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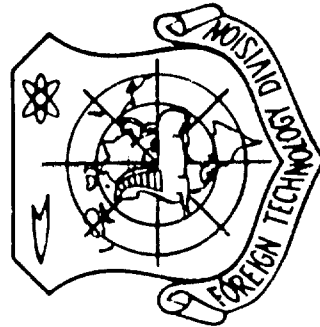


MEASURING AVERAGE WIND SPEED

by

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MEASURING AVERAGE WIND SPEED

V. Yu. Torochkov and D. Ya. Surazhskiy

Problems related to inaccuracy in measuring average wind speed by rotating wind measuring devices are examined and results of several field and laboratory tests are set forth.

It is now an established fact that anemometers can in some instances raise, and in other instances lower, the actual value of the average wind speed [2]. In work [1] especially it was demonstrated that one reason for this is the difference in the active aerodynamic moments of acceleration and deceleration of the anemometer. Heterogeneity of the aerodynamic moments which arise with a change in the sign of the time derivative of wind speed represents, from the standpoint of instrument construction, changes, as it were, in the structure (inertial properties) of the anemometer. Based upon this premise the transient processes of the anemometers during acceleration and deceleration must be different for the entire period that their general nature is retained.

To prove the above-stated a number of transient processes were recorded using a windmill and a cup anemometer (Fig. 1). Parameters of the devices tested:

- a) windmill anemometer with fixed pitch: angle of pitch at blade end $\alpha = 45^\circ$, diameter of sweep $D = 400$ mm;
- b) cup anemometer with fixed pitch: diameter of conical cups $d = 80$ mm, arm length $L = 125$ mm.

Two more curves are plotted on the resulting graph, for comparison: an exponential curve which approximates the given transient and a curve corresponding to the transient of the anemometer during acceleration. An examination of these curves indicates that the time constant of the exponent which approximates the transient during deceleration is approximately four times greater than the time constant of the analogous exponent obtained during acceleration of the windmill anemometer, and six times greater than that of the cup anemometer. The difference in the magnitudes of the exponent time constants corresponds to difference in the duration of the transient. From this it follows that the anemometer has, as it were, two frequency characteristics (Fig. 2): the first (curve 2) which is obtained when there is an increase in the magnitude of wind speed, and the second (curve 1) when there is a decrease in the magnitude of wind speed. The designation $[W(i\omega)]$ in Fig. 2 represents the transfer function of the anemometer in complex form [1]:

$$W(i\omega) = \frac{1}{iT\omega + 1},$$

where T is the time constant of the anemometer.

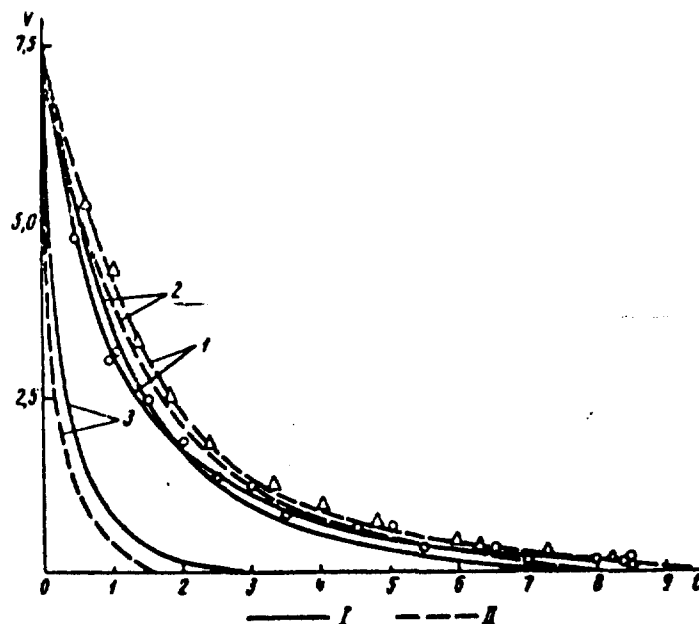


Fig. 1. I - Windmill anemometer; II - cup anemometer; 1 - experimental curve with acceleration and deceleration; 2 - approximating exponent with deceleration; 3 - approximating exponent with acceleration.

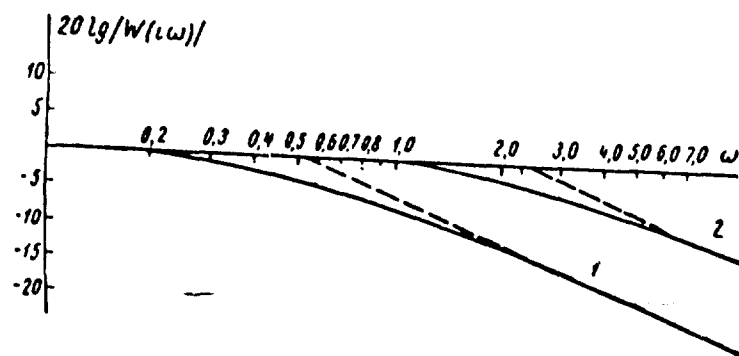


Fig. 2.

In this case it should be mentioned that due to the nonlinearity of the differential equation describing the work of the anemometer, the frequency difference (distance along the frequency axis) up to the connecting (reference) points ω_1 and ω_2 for the windmill anemometer (Fig. 2) and also the location of the frequencies at the axis, will to some degree depend on the speed of the air current. Taking into consideration that wind speed is a random process, it is possible to approximate, using frequency characteristics (Fig. 2), the expansion harmonics up to which the anemometer will correctly measure average wind speed. Obviously these will be harmonic components whose oscillation frequency will be less than the frequency ω_1 . If, however, the wind speed oscillation frequency is greater than ω_1 , then there will be a decrease in the average speed.

Figure 3 shows the results of comparative measurements of average wind speed between anemometers M-27 and M-12. Average wind speed is plotted along the abscissa. Along the ordinate is plotted the difference between the average wind speed measured by the anemogram of the M-27 and the speed measured by the anemogram of the M-12 [1]. It appears that up to a speed of approximately 10-12 m/s there is an increase and then a decrease in average speed measured by cup anemometer M-12 in relation to restrained anemometer M-27.

The material presented is especially representative, from the standpoint that true results can be obtained only when wind structure and dynamic properties of the anemometers are studied simultaneously. In this respect the use of analog computers for anemometer simulation and reproduction of wind as a random process

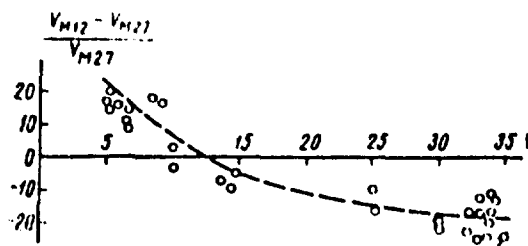


Fig. 5.

with desired statistical characteristics is highly expedient. The adoption of this simulation method to study anemometer functions and possibly instruments in general will allow a much faster parameter selection for anemometers designed for measuring the fast-changing parameters of the meteorological elements.

The above-stated concerns only devices for measuring wind speed. Obviously analogous problems exist for devices which measure wind direction. There is also a certain need for calculating dynamic characteristics when measuring pressure, temperature, and other meteorological elements, which is particularly felt in atmosphere sounding.

Because of the increased accuracy required in measuring the parameters of meteorological elements, designers have been presented the problem of perfecting meteorological instruments.

However, as indicated above, searches for essentially new solutions are required. The use of anemometers functioning in a restrained or similar system instead of rotating anemometers will be expedient, particularly in order to avoid substantial dynamic errors in measuring average wind speed and, to some degree, wind direction. In this case the bandwidth will be increased and the anemometer will always have an elastic restoring moment by which a dynamic as well as static balance of the measuring system is assured.

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ABSTRACT * 43 GICHESKIM PRIBORAM I METODAM NABLYUDENIY. TRUDY (RUSSIAN)

(U) An investigation was made of the transient response of rotating windmill and cup anemometers. In general, the experiments confirmed the contention that rotating anemometers indicate the average wind velocity as being higher or lower than the actual value, depending on the circumstances. The cause for this discrepancy is the difference in the effective aerodynamic moments during the acceleration and the deceleration of the rotor. The comparison of the transient response of cup and windmill anemometers showed that for the latter device the time constant of the transient process approximating the deceleration was four times greater than the time constant during the acceleration. For the cup anemometer this ratio was one to six. A comparative evaluation of the average wind velocity indication by a rotating cup anemometer using a restrained anemometer as a reference was also made. It was found that the rotating anemometer indicated higher average wind velocity for velocities up to 10-11 m/sec., and lower average wind velocity for higher values. The results of the investigation indicate that true results can be obtained only from a simultaneous study of the wind structure and the dynamic properties of the wind gages. Orig. art. has: 3 figures, 1 formula.