A Wind Tunnel Study on Aerodynamic Characteristics of Ice Accreted Transmission Lines

Background

Galloping is wind-induced, self-excited vibration of ice-accreted transmission lines. We have developed a practical galloping simulation program, CAFSS, and have been conducting analyses to clarify the characteristics of galloping phenomena as well as to propose a rational countermeasure for large amplitude galloping. For such analyses, the modeling of aerodynamic force has been quasi-steadily approximated based on the aerodynamic coefficients acquired from conventional wind tunnel tests. However, in many of past wind tunnel tests, not only were accreted ice profiles not clearly defined but also quasi-steady aerodynamic coefficients were obtained simply on single conductor transmission lines. Therefore, to perform more realistic simulations, we started a wind tunnel study on unsteady aerodynamic force of ice accreted four-bundled and single conductor transmission lines, as a joint study with the University of Tokyo.

Objectives

To conduct wind tunnel tests in order to take an accurate measurement of steady and unsteady aerodynamic coefficients of ice accreted four-conductor bundled and single conductor transmission lines, and to clarify the aerodynamic characteristics of them.

Principal Results

We conducted two types of wind tunnel test, namely three-component balance tests and large amplitude rotational oscillation tests under 10m/s wind velocity, and measured steady and unsteady aerodynamic coefficients of four-conductor bundled as well as single conductor section models with artificial accreted ice whose profiles were clearly defined (Figure-1, Table-1). The findings obtained in this study are as follows:

1. Steady aerodynamic characteristics(Figure-2)

If a conversion is carried out by taking account of the differences in typical diameter and number of conductors, the drag coefficient and lift coefficient of a single conductor almost agrees with that of four-conductor bundle. However, because the effect of wake from upstream conductors in four conductors can not be taken into account, the aerodynamic moment coefficient does not agree between the conductor bundle and single conductor.

2. Unsteady aerodynamic characteristics(Figure-3)

The unsteady aerodynamic coefficients, which were measured by using an apparatus that can forcibly oscillate the models with large rotational amplitude around the models axes (amplitude: ± 55°, frequency: 0.3Hz), were affected by the angular velocity of the models rotation. And on the single conductor section model, the unsteady moments coefficients were not affected too much by angular velocity whereas on the four-conductor section model, the unsteady moment coefficients took quite different values from the steady moment ones. So the expression for the unsteady aerodynamic force of multi bundled conductors based on a single conductor ice accreted transmission line is difficult and it should to be studied further.

Future Developments

We will conduct several cases of numerical simulations using CAFSS in order to clarify the relation between the unsteady aerodynamic characteristics and galloping phenomena.

Main Researcher: Mikio Shimizu, Ph.D.,
Research Engineer, Structural Engineering Sector, Civil Engineering Research Laboratory

Reference

Shimizu, M. et al., 2004, “A wind tunnel study on quasi - steady and unsteady forces of ice accreted four bundled and single conductor transmission lines”, CRIEPI REP. U03044 (in Japanese)

(a) section model (4-1.00D) (b) measurement apparatus (c) cross section of the model

Fig.1 Section model, measurement apparatus and cross section of the model for wind tunnel tests

The above apparatus can forcedly oscillate the models with large rotational amplitude around the models axes.

Table 1 Specification of the models

Model Name	Number of conductors	Conductor length L(mm)	Conductor diameter D(mm)	Height of ice* (mm)	Projected area A(mm²)	Typical length B(mm)	Remarks
4-1D	4	1270	19	19(=D)	48260	247	A is calculated by 2D×L and B is assumed as the interval between conductor.
1-1D	1	1270	30	30(=D)	38100	30	A is calculated by D×L and B is assumed as D.

*) Height of ice represents the minimum distance from the tip of accreted ice to conductor surface. Refer to Figure-1(c).

C_D^4 : Drag coefficient of 4-1D
C_L^4 : Lift coefficient of 4-1D
C_M^4 : Moment coefficient of 4-1D
B_4 : Typical length of 4-1D
C_D^1 : Drag coefficient of 1-1D
C_L^1 : Lift coefficient of 1-1D
C_M^1 : Moment coefficient of 1-1D
B_1 : Typical length of 1-1D

$C_D^{1\text{-}4}=2C_D^1$ ·········· (1)
$C_L^{1\text{-}4}=2C_L^1$ ·········· (2)
$C_M^{1\text{-}4}=2C_M^1 \cdot B_1/B_4$ ···· (3)

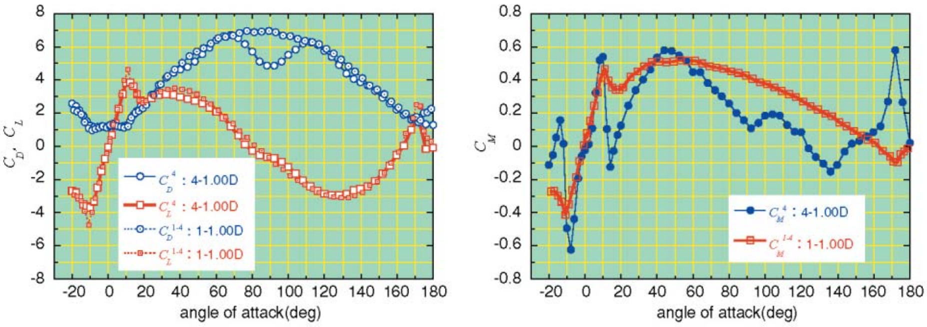

Fig.2 Steady aerodynamic coefficients obtained by three-component balance tests

By the conversion using the above equations, the drag and lift coefficient of 1-1D ($C_D^{1\text{-}4}$, $C_L^{1\text{-}4}$) almost agrees with that of 4-1D (C_D^4, C_L^4). But the aerodynamic moment coefficient does not agree with between them($C_M^{1\text{-}4}$ and C_M^4).

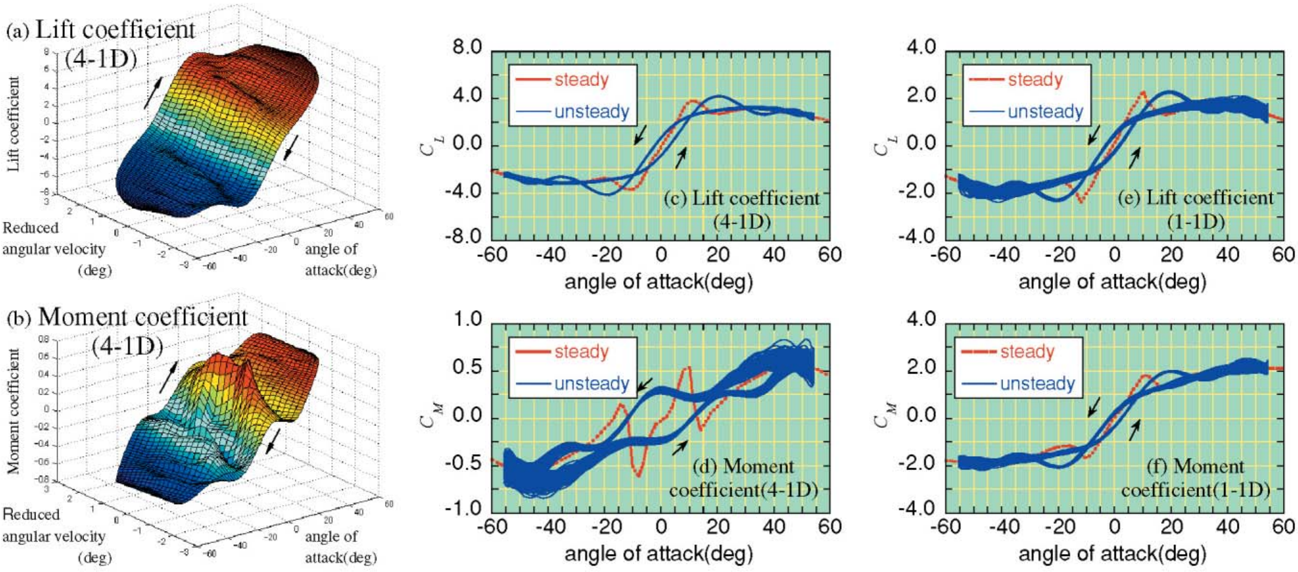

Fig.3 Unsteady aerodynamic coefficients obtained by large amplitude rotational oscillation tests

The coefficients were affected by the angle of attack, direction of oscillation (arrows in figures) and angular velocity.