AERODYNAMIC FLOW VISUALIZATION

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THE AERODYNAMICS PROBLEM

Aerodynamics is a difficult science because the medium with which the aerodynamicist works (air) *is not visible under normal conditions*. Valuable insights into the physical features or behavior of an air flow could be achieved if the entire flow field or certain streamlines or regions could be seen by the eye or by a recording device. *If the flow could be made visible by some kind of flow visualization technique, then it would be possible to observe flow phenomena which are essentially inviscid (e.g., vortical flows, flows distant from surfaces) as well as those phenomena which are dominated by the effects of viscosity (e.g., boundary layer flows, separation).*

FLOW VISUALIZATION

Flow visualization in air may be broadly divided into surface flow visualization and off-the-surface visualization.

Surface flow visualization involves tufts, fluorescent dye, oil or special clay mixtures which are applied to the surface of a model. Visual inspection of such tufts and coatings as a function of time, or after some time, will give valuable information on such things as the state of the boundary layer (laminar or turbulent), transition, regions of separated flow and the like. **It must be remembered** in such visualization that *what is observed on the surface is not always indicative of what is happening away from the surface*.

FLOW VISUALIZATION

The second type of visualization is off the surface and involves the use of such tracers as smoke particles, oil droplets or helium-filled soap bubbles.

The smoke particles and oil droplets are *very small and are light enough that they will follow the motion of the flow*; the soap bubbles *are small and are filled with helium to make them neutrally buoyant*. Each of these methods requires appropriate lighting and some device for recording the image such as a still or video camera. If the flowfield is illuminated in a plane by appropriate masking of the light source it is possible to examine discrete sections or slices of the flow.

FLOW VISUALIZATION

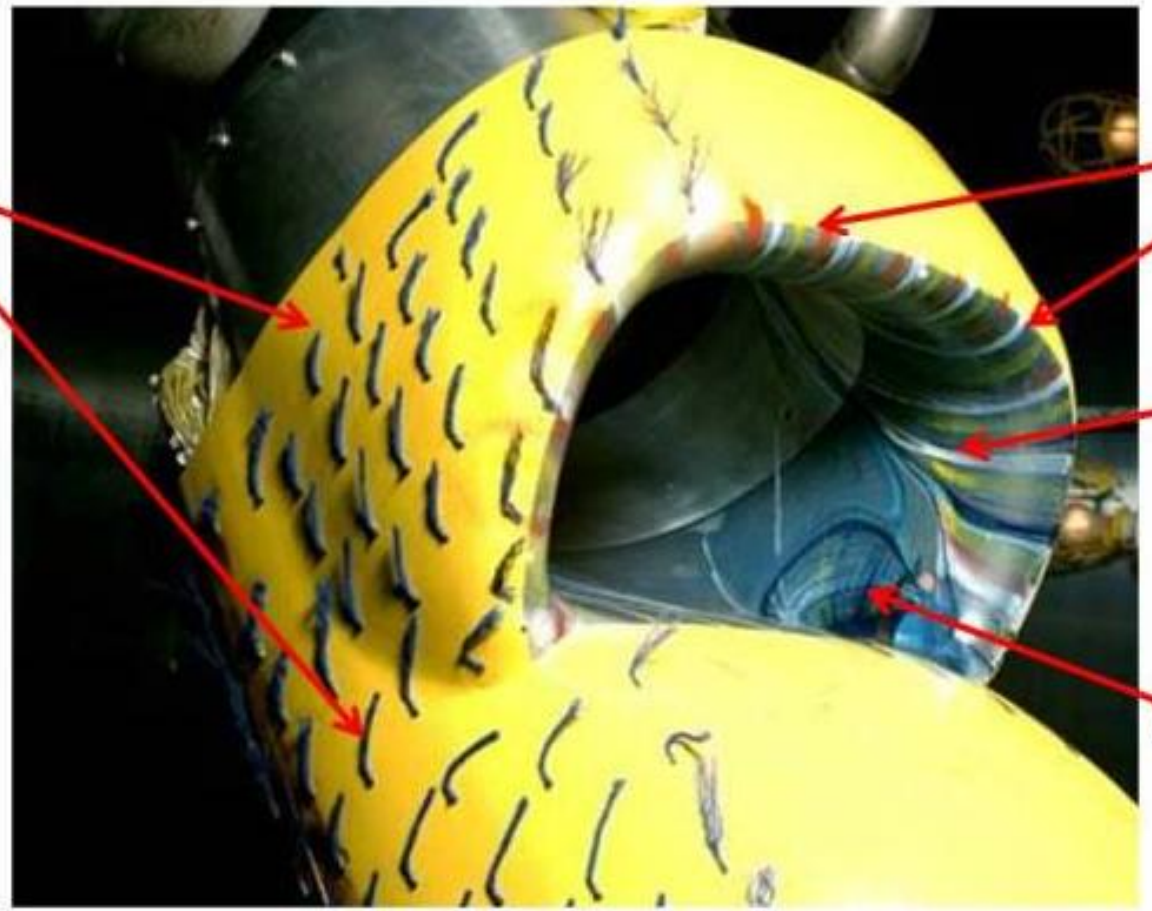
Flow visualization is an important factor in the aerodynamic development of passenger cars and ground vehicles. Includes numerous full-color photographs showing various flow fields. The following flow visualization techniques are used:

- Surface Flow Description Using Yarn Tufts
- Surface Flow Description Using a Continuous Oil Film
- Flow Field Description Using Smoke Streamers
- Flow Field Description Using Helium Bubbles Streamer
- Flow Field Description Using a Continuous Motion Survey - Computer Generated Graphics
- And Many More

SURFACE OIL FLOW VISUALIZATION

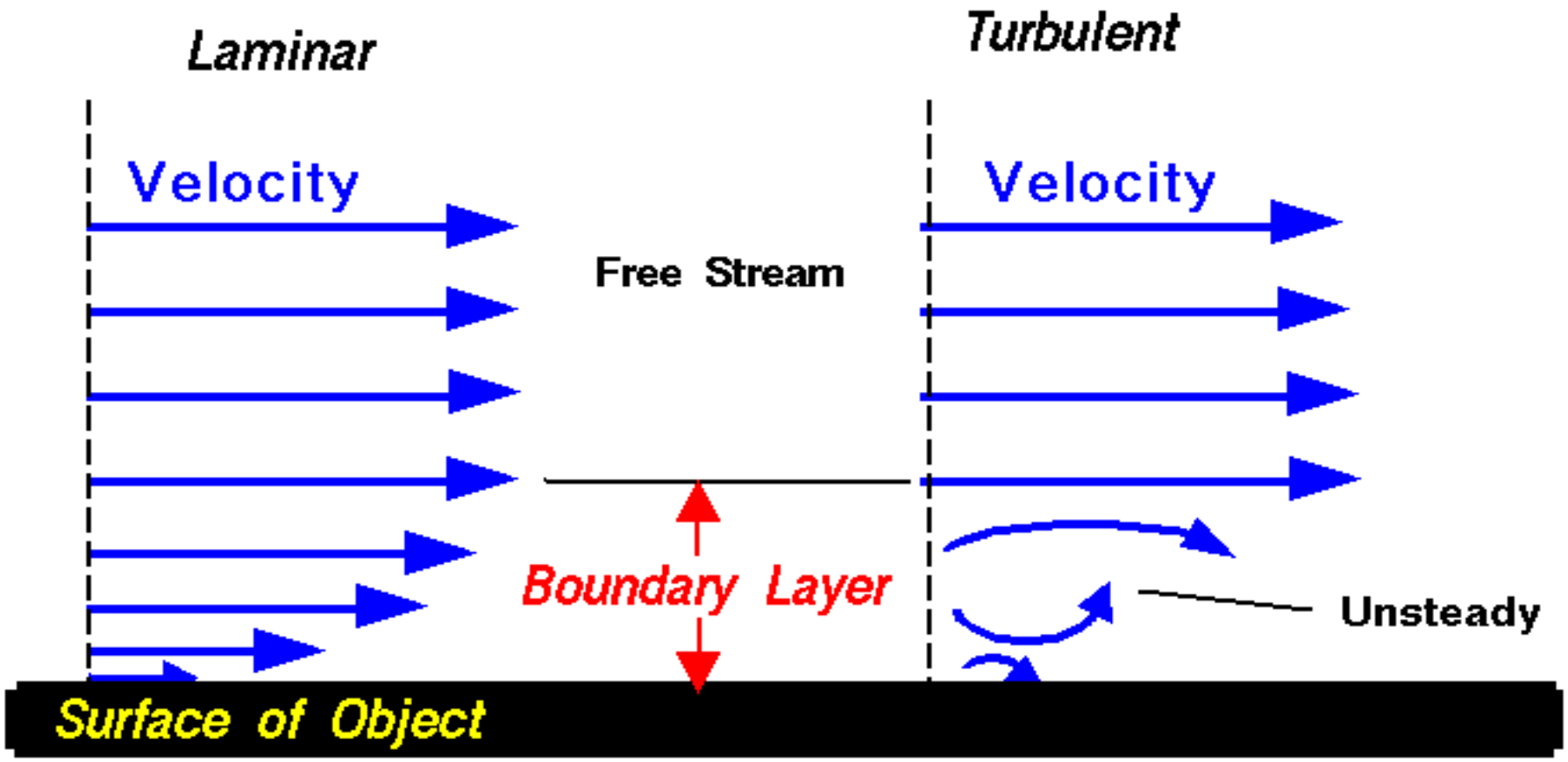
- An immiscible fluid may be applied *to the surface of a model* to provide a less intrusive method of sensing the *surface velocity of fluid flows*. The fluid will shear under the stress applied by the flow field. In wind tunnel aerodynamics it is common to perform oil surface flow visualization. *The oil travels in the direction of the airflow, and it may also be affected by pressure gradients applied over the surface. Pigment may be added to the oil to further show its flow properties and directions.*
- *Surface oil flow visualization can be quite useful but suffers from several drawbacks. The oil, like any fluid, is affected by gravity and will tend to flow down an inclined surface. If the body force of the oil is not strongly overcome by aerodynamic shear force then the results of the visualization may become unclear.*

Surface Oil Flow



Boundary Layer

Glenn Research Center



Velocity is zero at the surface (no – slip)

SURFACE OIL FLOW VISUALIZATION

The flow of the oil is time dependent, hence certain oils may be more capable of rendering dynamic effects than others. The oil can also be quite messy and will often flow into unwanted areas. The oil presents a moving boundary on a surface, and hence may change the characteristics of the flow field. The oil will also tend to reduce the roughness of the surface, and it can change the effective geometry of the surface by puddling and forming waves. All the same, the oil surface flow visualization method represents a useful class of flow visualizations.

LASER BASED FLOW VISUALIZATION

Flows may also be visualized by adding seed particles. *The seed particles should be able to maintain adequate dispersion in the flow, and ideally they should move with the fluid exactly. Seed can be added along selective dimensions or in a homogenous manner. The seed particles are also prone (склонный) to being ejected from vortices due to centrifugal force, and if not properly chosen body force can affect their motion.*

The advent of the laser was followed by the appearance of many sensitive and useful laboratory apparatus that took advantage of a concentrated, coherent, and often polarized beam of light. *Several different flow visualization methods rely on laser power to illuminate the flow field. Certain materials fluoresce or scatter light under the application of a laser's beam allowing visualization. Reflective, refractive, and fluorescent seed particles such as smoke or mist may be added to a clear fluid to allow visualization.*

Laser Sheet

TUFT FLOW VISUALIZATION

In wind tunnel experiments, tufts are *short strings attached to various locations of the foil, and observed during the experiment*. Here, we model these tufts with polygon segments connected by springs. *They change their orientation and shape in direct relationship to the flow data being visualized*. **The color** and **length** of the tufts can be altered *to show other flow properties such as velocity magnitude, integration age, etc*.

Figure 1. Wind blown grass field.

National Aeronautics and Space Administration

Smoke and Tufts