Improvement of Windproof Performance for Tramway Carriers by Means of Fairing Device

*Hisao SATO, Naruyuki HOSOKAWA and Michio CHISHIMA

1. Introduction

A ropeway system in which a closed box type of carrier is suspended from an aerial rope is used generally for transporting passengers in mountainous districts because of such reasons as that (1) it can run even on sharp slopes and (2) it can run easily across rivers. In recent years, there are plans to introduce it as a means of transportation in cities, and it is expected to be widely used as a means of transportation in coastal districts, between large housing complexes and terminal stations.

One of the important technical problems that must be solved in this ropeway system is to increase the wind resistance of the ropeway carrier. If the carrier is moved excessively by wind, it may result in a serious accident such as collision of the carrier with a column and falling of the carrier due to derailing of the rope from the rope wheel. In order to improve the safety and reliability of transportation, it is very important to increase the wind resistance of the carrier, especially in lateral directions.

As a means of increasing the wind resistance of the carrier, fairings were installed on the carrier to improve its aerodynamic characteristics, and its effectiveness was examined in a wind tunnel test. The results obtained are reported as follows.

2. An increase in Wind Resistance of Ropeway Carriers resulting from the Installation of Fairings

*Hisao SATO
Traffic Safety and Nuisance Research Institute, Ministry of Transport
6-38-1, Shinkawa, Mitaka, Tokyo 181-0004, Japan
Tel: +81-422-41-3211 Fax: +81-422-76-8602 E-mail: h-sato@tsnri.go.jp

Increasing the wind resistance of the ropeway carrier is an important measure to be taken in order to safely operate the ropeway system. In particular, the wind resistance of the carrier in lateral directions must be increased positively because a limit of contact with columns in lateral directions is smaller than that in the running direction of the carrier and a damping effect as in running direction is difficult to be obtained.

For increasing the wind resistance of the carrier, it is considered that the installation of a damping device to the carrier, or, improving the aerodynamic characteristics of the carrier is favorable. Previously, the aerodynamic effects to be obtained by the installation of wings, as aerodynamic weighting, on the carrier were reported[1]. This time, the aerodynamic effects to be obtained by the installation of fairings were examined in a wind tunnel test.

A possible effect to be obtained when fairings were installed on the carrier is that the aerodynamic characteristics of the carrier are improved by a reduction in resistance caused by the separation of air flow over some portions of the carrier. On the other hand, it is important to set the installation conditions properly for the carrier because its projected area inevitably increases.

3. Outline of Experiment

The effects caused on wind resistance by installing fairings were examined using an aerodynamic carrier model in the wind tunnel test.

3.1 Aerodynamic Carrier model and Shape of Fairings

In this experiment, a 1/5 scale model of a typical carrier for single rope automatic circulating type ordinary ropeway systems used currently, was used. In manufacturing the carrier model, the shape of the hangers and detailed surface shapes of the carrier which were found to be less affected aerodynamically from the aerodynamic test results conducted using the actual carrier were facilitated as much as possible. A set of fairings was installed on the upwind and downwind sides of the
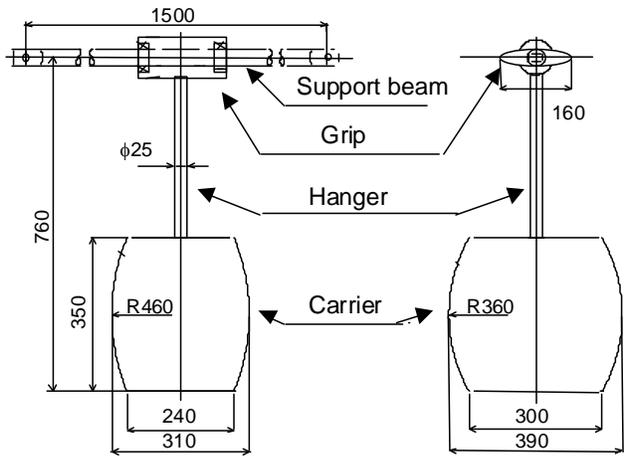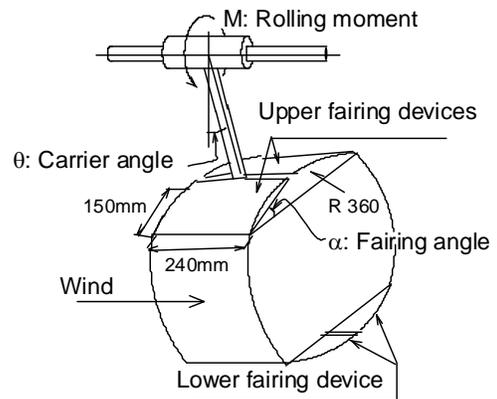
Fig.1 Shape of aerodynamic carrier model
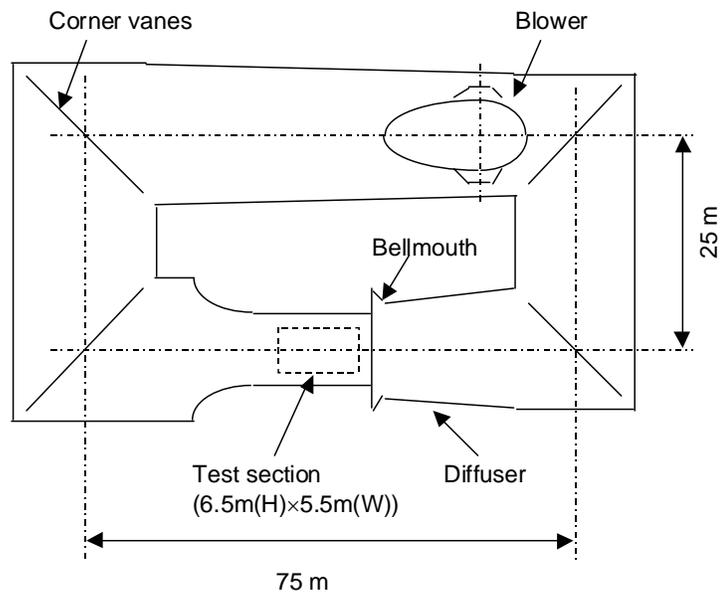

Fig.2 Shape of fairings

Fig.3 Wind tunnel

Table 1 Specifications of carrier model

		Scale model	Full size
Length from the rope center to the bottom of the carrier(m)		0.760	3.80
Size of the Carrier (m)	Width	0.390	1.95
	Hight	0.350	1.75
	Length	0.310	1.55
Side projected area (m²)	Carrier itself	0.101	2.07
	Carrier with hanger and grip	0.128	3.23

Table 2 Specifications of wind tunnel

Size of test section	Width(m)	5.5
	Hight(m)	6.5
Maximum wind speed (m/s)		60
Capicity of 6 component balance	Lift (N)	-2000～3750
	Drag (N)	-125～875
	Side force (N)	-500～500
	Pitching moment(N·m)	-1250～1250
	Yawing moment (N·m)	-750～750
	Rolling moment (N·m)	-750～750

4

carrier model under each experimental condition. The shape of the carrier model and its specifications are shown respectively in Fig. 1 and Table 1. Also the shape of the fairings are shown in Fig. 2.

3.2 Method of Experiment

This experiment was conducted using the large capacity low velocity wind tunnel of the Science and Technology Agency, National Aerospace Laboratory. The schematic of the wind tunnel and its specifications are shown in Fig. 3 and Table 2, respectively. This wind tunnel is called the closed circuit type, and it is capable of performing experiments at an air velocity of up to 60 m/s. Under the measurement unit, a pyramid type six-component balance is installed which can measure the forces and moments in three directions occurring in the carrier. As shown in Fig. 4, the carrier model is connected to the pyramid balance on the lower side through two columns installed at the measurement unit.

As stated previously, by increasing the wind resistance of the carrier, the wind resistance in lateral directions is considered to be more important to secure safety. Therefore this experiment was conducted on the wind resistance in lateral directions. For wind in a lateral direction, the relation between the carrier and the wind direction was expected to be as shown in Fig. 5 and, as the first step, testing was started at angles of θ = 0°, 10°, and 20°. The carrier was fixed aslant at these angles, and the possibility of increase in wind resistance in lateral directions by the installation of fairings was examined.

Three types of fairing mounting positions, i.e., upper surface only, upper and lower surfaces, and lower surface only were selected, as well as three types of fairing mounting angles of α = 10°, 20°, and 30°. Also the wind velocity was changed in increments of 10 m/s within a range of 10 to 40 m/s in stationary wind.

The items to be measured were specified as lateral force, lift, and rolling moment which were measured under the directions shown in Fig. 6 taken as positive ones.
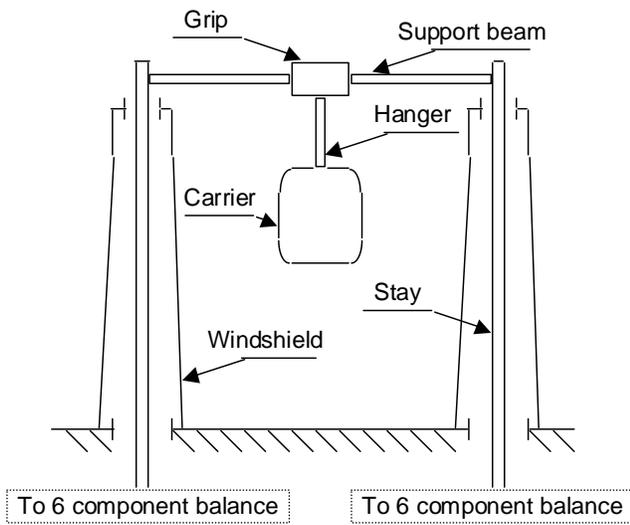
4. Results of the experiment
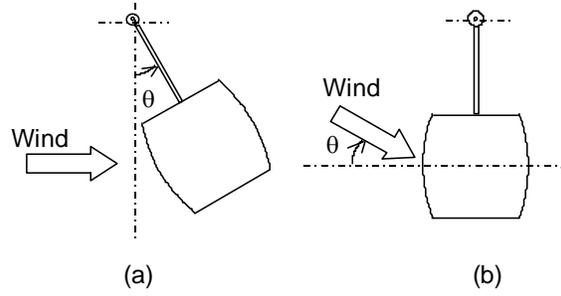
Fig.4 Experimental equipment
at measurement unit
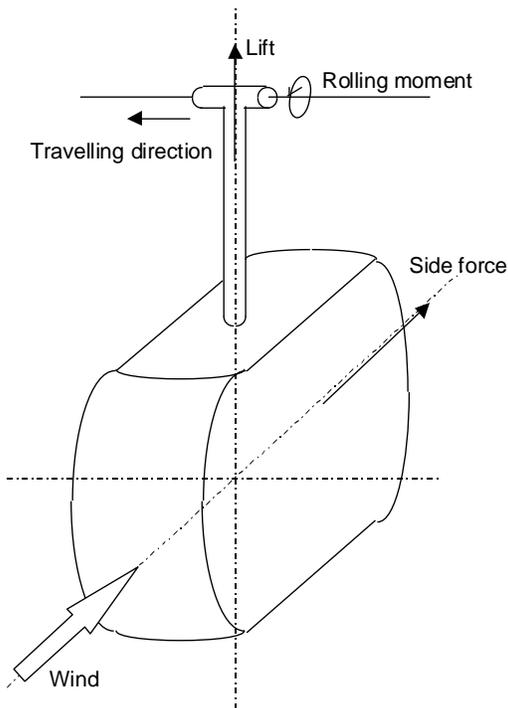

Fig.5 Relation between carrier
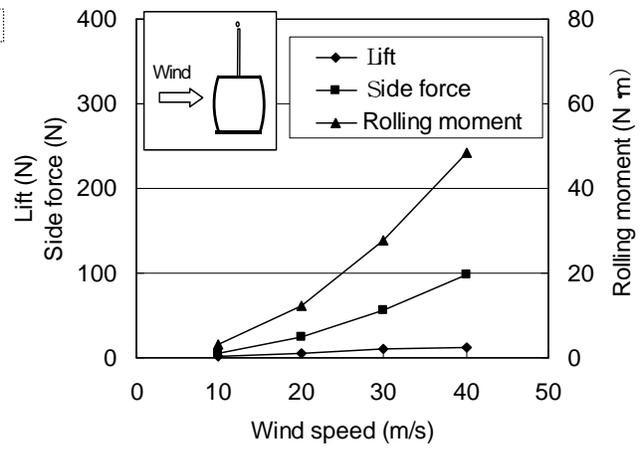and wind direction

Fig. 7 Aerodynamic characteristics
of carrier

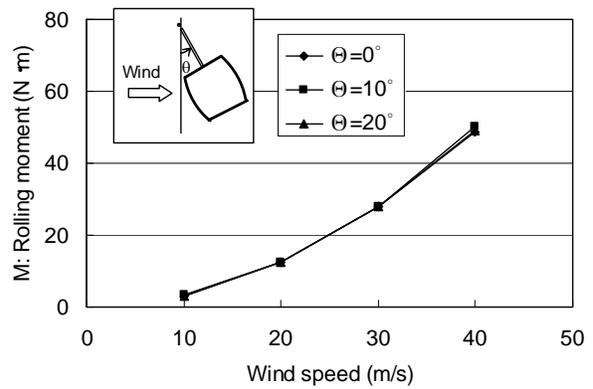Fig.6 Aerodynamic force and
rolling moment acting on carrier

Fig.8 Rolling moment of inclind carrier

4.1 Aerodynamic Characteristics of Carrier model

The aerodynamic characteristics of the carrier model obtained when fairings were not installed are shown in Figs. 7 and 8. From the experimental results shown in Fig. 8, the rolling moment of the carrier under inclined conditions is found to vary slightly according to the angle of θ but is kept approximately at a constant value.

4.2 Effects of Fairings

The experimental results are summarized for each fairing's installation position. In the figure, the ordinate indicates the amount of variation in the rolling moment (ΔM) of the carrier in which fairings were installed, relative to that of the original carrier. When the value is negative, it indicates that the rolling moment is reduced by the installation of fairings, i.e., its effects are apparent.

4.2.1 Effects Produced when Fairings were Installed Only on the Upper Surface of Carrier

The results obtained when fairings were installed only on the upper surface of the carrier are shown in Fig. 9. In this case, the amount of variation in the rolling moment (ΔM) increased, and effects caused by the installation of fairings were not produced. In addition, this tendency was more remarkable the more the fairing installation angle (α) was increased. It is felt that this was because the lift of the carrier increased as the result of the increase in air flow velocity over the fairings.

4.2.2 Effects Produced when Fairings were Installed Only on the Lower Surface of Carrier

The results obtained when fairings were installed only on the lower surface of the carrier are shown in Fig. 10. In this case, the amount of variation in the rolling moment (ΔM) tended basically to decrease. At the fairing installation angle of $\alpha = 10°$, the amount of variation in the rolling moment (ΔM) was decreased at the carrier inclination angle of $\theta = 0°$, i.e., its effects were produced. However, at the angles $\theta = 10°$ and $20°$ its effects were

negligibly produced. At the fairing installation angle of α

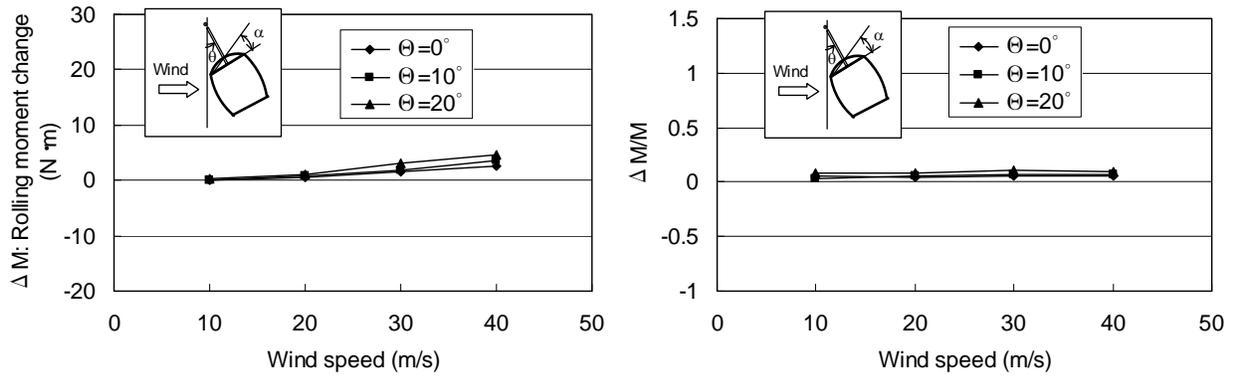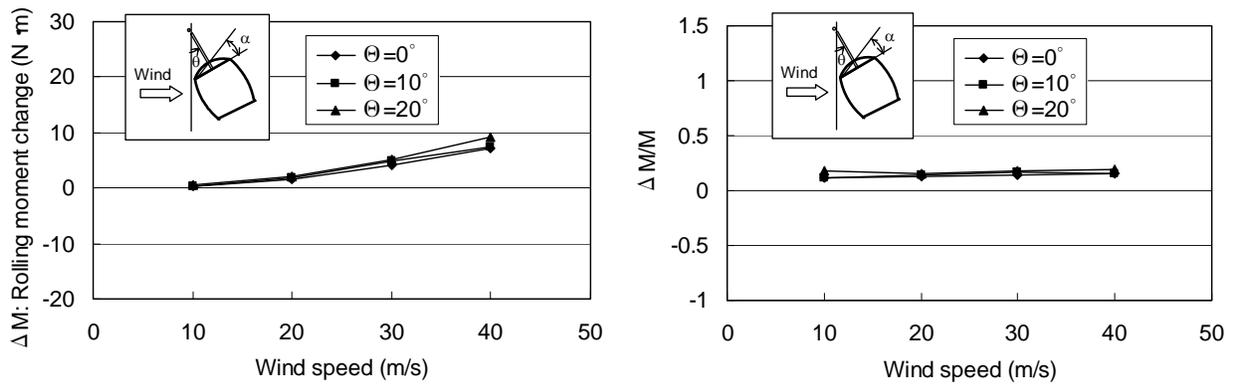Fig.9-1 Effect of fairing device (upper surface, α=10deg)

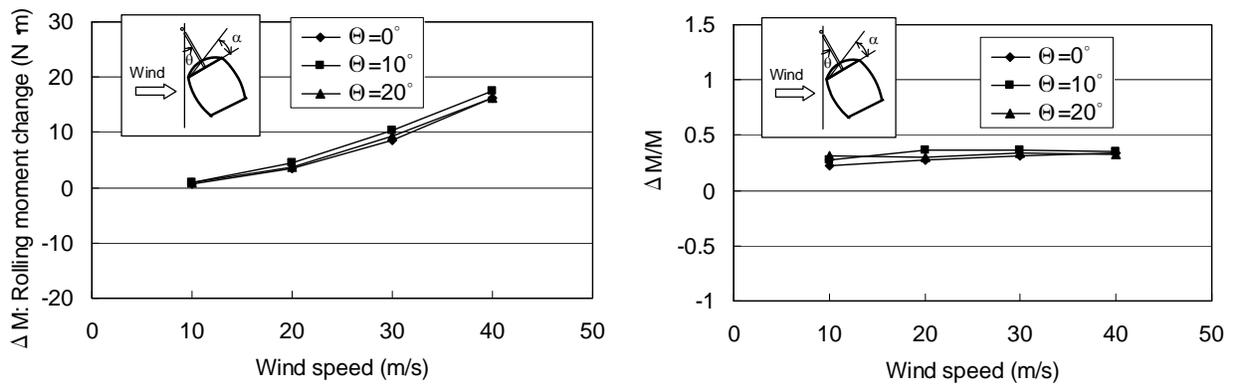Fig.9-2 Effect of fairing device (upper surface, α=20deg)

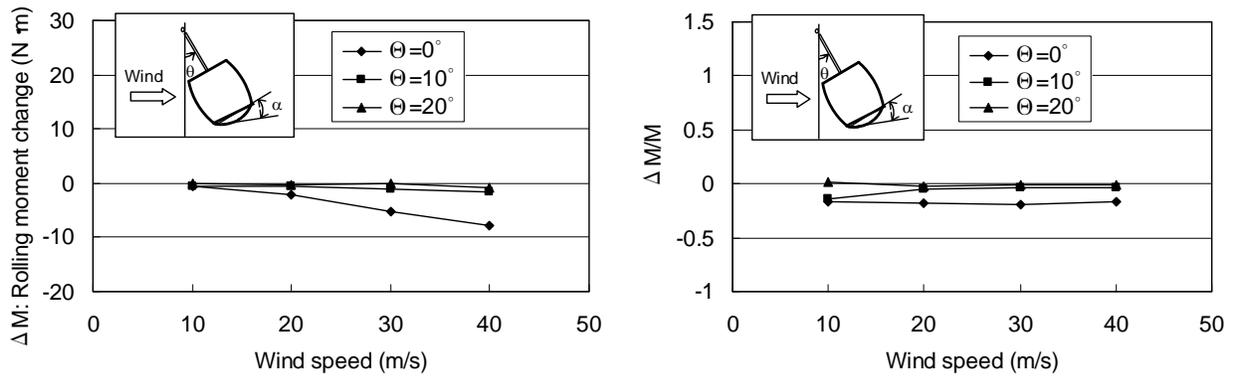Fig.9-3 Effect of fairing device (upper surface, α=30deg)

Fig.10-1 Effect of fairing device (lower surface, α=10deg)

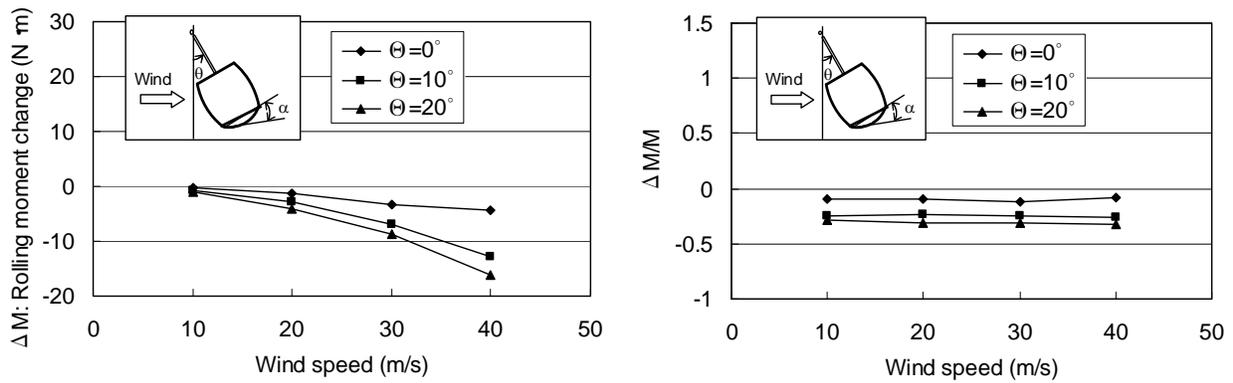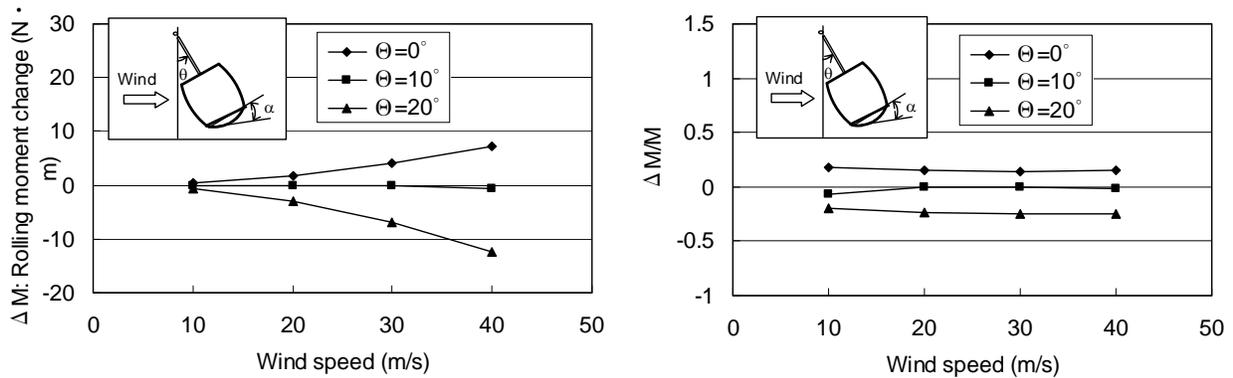Fig.10-2 Effect of fairing device (lower surface, α=20deg)

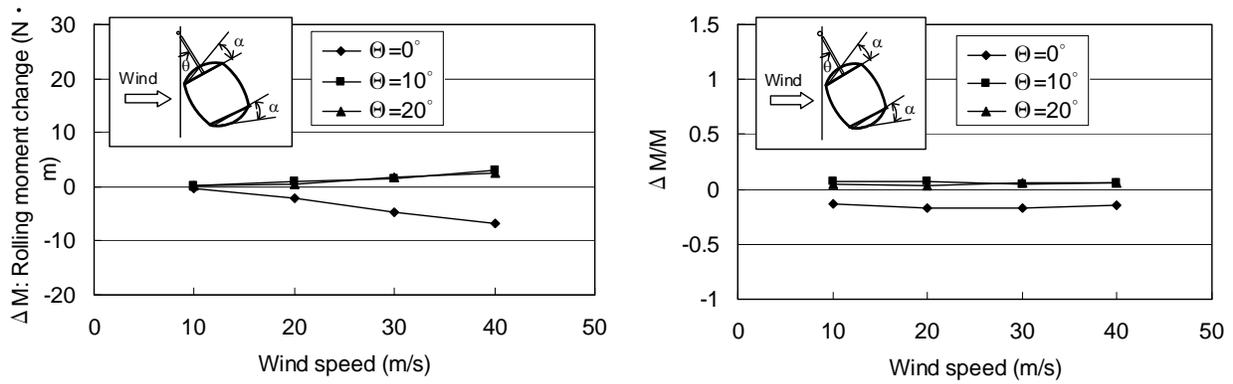Fig.10-3 Effect of fairing device (lower surface, α=30deg)

１０

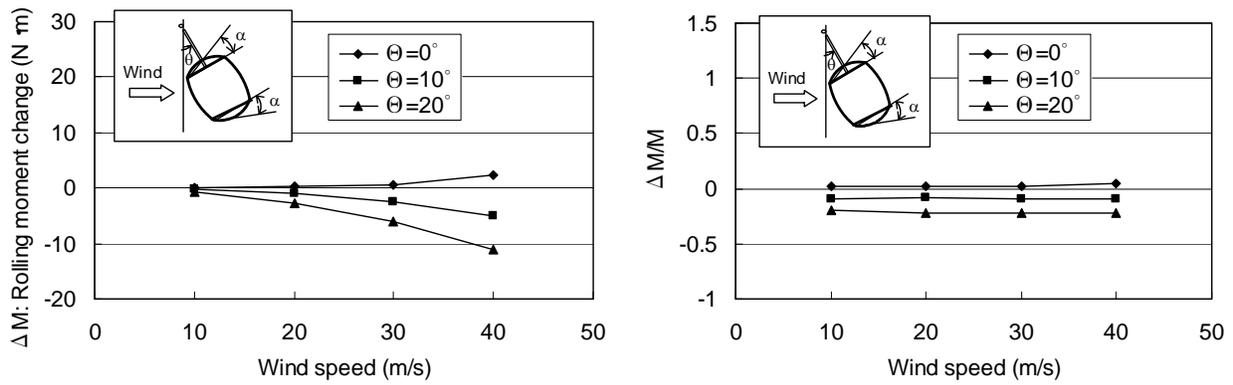Fig.11-1 Effect of fairing device (upper and lower surface, α=10deg)

Fig.11-2 Effect of fairing device (upper and lower surface, α=20deg)
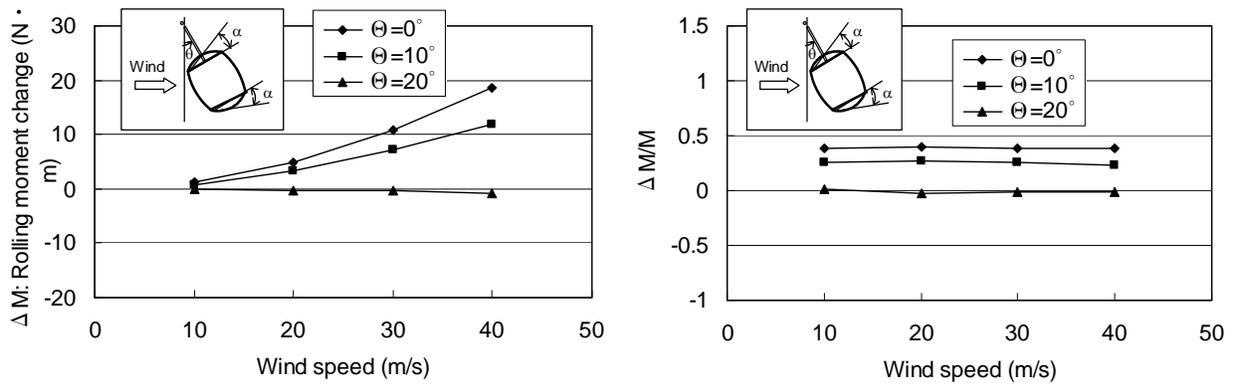

Fig.11-3 Effect of fairing device (upper and lower surface, α=30deg)

= 20°, the effects by the installation of fairings were produced irrespective of the value of θ. Its effects increased more as θ was increased more, and the rolling moment was reduced by approx. 33 % max., i.e., remarkably increasing effects were produced. Also, at the fairing installation angle of α = 30°, though the amount of variation in the rolling moment (ΔM) increased more when the carrier inclination angle (θ) was smaller, ΔM decreased more as θ was increased more, i.e., the effects caused by the installation of fairings were produced.

4.2.3 Effects Produced when Fairings were Installed on the Upper and Lower Surfaces of Carrier

Next, the results obtained when fairings were installed on the upper and lower surfaces of the carrier are shown in Fig. 11. In this case, at each fairing installation angle, the amount of variation in the rolling moment (ΔM) was near the sum of the values obtained when fairings were installed on each of the upper and lower surfaces of the carrier. At the fairing installation angle of α = 30° and the carrier inclination angle of θ = 0°, the experiment was suspended because abnormal vibrations occurred on the carrier at a wind velocity of 40 m/s. This phenomenon also occurred slightly in the other experimental conditions at the fairing installation angle of α = 30°, indicating that there is an optimum value for fairing installation angle (α).

5. Summary

The possibility of improving the aerodynamic characteristics of a carrier by the installation of fairings was examined using a carrier model in a wind tunnel test. The results obtained are summarized as follows.

(1) When fairings were installed only on the upper surface of the carrier, irrespective of the fairing installation angle (α), the amount of variation in the rolling moment (ΔM) increased, i.e., the effects caused by the installation of fairings were not produced.

(2) When fairings were installed only on the lower surface of the carrier, the amount of variation in the rolling moment (ΔM) was decreased basically, i.e., the effects

caused by the installation of fairings were produced.

(3) The effects obtained when fairings were installed only on the lower surface of the carrier were large when the fairing installation angle is $\alpha = 20°$, and the rolling moment was decreased by approx. 33 % max., i.e., remarkable effects were produced.

(4) The effects obtained when fairings were installed on the upper and lower surfaces of the carrier were near the sum of the values obtained when the fairings were installed on each of the upper and lower surfaces of the carrier.

Because the results of this experiment were obtained within the limited range of θ, in order to verify the effects caused by the installation of fairings, a wider range of examination must be performed on the carrier and wind direction. This will be taken as a problem to be solved in the future.

Lastly our special thanks are due to all interested people at the Aerodynamic Performance Department of the Scientific and Technology Agency, National Aerospace Laboratory who extended so much cooperation to us for this experiment.

6. Reference

(1) H. Sato, N. Hosokawa and M. Chishima, Improvement of Windproof Performance for Tramway Carriers by Means of Wing Device, OITAF-NACS 7th Symposium (1996)