GAČR P105/12/G059: Transient heat transfer coefficient on precooled circular cylinder at various Reynolds numbers

Ing. R. Král, Ph.D.
Ing. P. Beran, Ph.D.
prof. Ing. S. Kuznetsov, Dr.Sc.

The forced convection phenomena, usually expressed by the heat transfer coefficient, appear in many studies covering great number of scientific areas. It can be found, e.g. in the industrial cooling a drying applications, chemical processing industries as well as in development of new types of material for various disciplines. It has also an indirect impact on branches being on the first view far away from the thermal science. We can mention, for instance, the wind engineering in which the heat transfer coefficient helps to clarify the fluid flow characteristics in the vicinity of a body surface.

Heat transfer from a cylinder occurs through three mean mechanisms – convection, radiation and conduction. For this type of experiment, the effects of conduction and radiation are low. Hence, the majority amount of the heat energy is transported through the convection. The convective heat transfer from a cylinder depends on many factors. It is well known that the heat transfer rate is influenced both by fluid properties such as fluid velocity, dynamic viscosity or turbulence, and by parameters related to the body. Here, geometrical considerations of size and shape, material type, as well as roughness of the body surface, play significant roles. Although a large number of studies have been published on the heat transfer from a circular cylinder to the cross-flow, most of them used the experimental apparatus based generally on a heated aluminum cylinder that cannot correctly interprets all the above mentioned factors. When more porous materials of unstructured composition characterized by random surface imperfections are of interest, the results from this method are not entirely relevant and an alternative approach that better reflects the thermal and fluid flow characteristics of the examined element should be introduced.

In this work, the experimental investigation of unsteady averaged heat transfer coefficient is carried out. As distinct from conventional experimental methods which operate on the principle of a constant energy input in the form of electrical power, the specific volume heat capacity of the examined system is employed here. A pre-cooled circular cylinder with the known material parameters is heated naturally by airflow at a constant temperature. The heat transferred from the free-stream to the cylinder is determined by measuring the unsteady temperature distribution over the cross-section and also measuring the surface temperature. It provides an estimation of the fundamental parameters related to convective and conductive heat transfer phenomena at the same time.

In Figure 1 left, a view on the experimental specimen with measurement devices is displayed. On the right side, the figure shows the position of two sets of thermal probes placed in perpendicular planes oriented in the along-wind and cross-wind direction. The picture also presents the auxiliary frame that helped to set the thermistors in the required position while the concrete was being poured into the formwork, and its tamping. The frame consisted of two perforated plastic discs linked to each other by four metal threaded bars with nuts. This apparatus pre-stressed thick vinyl strings which formed a bearing orthogonal net for fixing the thermal probe. The probes were arranged in a sagittal form around the midspan in order to decrease the mutual influence of the measured points in the respective planes.

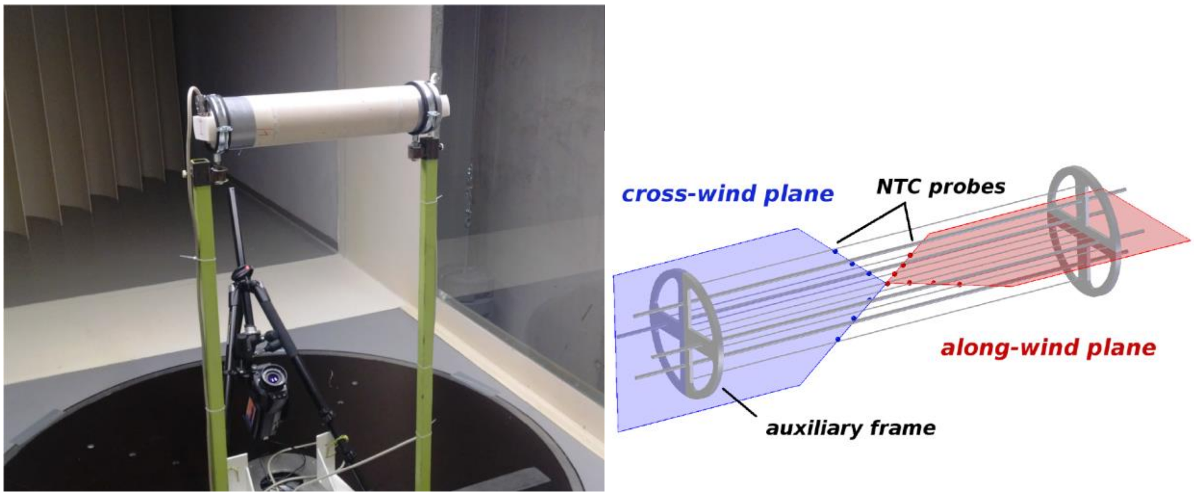

Fig. 1: Down-wind view on experimental set-up placed in the wind tunnel working section (left); Schematic diagram of NTC thermistor probes situated in two orthographic planes using auxiliary frame (right).

In Figure 2, the instantaneous temperature distributions over the circular cross-section are expressed over time. They were identified by means of the data measured by the thermal probes and multi-point thermovision. The red marks in the graphs indicate the position of the cylinder in dependency on the flow conditions. The mark *UP* indicates the top point on the cylinder circumference, whilst the mark *SP* stands for the front stagnation point. The approximation polynomials were constructed under the assumption of symmetric surface temperature distribution along the horizontal plane, so the thermovision measurement also applies to the upper leeward part of the cylinder. Due to the rounded shape of the cylinder, the surface temperature reading was limited by the angle of incidence of $\varphi < 60°$ defined as the angle between a ray incident on the cylinder and a perpendicular to the surface at the point of incidence.

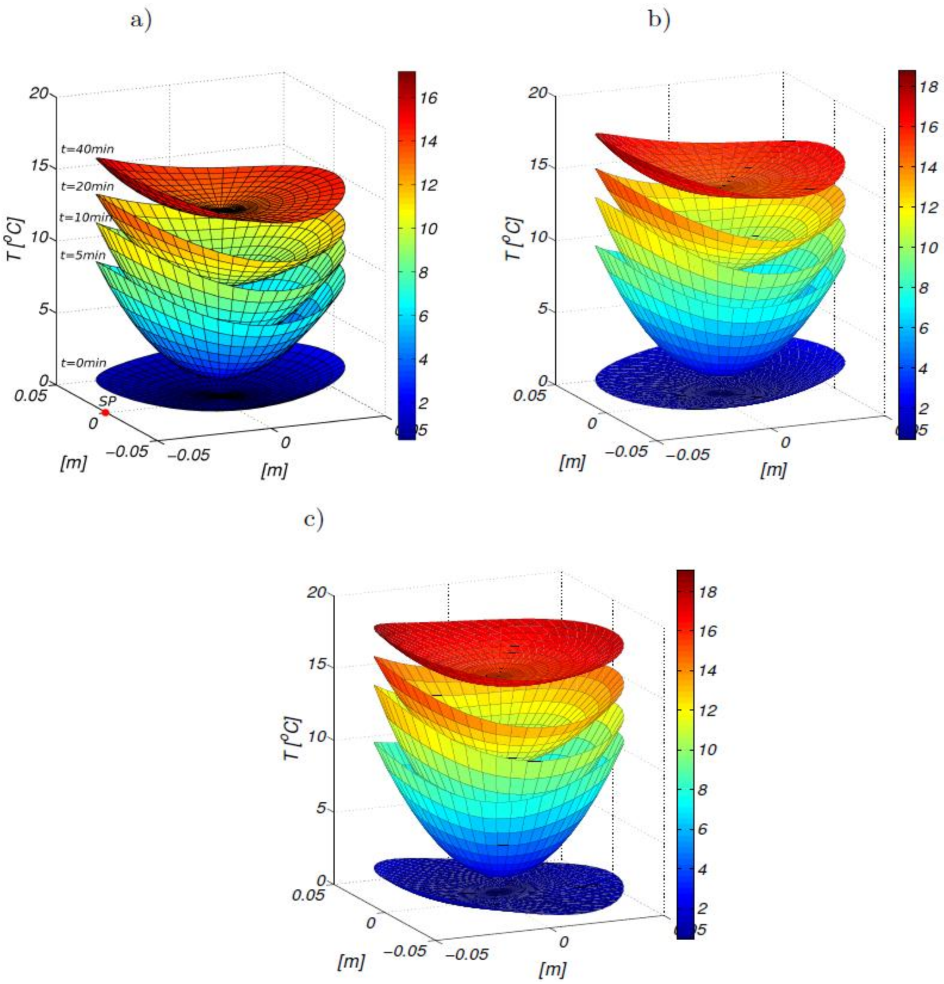

Fig. 2: Time evolution of temperature distribution over the cross-section at t = 0; 5; 10; 20 and 40 min at (a) U = 5 m/s; (b) U = 10 m/s; and (c) U = 15 m/s. The front stagnation point SP is marked with red dot.