EXPERIMENTAL STUDY ON THE COLLECTION COEFFICIENT OF POWER LINE ICING

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Abstract: The effectiveness of collecting water droplets by the power lines strongly influences the accuracy of the predictive models. In a simulated atmospheric condition, a number of experimental tests were carried out to get the collection coefficient. Through changing the air temperature, wind speed and other meteorological parameters, a series of results were then compared to that of the empirical formula. The error is less than ±17% .

1. INTRODUCTION

Wire icing is caused by impingement of supercooled water droplets in airflow on an exposed object at the low temperature.

Conductors icing is relate to the effectiveness of the captured supercooled water droplets frozen on the surface of conductors. The collection efficiency E, defined as the ratio of the actual mass flow of impinging water droplets on the wire to the water mass flow which would be experienced by the surface if the droplets were not deflected in the air stream.

In this paper, the lab of the artificial environment produced the needed natural environmental condition. Through changing the air temperature, wind speed, droplet diameter and other meteorological parameters, we obtained some laws of conductor icing collection coefficient under different meteorological conditions.

2. RESULTS AND DISCUSSION

Through analyzing and calculating we found that collection coefficient increases with the speed or the droplet diameter increase, while collection coefficient decreases with the wire diameter increases. The results are shown in Fig1.

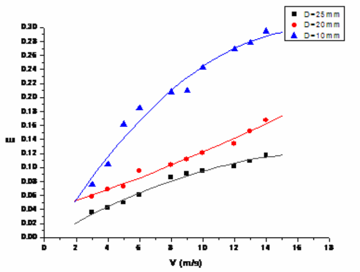

Figure 1: Effects of wind speed to the collection coefficient

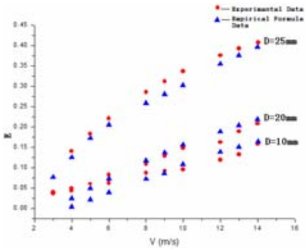

Figure 2: Comparisons between experimental data and results using empirical equation

Comparisons between experimental data and results using empirical equation are shown in Figure 2.

When wind speed is small, the weight of absorbent paper measured is small, resulting in relative large errors. So in addition to the low wind speed (< 4m/s) the error is less than ±17% .

The experiment data is completed by several tests. On each test, the flow of nozzle, the actual wind speed and the pressure on wind compressor are not the same, resulting in the liquid water content is not constant.

Because of the restriction of the experimental device, the wind speed increases with decreasing the temperature on the test section, the wind speed decreases with increasing the temperature on the test section. So high temperature - high speed and low temperature -low speed are not easily to achieve. Even achieved, the error causes.

3. CONCLUSION

The main factor affecting the collection efficiency is the wind speed while liquid water content and temperature have no effect basically. Collection coefficient increases with increasing wind speed, collection coefficient decreases with increasing the wire diameter.

4. REFERENCES

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Experimental study on the collection coefficient of power line icing

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***Abstract*— it is an often-seen, natural phenomenon that power lines covered by ice at icing areas in winter. Examples of engineering problems involving ice accretion are icing of aircraft, power transmission lines, telecommunication towers and other structures. In the case of power lines, predictive models can be used as design tools in maintaining a reliable power supply during harsh weather conditions, such as freezing rain storms. The effectiveness of collecting water droplets by the power lines strongly influences the accuracy of the predictive models. Laboratory experiments for the collection coefficient are investigated in this paper. In a simulated atmospheric condition, a number of experimental tests were carried out to get the collection coefficient. Through changing the air temperature, wind speed, droplet diameter and other meteorological parameters, a series of results were then compared to that of the empirical formula. The error is less than $\pm 17\%$ .The results of this study contribute to understand the mechanism of icing prevention on overhead lines.**

Keywords-collection coefficient; power line icing; cylindrical collector

I. INTRODUCTION

Atmospheric icing occurs when freezing raindrops, snow particles or supercooled cloud droplets come into contact with exposed surfaces. Wire icing is caused by impingement of supercooled water droplets in airflow on an exposed object at the low temperature. Damage to structures by ice loads causes huge economic losses and operational difficulties in electric power transmission and distribution, telecommunications, and so forth.

Conductors icing is relate to the effectiveness of the captured supercooled water droplets frozen on the surface of conductors. The effectiveness of conductors capturing the supercooled water droplets in the air describes as collection efficiency E, defined as the ratio of the actual mass flow of impinging water droplets on the wire to the water mass flow which would be experienced by the surface if the droplets were not deflected in the air stream, reflecting the efficiency of water droplets inertia agglomeration.

In this paper, the lab of the artificial environment produced the needed natural environmental condition. Through changing the air temperature, wind speed, droplet diameter and other meteorological parameters, we obtained some laws of conductor icing collection coefficient under different meteorological conditions.

As above-mentioned, wire icing is affected by the situation that wires capture the supercooled water droplets in the air. It relates to the droplet's diameter (d), wind speed (u), air density (ρ_a), viscosity and the wire diameter (D) and other factors [1]. Now integral model and droplet trajectory model are the major theoretical computation models.

Liu Heyun[2] proposed dimensional analysis of the collection efficiency, that the main factors affect the collection efficiency including wind speed u , liquid water content W , droplet diameter D , air kinematic viscosity υ and density ρ_a , etc. The correlation criteria described the collection efficiency of conductor icing was presented in:

$$E = f(\mathrm{Re}, De, We) \tag{1}$$

Here

$$\mathrm{Re} = \frac{uD}{\upsilon}\ ;\quad De = \frac{D}{d}\ ;\quad W_{\mathrm{e}} = \frac{W}{\rho_a}$$

With the rapid development of computer technology, simulation of conductor icing has made substantial progress. The model of icing is not only more comprehensive and integrative, but also is more complicated. Numerical computation of model includes the calculation of the atmospheric flow, droplet trajectories and other complex calculations, such as the calculation of the overall heat transfer coefficient HTC which determines the ice shapes. The NASA LEWICE model (Wright, 1993), tONERA model (Gent, 1990; Hedde, 1992), CANICE model (Paraschivoiu, 1994) and FENSAP-ICE model (Habashi, 1995) etc are well known numerical simulation models [3].

But most of the models are applied in the aircraft wing icing, quite little in conductor icing.

Ping Fu [3, 4] uses two-dimensional model to simulate the growth process of the overhead transmission lines icing. He uses CFD to solve the air flow, the Euler algorithm to solve the local collision coefficient, simulate the liquid collision efficiency LCE of water droplets LCE , the overall heat transfer coefficient HTC of the conductor icing and other parameters. But the results can be difficult to verify with the current experiments.

Yu Yang [5, 6] proposed a simplified gas-liquid two phase Eulerian model applicable to iced conductors, which is derived from Euler method used to calculate the local collection coefficient of iced airfoils. The simulation results show that: the maximum of the local collection coefficient appears in the area adjacent to the stationary point of the windward and the minimum at the upper or lower extremes of the conductor; the local collection coefficient is influenced mainly by the wind velocity and the droplet diameter; its distribution on the windward is influenced by the horizontal sextant angle and nothing influenced by the moisture content. Comparison between the simulation results and the experimental data in the literature show that the model can be used to calculate the local collection coefficient accurately in the icing condition.

Experimental investigation on the collection coefficient in ice wind tunnel is another method, but most of the ice wind tunnels are aimed at experiment of aircraft icing. Ice wind tunnels for the conductor icing are less. There are Canadian CIGELE icing wind tunnel, the United States CRREL laboratory, France Puy de Dome mountain wind tunnel [1] etc.

Zsolt Péter[7] did anti-icing experiments of the critical current in the wind tunnel with four different conductor types. In order to complete the mathematical model, it is necessary to assess the overall heat transfer coefficient (HTC) for stranded conductors. The HTC measurements are presented for conductors with different surface geometries. Personne [8] tested the collection efficiency in natural wind tunnel on the summit of Puy de Dome mountain in France. The discrepancies between the measured collection efficiencies and those predicted by Langmuir and Blodgett's theory increase with time and consequently with the ice thickness. Furthermore, the variations of the median volume diameter induce variations of the mass growth rate which are smaller than those predicted by the theory relative to smooth cylinders. These results point out the difficulties in modeling the detail of such ice profiles in the conditions which is on rough surface and the complex shape of the deposit is noncircular. However, these conclusions only apply to the range of experimental conditions.

II. EXPERIMENTAL SETUP

A. *Experimental facilities*

The experimental study was finished in the icing wind tunnel. This is a horizontal closed-loop low-speed icing wind tunnel, including a $2m$ long test section whose rectangular cross-section measures $0.25m$ in height and $0.30m$ in width. A rotating horizontal cylinder exposed to a flowing supercooled droplet cloud is placed in the mid-point of the test. The spray-bar system uses three nozzles located at the centre line. The maximum attainable air speed in the icing wind tunnel is around 30m/s. The cylindrical wire diameters are $0.025m$, $0.02m$ and $0.01m$, respectively, as illustrated in Fig.2.

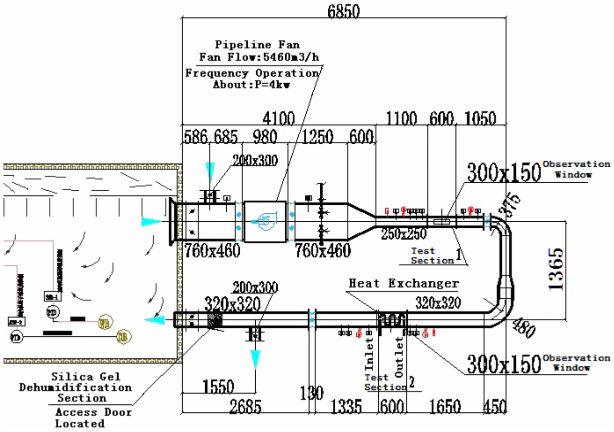

Figure 1. Sketch of experimental system

Figure 2. Experimental cylinders

B. *Measurement Methods*

Along the direction of flow, the water drops of certain diameter were sprayed into the wind tunnel with nozzle. When the flow field is stable and distribution of the water droplets is even, a small cylindrical surface which tied with absorbent paper (with diameter D and length l) exposed to the flowing supercooled droplet cloud in the wind tunnel. The water droplets are absorbed by absorbent paper after touching the cylinder. The cylinder is removed and the weight of water G is weighed after a period of time τ . The collection efficiency is then calculated by the following formula:

$$E = {}^{G}\!\big/_{DluW\tau} \qquad (2)$$

Here,

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E — collection efficiency; G — water weight(kg); D — the diameter of wire(m); l — the length of the wire(m); u — speed of air(m/s); W — the liquid water content(kg/m^3); τ ——time in the test(s).

The specimens are cylinders wrapped with absorbent papers of which diameters are $0.025m$, $0.02m$ and $0.01m$ and with experimental effective length. Experimental part of the cylindrical tube is covered by a plastic trap of diameter $0.03m$, available at both ends of the retreat. The purpose of this is to cover the sample and make it from the water droplets before and after the test. Specimens placed in the wind tunnel, and strictly ensure that its axis is perpendicular to flow direction. It rotated uniformly driven by a motor to $(80 \pm 20) r/\min$ around the axis of the specimen.

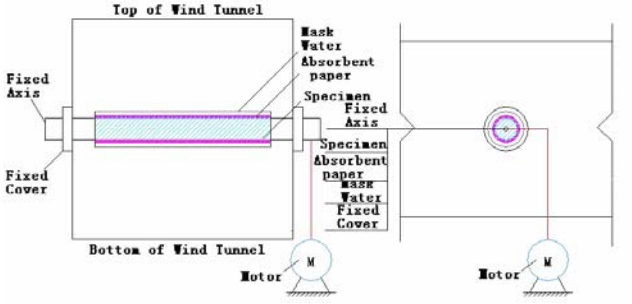

Figure 3. Schematic view of the specimen designed for collection efficiency

III. EXPERIMENTAL RESULTS

Through analyzing and calculating we found that collection coefficient increases with the speed or the droplet diameter increase, while collection coefficient decreases with the wire diameter increases. The results are shown in Fig4.

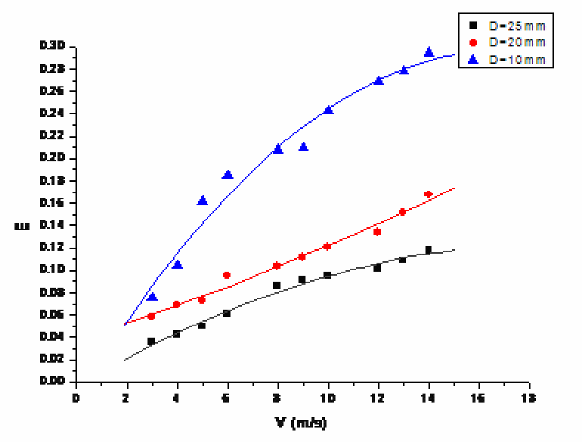

Figure 4. Effects of wind speed to the collection coefficient

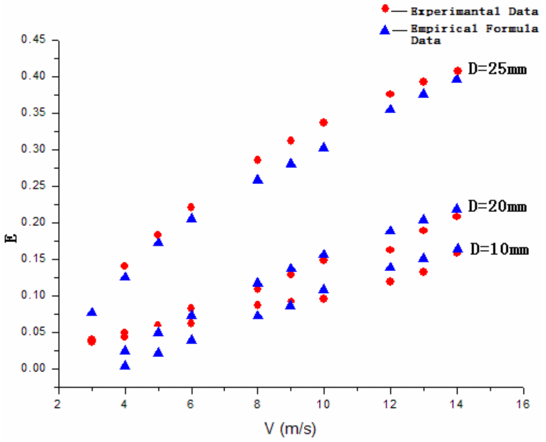

Figure 5. Comparisons between experimental data and results using empirical equation

The following fits to Langmuir and Blodgett's numerical data are used for comparison:

$$\left.\begin{array}{l} E_m = 0.5\left[\log\left(8K_0\right)\right]^{1.6} \quad for K_0 \leq 0.8 \\ E_m = K_0^{\;1.1}\left(K_0^{\;1.1} + 1.426\right)^{-1} \quad for K_0 > 0.8 \end{array}\right\} \tag{3}$$

Where

$$K_0 = K\left[0.087 \operatorname{Re}_d^{\;(0.76 \operatorname{Re}_d - 0.027)} + 1\right]^{-1} \tag{4}$$

Equation (4) is from Cansdale and McNaughtan. Here K is the inertia parameter and Re_d the droplet Reynolds number based on the free stream velocity v:

$$K = \rho_w v d^2 \Big/ 9\mu D \tag{5}$$

$$\operatorname{Re}_d = \rho_a d v / \mu \tag{6}$$

Using experimental condition with (3)-(6), we obtain theoretical E. Comparisons between experimental data and results using empirical equation [9] are shown in Figure 5.

When wind speed is small, the weight of absorbent paper measured is small, resulting in relative large errors. So in addition to the low wind speed ($< 4m/s$) the error is less than $\pm 17\%$.

The experiment data is completed by several tests. On each test, the flow of nozzle, the actual wind speed and the pressure on wind compressor are not the same, resulting in the liquid water content is not constant.

Because of the restriction of the experimental device, when do experiment, the wind speed increases with decreasing the temperature on the test section, the wind speed decreases with increasing the temperature on the test section. So high temperature -high speed and low temperature -low speed are not easily to achieve. Even achieved, the error causes.

IV. CONCLUSION

By the experimental researches, we can obtain the following conclusions:

*1）*The main factor affecting the collection efficiency is the wind speed while liquid water content and temperature have no effect basically.

*2）*Collection coefficient increases with increasing wind speed, collection coefficient decreases with increasing the wire diameter.

*3）*A series of experimental results were compared to that of the empirical formula. The error is less than $\pm 17\%$.

*4）*Through digital calculation, we can see that the size of supercooled water droplets in the air has impact on the collection efficiency. But because of the restrictions of time and conditions, studies of its impact are not researched in this experiment.

ACKNOWLEDGMENT

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