Making jets of air visible in the infrared

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Abstract

An easy experiment is suggested to visualize the shape of a jet of hot air, coming from a hair dryer, which encounters obstacles along its path. Quite simply, owing to the heating produced on a flat surface, it is possible to acquire infrared thermal images of the jet. As a particular example, we observe the entrainment of air which is the basis of the Coanda effect.

Infrared cameras are becoming increasingly popular in educational laboratories as a valuable support for the study of thermal processes [1]. Somehow unexpectedly, these devices can also be used in different fields, as long as there are temperature fields to be visualized, associated with a series of phenomena of various interests. In the present work, we suggest a new, simple and indirect method of obtaining information on the shape of a fluid jet. More specifically, we consider the Coanda effect as a particular case study in which a moving fluid (gaseous or liquid) follow a convex solid surface as a consequence of the viscosity and associated entrainment of the surrounding fluid during its motion. This process has been known for a long time and its applications to aerodynamics and hydraulic configurations are well established and addressed in the literature, despite the fact that the actual role of the Coanda effect in determining the lift of an airfoil is still an argument of discussion [2]. Furthermore, modern household hair dryers, vacuum cleaners and bladeless fans, also known as “air multipliers”, are based on this effect and motivate students’ curiosity [3].

In general, we are all aware of very nice and effective computer-based visualization of fluid streams surrounding various aerodynamic profiles while it is well known that the direct, experimental observation of moving fluids is very challenging and not within the reach of school laboratories. With no pretending to overcoming these difficulties, and with simple demonstrative rather than quantitative intentions, we illustrate how to see the Coanda effect (as well as other fluid motions) using a domestic hair dryer and a thermal imaging camera.

In our setup the jet of hot air from the hair dryer is directed in a grazing direction to a flat and horizontal surface and along its path some obstacles are placed, as sketched in Fig.1. The flowing air heats the surface and its temperature is visualized using an infrared camera (it should be noted that this device does not acquire a direct signal from the flowing air because of the absent absorption features of this gas within the spectral range of the camera itself). The surface is painted with a black matte paint, thus ensuring reasonably good black body behavior. The images can be considered as an averaged representation of the air jet. To illustrate the effectiveness of this technique, we show some pictures taken with a FLIR One camera connected to a smartphone [5]. The hair dryer operated at intermediate air speed/temperature (precise values were not influential in this experiment). Infrared photographs were taken by starting from the “cold” table and letting the hot air to heat the surface for approximately 5-10 seconds before shooting the picture in order to produce a defined thermal imprint.

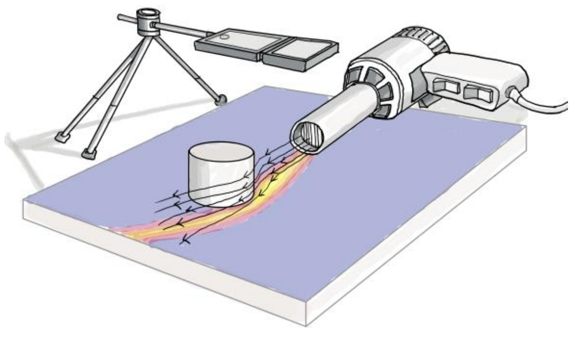

Fig 1: Schematic view of the experiment: the IR camera is placed above the surface heated by the warm air jet coming from the hair dryer.

In our laboratory, the environment temperature (about 16°C) allowed a relatively rapid cooling of the surface after switching off the hair dryer: obviously, before taking new photos, one has to wait for the previous thermal trace to disappear. The airflow from the hair dryer is turbulent, but the thermal signature is an averaged signal in which the turbulent wakes are smoothed out. The (false) color scale of the infrared image, that is. the temperature values, can be placed in approximate correspondence with the pressure/density field of the fluid stream, which is acceptable if we assume that the temperature of the jet is axially uniform. Because this is only partially true and because of complex temperature variations of the heated surface due to conductive and convective processes, the infrared image must basically only be interpreted from a visual, albeit quite suggestive, perspective. Fig.2 shows the “free” airflow, whilst Fig.3 depicts three cases of the air flow deflection attributable to the Coanda effect which acted on the fluid jet encountering various solid obstacles along its path. In the first, a flat wall was approached by the fluid despite its angle of inclination: the proximity with the wall reduces the amount of air which can be entrained and, correspondingly, it justifies a higher pressure at the opposite side of the jet, along which there is no upper limit to the amount of air that can be entrained. The infrared imprint shows quite clearly the onset of a “boundary layer” of fluid adhering to the bent wall. Similarly, the second and third photos in Fig.3 depict other cases of the Coanda effect along curved walls: a cylinder

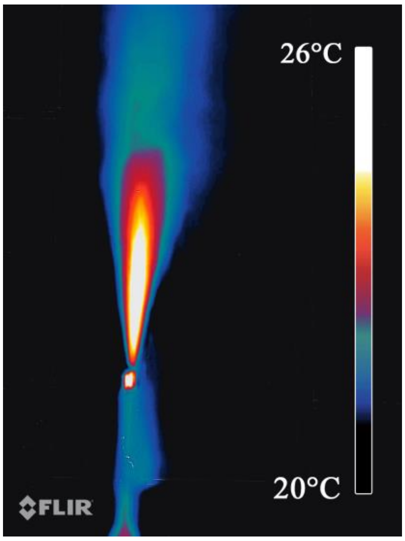

Fig.2: Thermal imprint of the free air jet. The hair dryer nozzle is in the lower part of the picture. The whole image covers an extension of approximately 50 cm x 70 cm.

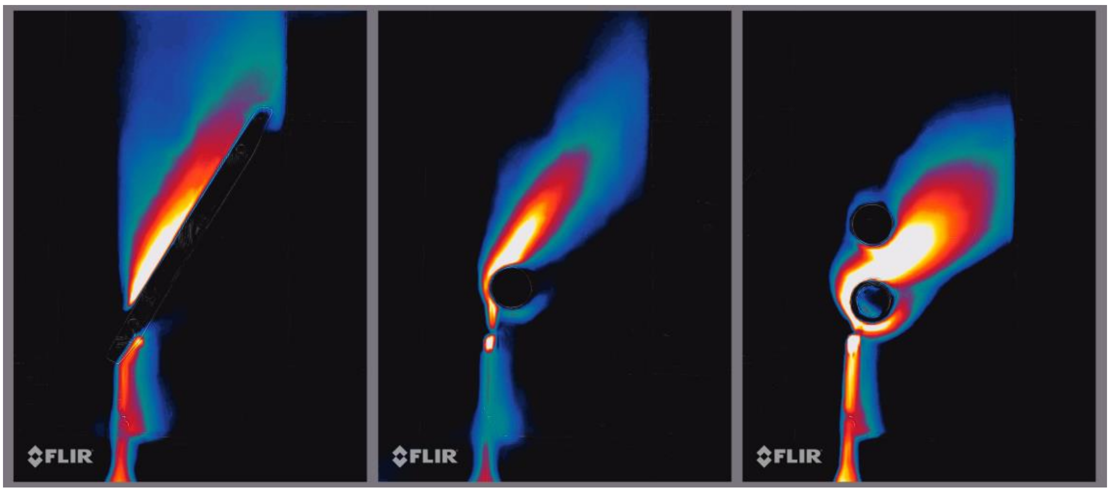

Fig.3: Three cases of Coanda effect. Left: a flat inclined wall; center: a (cardboard) cylinder; right: two cylinders. Temperature scales are the same as in Fig.2. The jet of hot air comes from the bottom of the pictures.

(here the internal cardboard roll of adhesive tape) that was hit laterally by the air flow led to its deflection at an angle of approximately 30°. A second cylinder was then added (as shown in the third photo) to obtain a sort of slalom path of the air jet. Recall that the deflection of air around the circular wall is related to the well-known and often made spectacular experiment of a ping-pong ball floating on a vertically directed jet stream. Its explanation goes beyond balance between the static weight and the upward push of the fluid, because buoyancy also occurs quite stably when the air jet is not vertical: it is the Coanda effect which leads to stationary equilibrium of forces in the horizontal direction [6]. We schematize in Fig.4 the dimensions and the positioning of the experimental setup adopted for taking the pictures reported in Fig.3.

Other obstacles, and more generally, different fluid paths and orientations can be considered and made visible using this simple approach. As previously mentioned, this technique is not intended to provide quantitative measurements of the processes under examination. However, it forms the basis for further discussion and, if necessary, could lead to more detailed studies on the fascinating world of fluid motion.

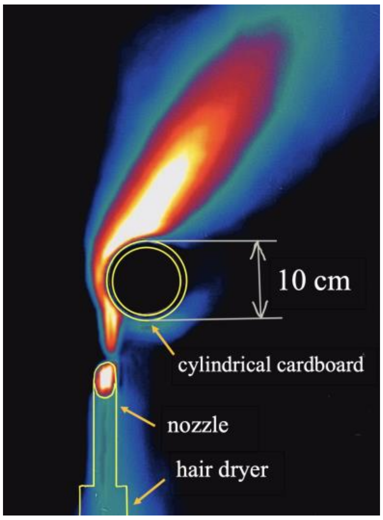

Fig.4 Schematic view of the apparatus superimposed to the infrared image.

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