Generation of Velocity Profiles Using Screens of Nonuniform Solidity

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Theme

DUCT-LIKE elements of propulsion systems (engines, diffusers, nozzles, deflectors, etc.) typically operate with nonuniform inlet velocity distributions. Separate testing of such components can be meaningful only if the actual approach conditions are closely simulated. Numerous methods have been proposed[1-4] to generate arbitrarily prescribed velocity profiles for this purpose. This Synoptic describes a new technique developed to produce arbitrary, axisymmetric velocity distributions. The technique is also applicable to other cross-section shapes.

Contents

The technique utilizes a plane screen of radius-dependent solidity located at or shortly upstream of the model inlet, perpendicular to the flow. The screen is mounted on a ring clamped by a suitably shaped model flange. Radial variation of solidity is achieved by electroplating the stainless steel screen while it rotates around its horizontal axis, partially immersed in an electrolyte (Fig. 1). Plating in this fashion results in a radial deposit thickness distribution characteristic to the particular immersion depth. Plating at various depths for various lengths of time superimposes these characteristic distributions thereby achieving arbitrary solidity profiles. By reversing electrode polarity, deposits are removed in identical patterns, thereby assuring complete freedom to specify any desired velocity profile.

The choice of screen mesh size provides a coarse control over the general level of turbulent intensity. Core flow turbulence intensities from 0.5% to 5% have been generated. A coarser grid size somewhat reduces the tolerance in achieving the desired mean velocity distribution.

The technique has been demonstrated in room-temperature air flows at low subsonic speeds ($M \leqq 0.2$), using 10.2-cm (4-in.) diam screens and mesh sizes from 2 to 41/cm (5 to 105/in.). Two-dimensional distributions in rectangular cross sections and azimuthal variations in annular cross sections are also feasible and should be considerably simpler to accomplish, because only

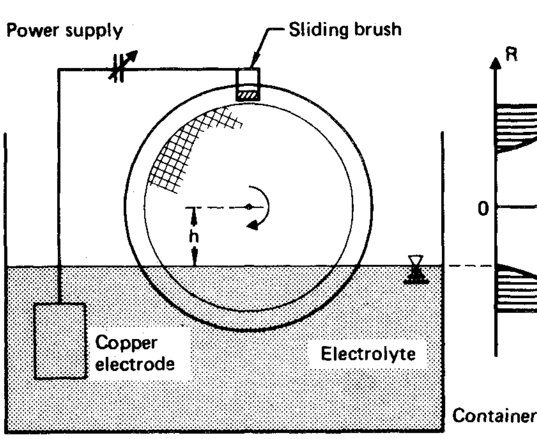

Fig. 1 Screen fabrication scheme.

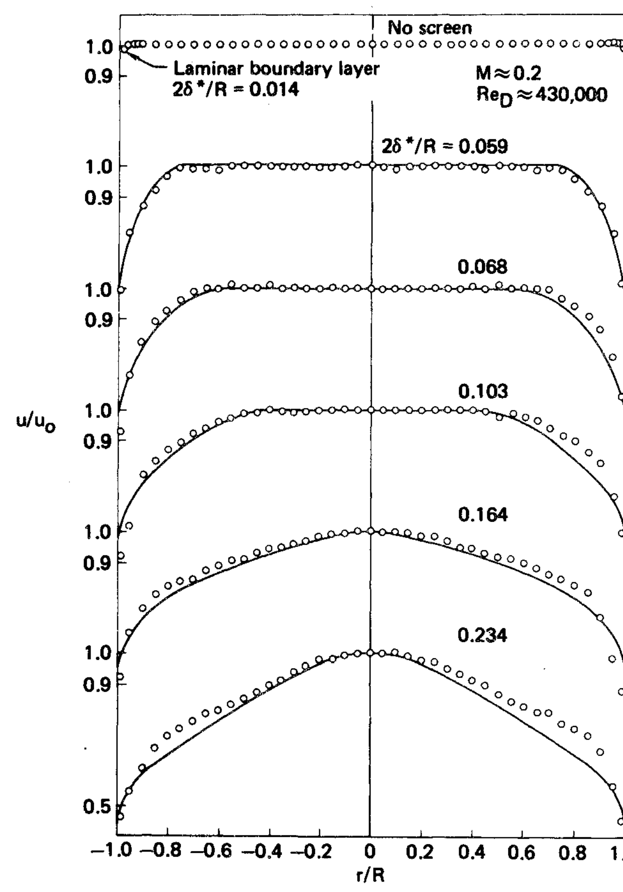

Fig. 2 Prescribed and measured mean velocity distributions 2 in. downstream of screen, $R = 2$ in., u_o = centerline velocity, $\delta^* \doteq$ axisymmetric displacement thickness. Labels refer to measured $2\delta^*/R$ values.

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repeated plating is required without rotation. The plating apparatus and procedures are described in detail in Ref. 5 together with an optical device for measuring screen solidity. Both devices are simple and can be constructed inexpensively.

Design procedures have been developed to compute plating times for each immersion depth required to achieve a prescribed velocity distribution. The number of depths controls the resolution (20 steps, i.e., 0.1 in. increments, were used). The computation involves three successive steps: 1) compute the required local pressure loss coefficient from the specified velocity distribution, using the theory of McCarthy;[3] 2) compute the corresponding local deposit thicknesses; and 3) compute the required plating times for each depth. Step 3 is done by expressing the desired deposit distribution as a sum of N (empirically determined) characteristic distributions, each weighted by an unknown plating time. Solution of the resulting system of linear equations yields the desired plating schedule.

Figure 2 shows five different profiles generated by this method. Solid lines show the original specifications; circles are velocities measured with a hot-wire anemometer. The agreement is quite satisfactory for engineering purposes. Turbulence intensity distributions (measured but not given here) differ from those found in naturally developed flows. These differences were found to be secondary in importance to simulating the mean velocity profiles in a recent study of four conical diffusers.[6]

The present technique requires negligible axial space and offers complete freedom to specify the profile (within the resolution chosen). Fabrication of the screens requires only inexpensive materials and equipment. Extension to higher speeds, larger sizes and higher temperatures appears feasible.

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