is the drop in separation performance in low flow regions as rotational flow is more difficult to generate. The purpose of this research is to improve the performance of separation in low flow regions. FIGURE 2. shows the rotational-flow generator and the shape of a single guide fin taken out. The rotational flow generator has 21 angled fins, and a fluid flows between the fins to generate a rotational flow. We will improve the performance by changing the shape of this fin. We will investigate both CFD (Computational Fluid Dynamics) analysis and characteristic experiment. According to JFPS2013-1, the performance required for practical use is that 100 [ml / min] can be separated under the equipment use conditions.

FIGURE 1. The cyclone type drain separator [2]

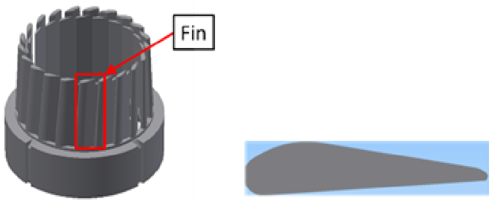


FIGURE 2. Rotational flow generator and fin shape

FIN SHAPE SUITABLE FOR LOW FLOW

When calculating the Reynolds number for the environment used in this device, Re = 1×10^4 [-]. This range of Reynolds numbers is referred to as the ultra-low Reynolds number region, and the horizontal flight of dragonflies fit in this region. In aeronautical engineering, there are reports of better performance when using thin fins that are bent rather than thick fins in this region [3]. This research is made under the assumption that these characteristics are also valid for this device.

The test shape of the bent guide fins is based on the actual fin cross-section of a dragonfly and fabricated using stereolithography. FIGURE 3. shows the bent guide fin model using stereolithography and fin cross-section.

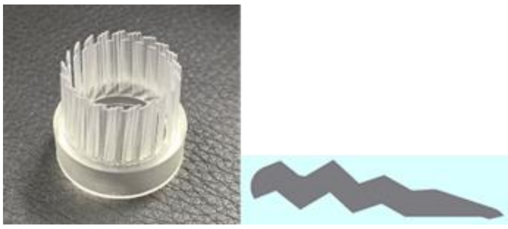


FIGURE 3. Dragonfly shape stereolithography

AIR-LIQUID SEPARATION EXPERIMENT

An experiment was conducted to examine the validity of bends by measuring the maximum drainage and pressure loss of the dragonfly shape fin. The experimental model is the product shape and the dragonfly shape fin model. The experimental conditions are inflow pressure 0.4 [MPa], inflow flow rate 600, 800, 1000, 1200 [L / min (ANR)]. We introduce air and water into the drain separator and measure the performance. The experiment was conducted along JFPS2013-1. FIGURE 4. and TABLE 1. show the experimental setup, and FIGURE 5. shows the experimental results.

Compared to the conventional fins, the dragonfly shapes showed that despite a drop in the separation, there is less pressure loss.

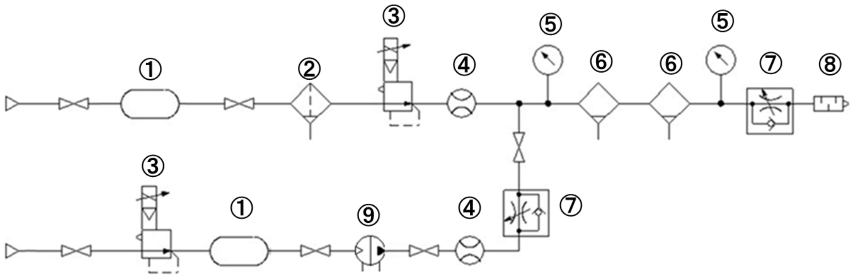


FIGURE 4. Experimental device

TABLE 1. Experimental device name

Reference Number	Name of Equipment
①	Tank
②	Air filter
③	Regulator
④	Flow meter
⑤	Pressure gauge
⑥	Drain separator
⑦	Speed controller
⑧	Exhaust filter
⑨	Air-Hydro converter

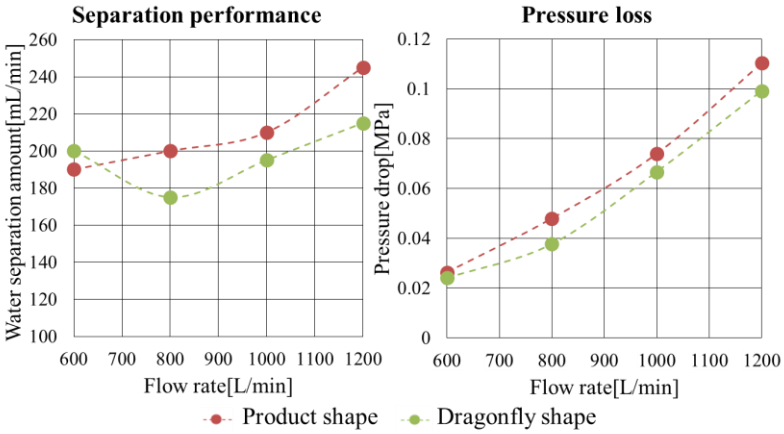


FIGURE 5. Experiment result

3D SIMULATION

To reduce the number of experimental trials and to clarify the internal flow, analysis was conducted by creating a simple 3D model using ANSYS Fluent analysis software. FIGURE 6. shows a simple analysis model. This is designed so that the flow path has a cylindrical shape from the double cylindrical inlet through the rotational flow generator. The fluid flow is a simple flow going from the inlet through the rotary flow generator to a rotating flow and going to the outlet. FIGURE 7. shows the analysis result of the pressure and velocity of the rotational-flow generator position. The horizontal axis indicates the length in the radius from the device center (y=0) and the vertical axis show the pressure and velocity.

Although FIGURE 7. shows less pressure difference for the dragonfly shape, the velocity is slower for the dragonfly shape. When viewing the analysis result with difference of the pressure as pressure loss and the velocity as the separation performance within the analysis model, it can be seen that the values are close to the experiment values.

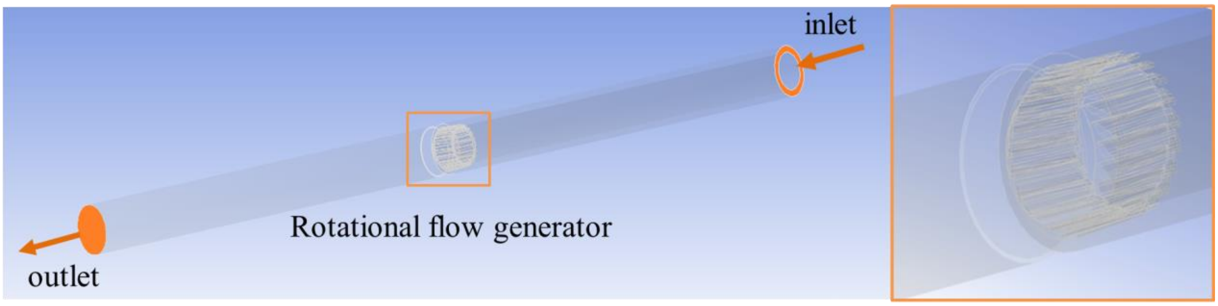


FIGURE 6. Simple analysis model (left : Overall view , right : Enlarged view)

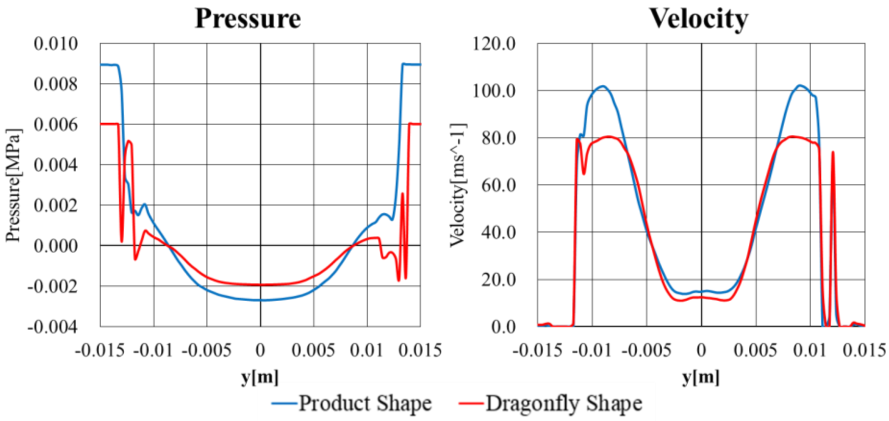


FIGURE 7. Analysis result

EXAMINATION OF CHANGED FIN SHAPE

For the purpose of changing the number of vortices surrounding the fins, fins with different number of bends as shown in FIGURE 8. were fabricated for comparison. A simulation and an experiment ware conducted to examine the validity of number of bends of the changed shape fin.

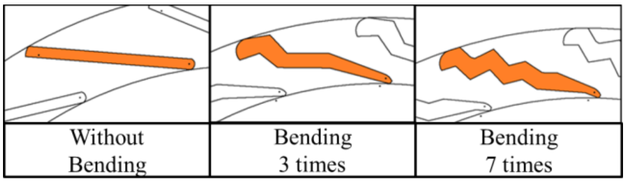


FIGURE 8. Model changed fin shape

3D Simulation of Changed Fin

3D simulation was carried out in the same method using the analysis model of FIGURE. 6 for the three models of FIGURE. 8 and the product shape model. FIGURE 9. shows the analysis result of the pressure and velocity of the rotational-flow generator position. The horizontal axis indicates the length in the radius from the device center (y=0) and the vertical axis show the pressure and velocity.

FIGURE. 9 shows that the product shape having the smallest flow passage area is smaller pressure loss and highly flow velocity. However, the pressure loss and the velocity of three changed fin shape models are smaller in bending model than in without bending model with the largest flow area. From this result, it is conceivable that bending the fin and creating a flow vortex around the fin has a function to reduce the flow velocity and pressure loss.

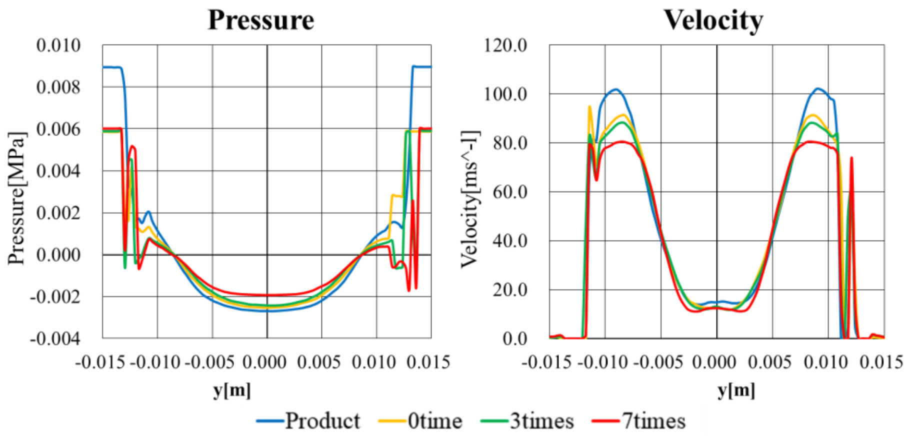


FIGURE 9. Analysis result of changed fin models

Air-liquid Separation Experiment of Changed Fin

An experiment was conducted to examine the validity of number of bends and simulation result by measuring the maximum drainage and pressure loss of the changed shape fin. The experimental model is the product shape and the without bending model and the bending 3times model, the bending 7 times model. The experimental conditions are inflow pressure 0.2 [MPa], inflow flow rate 600 [L / min (ANR)]. We introduce air and water into the drain separator and measure the performance. The experiment was conducted along JFPS2013-1. FIGURE 4. and TABLE 1. show the experimental setup, and FIGURE 10. shows the experimental results.

Figure 10 shows that the difference in separation performance between the product shape and other shapes was close to simulation, but there was no big difference in the three changed fin shape models.

Although there were differences in pressure loss depending on shape, there was not so large difference among the models of the three changed fin models. For the purpose of the verification, experiments are carried out under other conditions on the pressure loss.

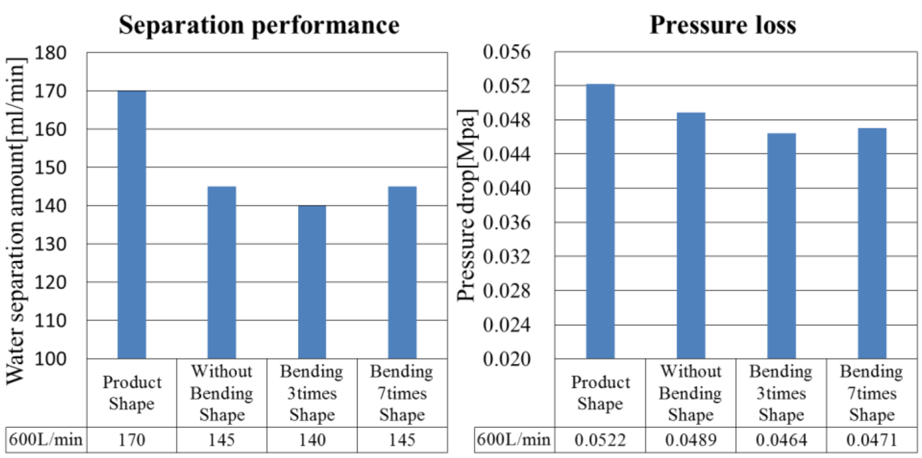


FIGURE 10. Air-liquid separation experiment result of changed fin

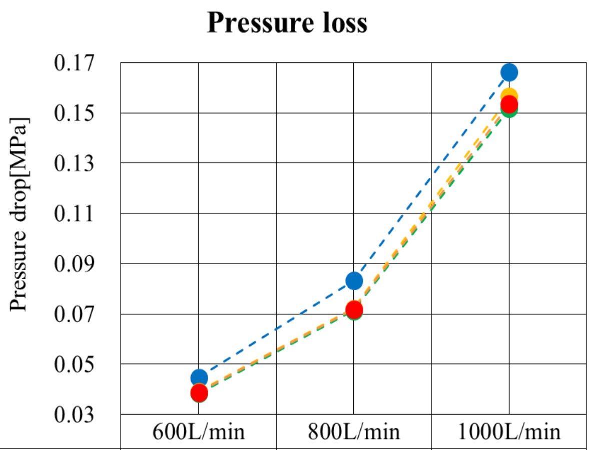
Experiment to Measure Pressure Loss of Changed Fin

An experiment was conducted to examine the validity of number of bends by measuring pressure loss of the changed shape fin. The experimental conditions are inflow pressure 0.3 [MPa], inflow flow rate 600, 800, 1000 [L / min (ANR)]. We introduce air into the drain separator and measure the pressure performance. We used experimental equipment excluding water supply line in FIGURE 4. FIGURE 11. shows the experimental results.

FIGURE. 11 shows that there is a large difference in pressure loss between the shape of the product and the model of the changed fin shape, and there is a small difference among models of the changed fin shape.

From these results, although the cross-sectional area of the fin is dominant for determining the performance, there is a possibility that performance can be influenced to suppress the pressure loss by using the bent shape.

In the model of the changed fin shape, simulation showed a tendency that the pressure loss became smaller as the number of times of bending increased, but experiment showed result that the bending shape 3 times model is the lowest pressure loss. This is thought to result that only air is included in the simulation, whereas air and water are put in the experiment, and the measurement points of the simulation do not match. However, it seems that the difference in pressure loss of the changed fin models is not such a big difference as to exert a big influence on performance. Therefore, in the future, we will examine the improvement of the accuracy of the simulation and the influence on the performance of the unevenness.



	600L/min	800L/min	1000L/min
Product	0.045	0.083	0.166
0 time	0.039	0.072	0.156
3 times	0.038	0.071	0.152
7 times	0.039	0.072	0.153

FIGURE 11. Pressure loss experiment result of changed fin model

CONCLUSION

The usefulness of the guide feather shape of the rotational flow generator, which is a main component of the cyclone type drain separator, was studied from the viewpoint of biomimetics. The tendency of the performance of the bending shape in the ultra-low Reynolds number region was clarified by experiments of separation of air-liquid and 3D simulation. Compared to the conventional fins, the dragonfly shapes showed that despite a drop in the separation, there is less pressure loss.

And experiment and simulation were carried out by changing the state of bent shape. Both results show that there is an influence on the performance depending on the state of bent shape, and concretely showed the possibility that there is a function to suppress the pressure loss.

In future, we will examine the improvement of the accuracy of the simulation and the influence on the unevenness performance, aiming at further improvement of the performance.

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