REMOTE CONTROL CONSTANT CURRENT ANEMOMETER

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Usually, a hot-wire anemometry equipment used in practice of aerophysical research should provide a number of manual operations at the adjustment and measuring. It is necessary to make compensation of a cable, measuring cold resistance of a hot-wire probe, switching circuit components for the overheating setting (resistance of heated hot-wire probe), set-up and optimization of frequency parameters of the electronic circuit, etc. Thus all data about state of the device also should be written down manually. All these operations make the measuring procedure as a time consuming process, especially when experimental conditions are far from ideal. Besides the length of the interconnect cable between the probe and a hot-wire anemometer has limitations as well. It is impossible to increase the length of the interconnect cable too much as resistance of a cable becomes comparable to the resistance of the probe sensing element, that causes a corresponding decrease of a level of the useful signal and essential cutting down of the anemometer frequency band. It is necessary to note that Constant Temperature Anemometer (CTA) is more sensitive to increase of the cable length with comparison to Constant Current Anemometer (CCA). CTA cannot be adjusted correctly with long cables. At the same time, when conditions of experiment do not allow to place the hot-wire anemometer close enough to the measuring point, the necessary length of a cable can amount to a few tens meters, instead of usual several ones. Such conditions can arise in wind tunnels with high level of acoustic noise, cryogenic wind tunnels etc., i.e. when ambient conditions around the measuring place do not allow the personnel to stay near it and at the same time the equipment should be controlled manually. It means that it is necessary to use the hot-wire anemometer with completely remote control to make measurements at such conditions.

Within the frames of the project TELFONA implementation it is supposed to perform measurements of flow fluctuation characteristics in test sections of cryogenic facilities PETW and ETW by means of fluctuation diagram technique. Thus, the possibility of using CTAs is limited. The given circumstance together with the above-stated problems has given in necessity of design of a remote-controlled constant current anemometer allowing to set required settings and transfer the measuring information on a computer equipped with the software for data processing. Such kind of hot-wire anemometer (CCA-6) was designed at Khristianovich Institute of Theoretical and Applied Mechanics. Front view of CCA-6 is shown in Fig. 1. There are the connectors for the probe, for measuring mean signal (DC), pulsation signal (AC) and the synchronization output (Sync) on the forward panel. From the synchronization output can be taken the rectangular signal produced by the integrated square wave generator. The same rectangular pulse is supplied to the hot-wire probe during a time constant selecting. The connector DC is mainly used to check the mean signal. Actually, the mean signal is measured by the built-in 12-bit analog-to-digital converter of CCA-6 and can be directly transmitted to the computer. The instantaneous signal of a hot-wire anemometer output, without the mean component, is taken from the connector AC. There are the control connector of standard port RS-232, power socket and the power switcher on the back panel of the CCA-6.
The typical measuring system on the base of the CCA-6 is given in Fig. 2. The personal computer, the external 14-bit analog-to-digital converter E14-440, the CCA-6 device and interconnect cables with adapters are necessary to realize a measuring procedure. The fluctuation signal from a hot-wire anemometer output (AC) is digitized by using the external analog-to-digital converter. Communications and control of the CCA-6 are provided with the help of a computer. The same computer is used to control the external analog-to-digital converter what simplifies the process of measuring essentially and allows one to save all data on the hard disk in automatic mode. Transmission between the personal computer and the hot-wire anemometer is realized through the COM port RS-232 of the CCA-6 and USB-COM adapter under the standard interface protocol with switching speed 9600 Kbit/s.

The hot-wire anemometer has the built-in microcontroller ADuC-842 with integrated 12 bit analog-to-digital and digital-to-analog converters. With the help of these devices are performed measuring all internal parameters of the CCA-6 (current, voltage, etc.) and its direct control. The CCA-6 control driver is kept inside the flash storage of the microcontroller. The given driver can be exchanged, if necessary. CCA-6 can supply the hot-wire probe with the constant current within the
range from 0 up to 300 mA. However, the limiting voltage across the electric circuit including the hot-wire probe together with the cable cannot exceed 2.5 V with the maximum power on the probe no more than 250 milliwatt. Here the resistance of the hot-wire probe can be changed up to 20 Ohm. The given CCA-6 characteristics are typical for hot-wire probes with a tungsten filament from 1 up to 10 microns in diameter.

Interconnection of the hot-wire probe directly with device CCA-6 is provided by means of four-wire scheme. Such manner of interconnection takes into account the resistance of the cable connecting the probe with hot-wire anemometer automatically and spare from the necessity of fulfillment of the procedure of compensation of the cable which cannot be performed in automatic mode.

Besides transmission of all working parameters from CCA-6 to the computer, there is possible to set the following parameters as well:
- Gain coefficient of the instantaneous output signal (AC) - 1, 10, 100 and 1000;
- Cut off frequency of the filter for the instantaneous signal (AC) - 200, 100, 50 and 25 kHz;
- Gain coefficient of a mean signal (DC) - 1, 10, 100 and 1000;
- Current value across the hot-wire probe;
- Time constant values for the compensating amplifier;
- Amplitude and duration of the square wave signal;
- To set operational mode of the CCA-6.

The hot-wire anemometer can work in 4 operational modes:
1. The mode of a short-circuited input. In the given mode the conductors connecting the probe with CCA-6 are closed by the internal low-value resistor what makes possible to change the hot-wire probe safely.
2. The mode of cold resistance measuring. In the given mode the fixed current 2.5 mA is put to the probe. The voltage across the probe is amplified in 10 times to increase the measurement accuracy of the probe resistance.
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3. The operation mode. In the given mode it is possible to set a constant current, i.e. the probe overheating, and measure the fluctuation signal by the external analog-to-digital converter.

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\text{Nu} = 0.54x - 0.28
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Fig. 4. Calibration of hot-wire anemometer on mass flow for CCA-6 and DISA55M01

4. The mode of time constant adjusting. In the given mode the square wave pulse from the internal generator is supplied to the probe. It is possible to adjust a time constant of the compensating amplifier in such a way the perfect square wave pulse at the output of the device is achieved. In this case the device is set correctly.

There are two amplifiers of the fluctuating signal in CCA-6: linear and compensating ones. The linear amplifier gains the signal 10 times within the whole frequency band. The response of the compensating amplifier is reverse to the frequency characteristic of hot-wire probe. The gain is changeable to compensate the frequency distortion of a signal from the hot-wire probe. The real
amplitude-frequency characteristics of the compensatory amplifier and theoretical curves calculated for the same time constants are compared in Fig. 3. It is clear there is a good agreement between them demonstrating the correct work of the compensating amplifier.

Two calibration relationships of Nusselt number Nu over Reynolds number based on the wire diameter Re_d obtained by CCA-6 and CTA DISA55D01 [1] at the similar working conditions are presented in Fig. 4. Test experiments were carried out in transonic test section of ITAM wind tunnel T-325M at freestream Mach number M_x = 0.7 and unit Reynolds number Re_1 = 15*25*10^6 1/m [2]. The probe with the gold plated tungsten wire 8 mkm in diameter was used [3]. Calibration data obtained by CCA and CTA type are in a good agreement, serving a clear confirmation of the correct operation of CCA-6. There are two fluctuation diagrams measured at the frequency 10.5 kHz within frequency band 200 Hz at Mach number M_x = 0.7 and unit Reynolds number Re_1 = 20*10^6 1/m shown in Fig. 5. An orifice of diameter 5 mm with movable piston inside was used as the generator of acoustic disturbances [4]. The generator has been located on a side wall of the test section. The probe was placed on the test section axis 15 mm downstream the generator. Both fluctuation diagrams are of the typical acoustic mode shape looking like V-letter [5, 6] and well coincide for new designed CCA-6 and industrial CTA DISA55D01.

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REFERENCES