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Interaction of Wind with the Ice-Covered Structural Members

Effets du vent sur des éléments de structures recouvertes de glace

Wirkung des Windes auf vereiste Bauteile

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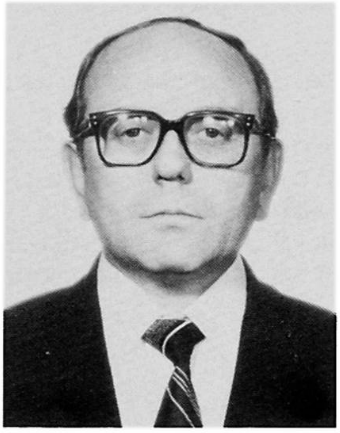

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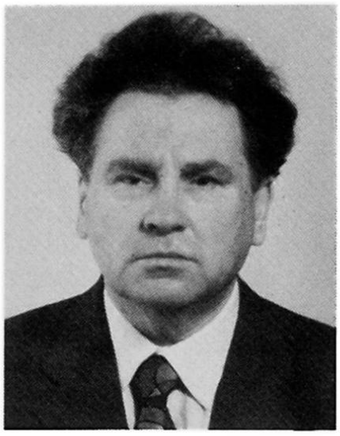

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SUMMARY
In the paper, the following problems are investigated: the nature of the flowaround and the aerodynamic characteristics wind/loads of different ice-covered structure models as a function of the wind flow velocity, angle of attack and the degree of its turbulence. The types of ice-covered models were chosen because of the analysis of the real ice-rimmed accretion forms on the structural members corresponding to the physical process of their formation.

RESUME
L'écoulement et les propriétés aérodynamiques de différents modèles de structures couvertes de glace sont étudiés en fonction de la vitesse du courant d'air, de l'angle d'attaque et du degré de la turbulence. Le choix des types de modèles recouverts de glace est réalisé à partir de l'étude des formes réelles des concentrations de givre et de glace sur les éléments de construction, en correspondance avec le processus physique de leur formation.

ZUSAMMENFASSUNG
Es werden das Umströmungsverhalten und die aerodynamischen Eigenschaften verschiedener Modelle vereister Konstruktionen untersucht, die von der Geschwindigkeit des Windstromes, der Angriffsrichtung und dem Grade der Turbulenz abhängig sind. Die Auswahl der Modelle erfolgte aufgrund eines Studiums von in der Wirklichkeit vorkommenden Bauteilen, die mit Eis oder Rauhreif beschlagen sind.

1. INTRODUCTION

The aeroelastic instability of the bearing structural members of constructions, machine building structures communication lines, power transmissions and antenna systems takes place due to the formation of the ice-rimed accretion during the desposition and freezing of the overcooled water drops in the rain, fog or wet snow medium at the sublimation of water steam. The origin of such formations is caused by the interaction of the wind flow with the ice-covered structural members. This phenomenon is investigated in the given paper.

In this paper the following problems were investigated: the nature of the flow-round and aerodynamic characteristics (wind loads) of different ice-covered structure models depending on the wind flow velocity, angle of attack and the degree of its turbulence. The types of ice-covered models were chosen due to the analysis of the real ice-rimed accretion forms on the structural members in relation to the physical process of their formation.

2. THE SELECTION OF MODELS

2.1. The grounds

The analysis of ice-rimed accretion forms on the structural members and their generalization gave opportunity to choose four types of ice-rimed accretion models which are the most characteristic and which differ in geometrical dimensions (elongation of cross-section form) and in texture (Fig. I). These qualities of the models are caused by the physical processes of ice-rimed accretion formation.

The type of ice-rimed accretion depends on the size of the drops, velocity of their freezing in the moment of the contact with structural members and on the location of the constructions and their neighbourhood to the water reservoirs. At the deposition of large drops the freezing is going on slowly at the temperature close to zero centigrade. Large drops have time to spread over a surface and to form smooth water film, frozen in the form of the smooth ice deposit-glaze. Due to the observed data of the Applied Climatology Department of the Vojejkov Central Geophysical Observatory, the glaze [1] appears at the temperature of the air 0... -3°C. As a rule, such type of deposit is observed on the horisontal and sloping members. The shape (geometry) of the deposit is characterized by the velocity of the freezing and formation of glaze. It is reflected in the dimensions of three first models.

The fourth model corresponds to the formation of ice deposit when freezing of the small drops without their spreading over the surface. The air bubbles remain between the freezing pieces of ice-drops, therefore the ice surface is rough, with separate bulges and grooves. The glaze deposits, formed during the sticking of wet snow, have the same texture. These types of deposits are characteristic not only for horisontal or sloping but also for vertical members.

2.2. The geometrical characteristics of models

The models are made of foam plastic and covered with nitrocellulose enamel. Their geometrical parameters are given in the Table 1.

NN of models	Chord b, mm	Cross size, d, mm	Centre position X_T mm	Section elongation characteristic $\bar{c} = d/b$	Lower edge radius Rmm
1	62,5	50	25	0,8	16
2	75	50	25	0,67	9
3	110	52	26	0,47	6
4	120	46	30	0,38	2

Table 1 The geometrical parameters of models

Models of the length 1 = 400 mm are supplied by the end plates which provide their two-dimensional wind flow.

3. THE EXPERIMENTAL TESTS

3.1 The aerodynamic loads

The aerodynamic drag coefficient C_x, lift coefficient C_y and longitudinal moment m_z are received by the weight method by means of measurement of the corresponding aerodynamic forces X, Y, M_z by three-dimensional strain-measuring device:

$$C_x = \frac{X}{qS}; \qquad C_y = \frac{Y}{qS}; \qquad m_z = \frac{M_z}{qSb},$$

where q - velocity head, $q = \rho V^2/2$; S - model characteristic area, $S = l \cdot b$; b - model chord; ρ - air tightness. The wind tunnel tests were carried out at flow velocities V = 10... 40 m/sec. The corresponding Reynolds numbers are $Re = (0,4... 2,6) \cdot 10^5$. The angle of attack changed in the range α = 0... 180°; turbulence intensity changed in the range ε = 0,5... 8%.

3.2 The influence of the flow turbulence

To receive the aerodynamic characteristics close to the real conditions of structural member flowed by the turbulent lower atmosphere layer, the air flow in the effective part of the wind tunnel was turbulizated by means of special nets with cells of different dimensions and different diameters of the wire. These nets were set up in the wind tunnel nozzle section. The degree of the flow turbulence is averaged after the measurements with the help of the hot-wire anemometer longitudinally and transverse to the flow in the model location area, at least in 10... 12 points. The parameters of the turbulent nets are given in the Table 2 [2] .

Cell dimensions, mm	60 x 60	30 x 30	60 x 60	50 x 50	90 x 90
Wire diameter (bar), mm	0,5	0,5	6	10	20
Flow turbulence degree $\mathcal{E}$, %	0,8	1,5	2,5	6	8

Table 2 The parameters of turbulating nets

3.3 The experimental results

The results of the wind tunnel tests of models N 2 and N 3 are given in the Figures 1 and 2. These models turned out to be the most sensitive to the wind flow effect. It is confirmed by the character of the lift force change with the increase of the angle of attack. Three regions of angles of attack $0 < \alpha_1 < 15^o$; $85^o < \alpha_2 < 95^o$; $120^o < \alpha_3 < 160^o$ were discovered. In these regions the negative gradient $c_y^\alpha = dc_y/d\alpha$ surpasses by far the drag coefficient.

4. CONCLUSION

The analysis of the wind tunnel test results of all models made it possible to come to the following conclusions:

- there are three main regions of angles of attack, in which aeroelastic instability according to Den-Gartog self-excited galloping oscillations is possible to appear;
- the critical velocity of galloping is minimum for the model N 2 at the angles of attack in the region $\alpha_2 (c_y^\alpha + c_x = -7.6)$ and for the model N 3 at the angles of attack in the region α_1 $(c_y^\alpha + c_x = -1.4)$;
- the prediction of criteria of appearance and parameters of aeroelastic self-excited oscillations according to Den-Gartog at glaze-wind loads is possible to realize due to formulae [3]: for the critical velocity

$$V_{cr} = \frac{2 m \delta \omega_o}{-(c_y^\alpha + c_x)\pi \rho d} ,$$

and for the amplitudes

$$\bar{a} = \frac{2V}{\omega_o d}\sqrt{1 - \frac{V_{cr}}{V}} ; \quad \bar{a} = \frac{a}{d} ; \quad V > V_{cr} ,$$

where δ, m, ω_o, d are, correspondingly, oscillation logarithmic decrement (at $V = 0$), linear mass, natural angular frequency of vibrations and midship section (at $\alpha = 0$).

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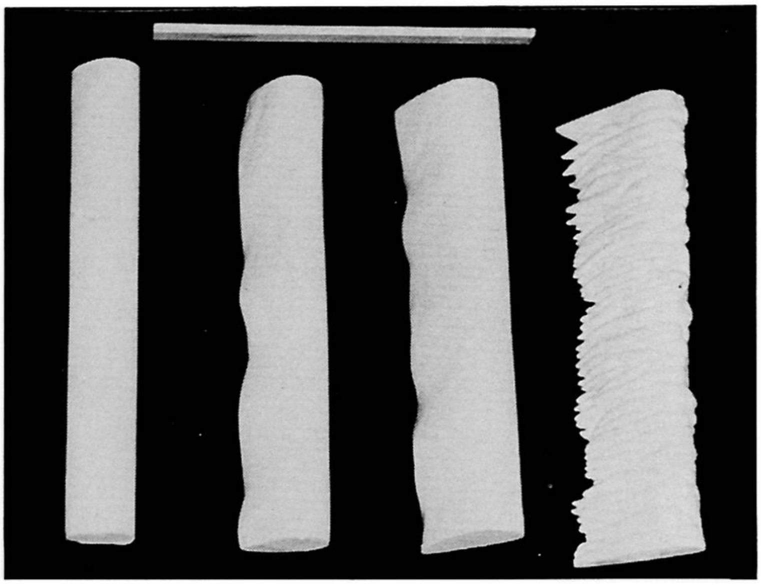

Fig.1 The general view of models

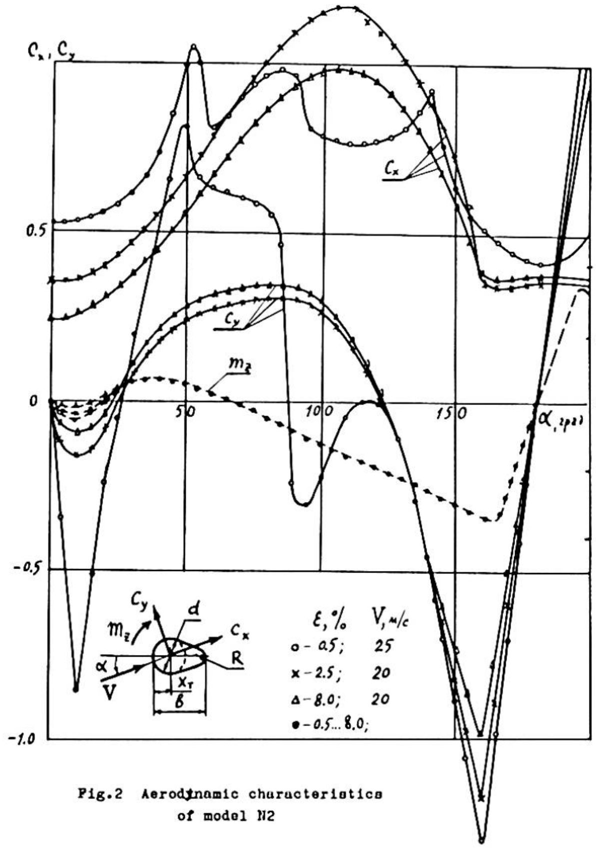

Fig.2 Aerodynamic characteristics of model N2

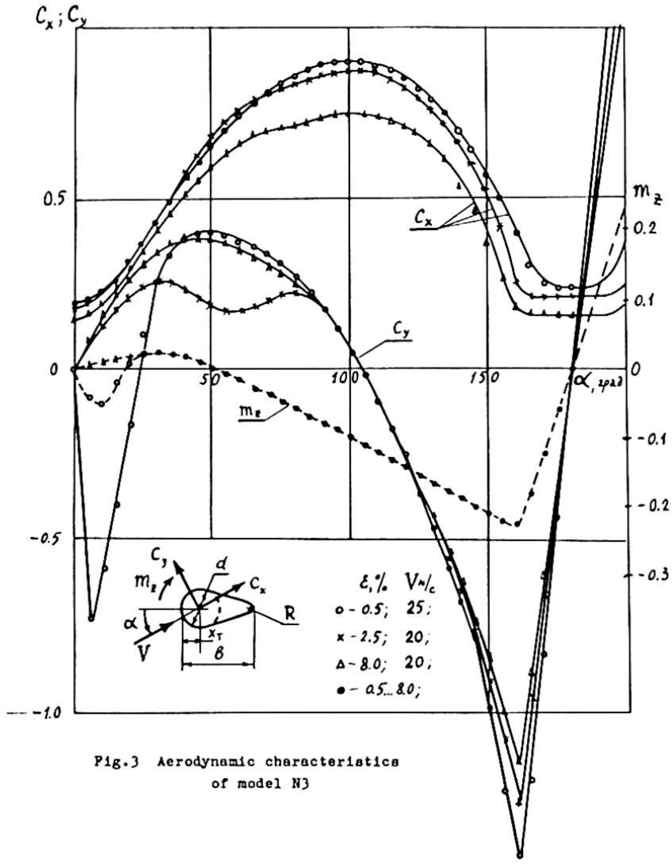

Fig.3 Aerodynamic characteristics of model N3

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