Surface Pressure Measurements on a Spinning Wind Tunnel Model

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Theme

A NEW experimental technique has been evolved to measure the pressure distribution acting on the surface of a spinning wind tunnel model. The technique is unique in that all elements of the instrumentation are internal to the model or are located outside of the wind tunnel, thus avoiding many of the technical problems and operational limitations associated with previous attempts to obtain these measurements. The approach is based on the use of a two part model with a nonspinning inner portion containing the pressure measuring instrumentation and a spinning outer portion representing the aerodynamic surface. The technique was successfully demonstrated by a series of subsonic wind tunnel tests of a spinning right circular cylinder in crossflow. Surface pressure distributions were obtained for selected tip speed ratios at subcritical, critical, and supercritical Reynolds numbers. The validity of the data was established by comparing the integrated pressure values with directly measured force data. The resulting pressure profiles provide a quantitative measure of the Magnus forces and allow interpretation of boundary-layer and flow-separation effects. The basic technique should be applicable to a variety of model configurations, angles of attack, and Mach number regimes.

Contents

The details of the cylindrical wind tunnel model are shown in Fig. 1. The model includes a stationary (i.e., nonspinning) cylindrical core. A thin-walled, cylindrical shell is located concentrically around the core and attached to the core by means of bearings located at each end. The shell is thus free to rotate or spin about the core and represents the external surface of the spinning model body. End plates are included to reduce tip effects. A pressure tap is located in the core at mid-span and oriented radially outward toward the point on the surface at which the pressure is being measured. A small vent hole is located through the shell at mid-span, such that it will line up with the face of the pressure tap once every revolution of the shell about the core. The gap between the face of the pressure tap and the inner surface of the shell is sealed in all directions (i.e., longitudinally and circumferentially) by means of a circular seal located around the face of the pressure tap. The cavity created within this seal will be open to the pressure acting on the outside surface of the shell when the vent hole is aligned with the tap. Once the vent hole rotates past this aligned position, the seal will cause the cavity to retain this pressure. The cavity will eventually assume a constant pressure with time; that being the pressure acting on the surface of the spinning body at that particular circumferential location.

The pressure tap is held in place by a cylindrically-shaped seal block whose outer surface is shaped to the inner contour of the shell. The surface includes a semi-circular groove into which a rubber "o" ring washer is placed. This washer represents the most important element of the system in that it provides the sealing function between the cavity and the rotating shell. Springs located within the seal assembly press the rubber "o" ring against the inside surface of the shell. Vacuum grease is placed on the inner surface of the shell to aid in lubrication and sealing.

Pressure measurements at various points on the surface of the spinning body can be obtained by positioning the core and the attached tap at different attitudes to the air flow. This is accomplished by simply rotating the core about its longitudinal axis to a particular angle and holding it there sufficiently long to obtain the pressure measurement.

Wind tunnel installation and instrumentation arrangement are shown in Fig.2. The model was mounted with its longitudinal axis (i.e., spin axis) vertical. Model spin was ob-

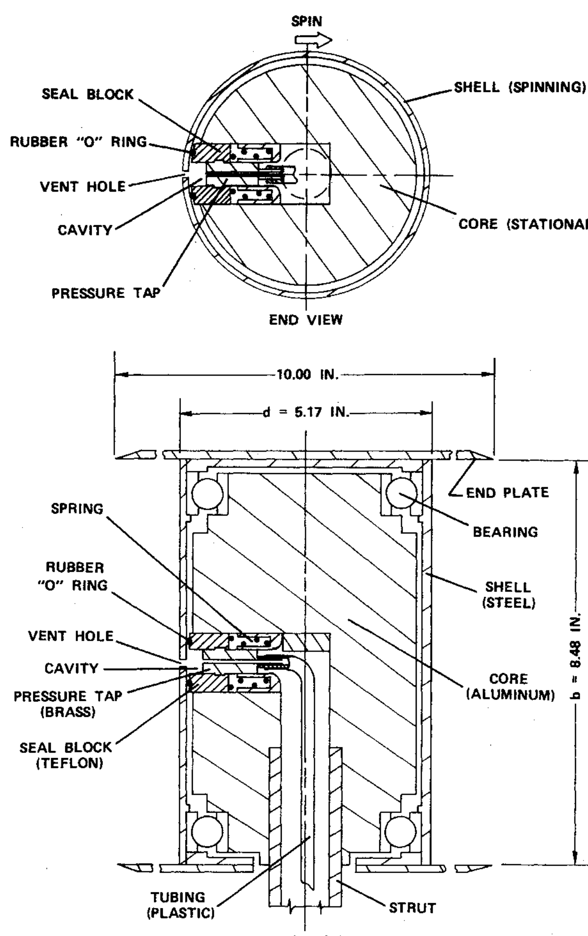

Fig. 1 Wind tunnel model.

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Index categories: Research Facilities and Instrumentation; Subsonic and Transonic Flow: Jet, Wakes, and Viscid-Inviscid Interactions.

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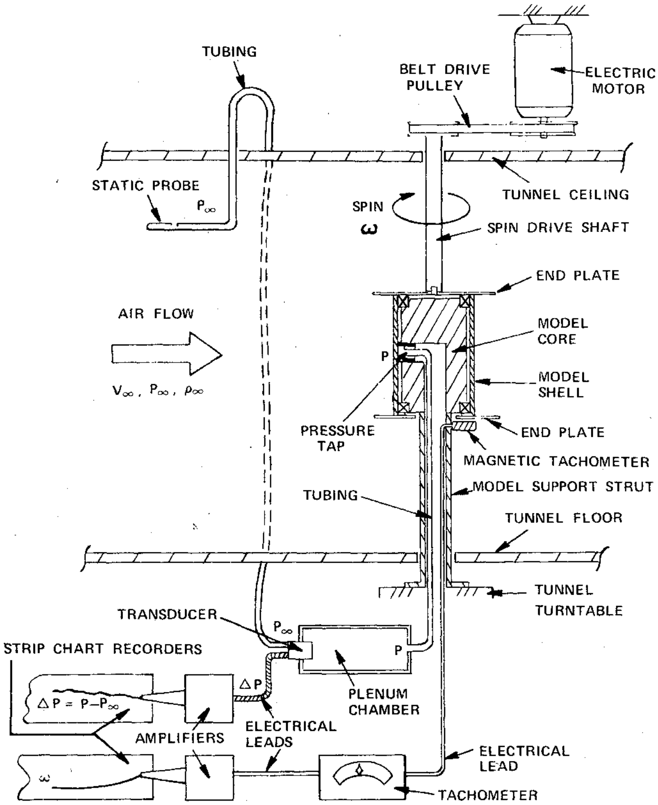

Fig. 2 **Wind tunnel installation.**

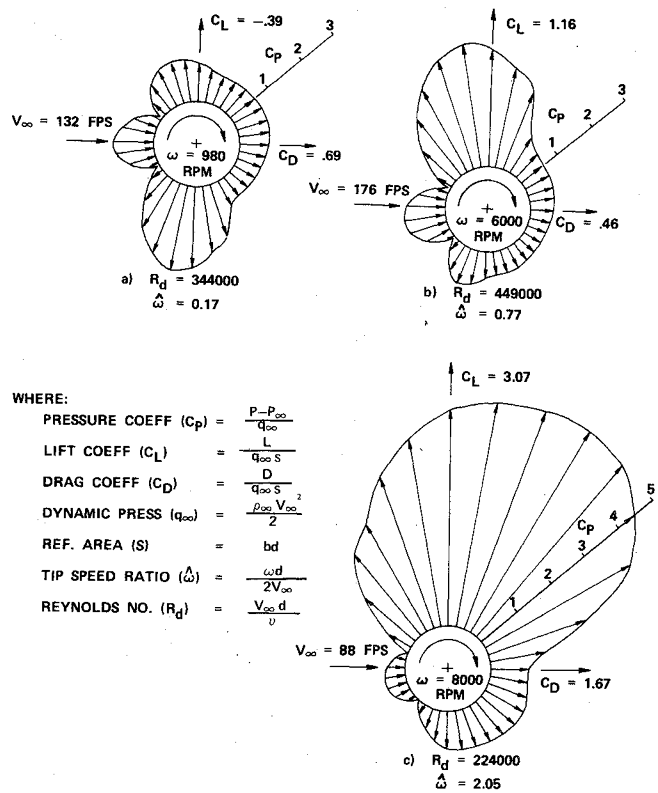

Fig. 3 **Typical pressure data.**

tained by means of an electric motor mounted on top of the wind tunnel with the drive shaft extended through the roof of the test section to the top of the model. The core of the model was attached to a support strut mounted to the turntable under the test section floor. The turntable was rotatable through 360°, allowing the core and pressure tap to be set at any angle to the flow. A magnetic tachometer indicated model spin rate. The pressure in the cavity was transmitted by flexible plastic tubing which was routed from the pressure tap, through the support strut, and out of the tunnel where it was attached to one end of the plenum cylinder. The plenum cylinder was a hollow enclosed container which provided sufficient volume to reduce any pressure noise effects. The pressure was measured by means of a transducer located at the end of the plenum cylinder.

The pressure transducer was located outside of the tunnel and did not experience any acceleration loads which could adversely affect its accuracy or structure. Also, since the pressure reading is constant, the transducer response time is not critical. The freestream static reference pressure was obtained by a static pressure probe located in the tunnel test section. The output from the transducer and magnetic tachometer were traced out as a function of time on a strip chart recorder.

With the tunnel running at the test velocity and the model shell spinning, the test procedure was to rotate the core to the desired position, hold it there until the pressure measurement was obtained, then rotate it to the next position. Rotation of the core to the new position was accomplished rapidly. The new pressure reading required only a few seconds to stabilize. This procedure was then repeated until the entire circumference of the model surface was surveyed.

The pressure data were reduced to coefficient form and presented graphically, where the magnitude and sign of the pressure coefficient at each circumferential location is denoted by a proportional length arrow emanating from an outline of the cylinder. The pressure distribution for each run was integrated over the surface of the cylinder to obtain the resultant lift and drag force coefficents. Figure 3 includes representative pressure distributions measured on the cylindrical model.

The most important features of this testing technique are summarized as follows: a) all elements of instrumentation located within model or outside tunnel test section; b) no inertial or dynamic loads acting on transducer; c) direct connection between pressure tap in model and instrumentation outside tunnel; d) constant pressure reading does not require high response transducer; e) rapid pressure survey possible; f) applicable to any model orientation to freestream; g) can be used in any speed regime including subsonic, transonic, and supersonic; h) will function with models having irregular external surface features.