Simple Method to Detect Pipe Turbulence

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Consider a fluid flow through a pipe having length to diameter ratio 7500 (or just too big a number). The flow is driven by a constant pressure head (H) and exits the pipe by gravity ensuring a constant pressure difference along the pipe. How to determine the flow is laminar or turbulent? The diameter is very small so sophisticated cross sectional local velocity measurement using Particle Image Velocimetry or Laser Doppler anemometry is not possible (at least not straight forward) to determine the local turbulence. Also, static pressure measurements along the pipe length could disturb the wall surface, if one needs to carry out sensitive experiments with the flow. So, is there a simple way out?

We know for a laminar fully developed flow, at any length along the pipe, the cross sectional velocity variation from the pipe wall to the axis is parabolic (maximum at the pipe axis, zero at the pipe wall). Correspondingly, in turbulent flow of the same mass flow rate, the velocity profile would be flatter and more uniform along the cross section. Velocity at the axis, in this case, would be lesser than that of the laminar case (reduced by approximately 30 percent) but more near the walls. This difference in the velocity profile causes the laminar and turbulent flows to exit the long pipe at different angles. This is shown in the accompanied figure. Measuring the angle of exit, without having to touch the flow in the pipe in any way, allows us to determine the nature of the mean flow.

This method is used recently by Hof et al. [1] in their paper. The method itself is old and seems to be reported earliest by Rotta, J. C. (1956, German language paper, available free on the web).

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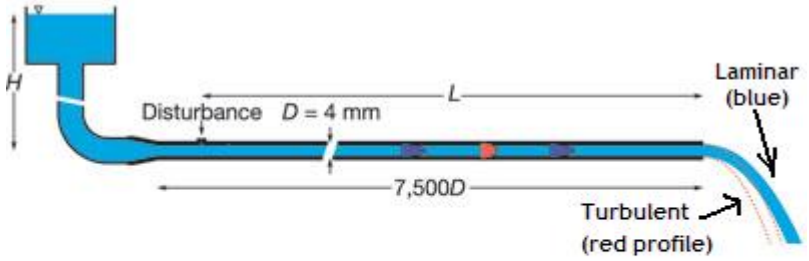
[1] intended as course notes.



Original Image Source: Nature 443, 59-62 (7 September 2006)
[http://www.nature.com/nature/journal/v443/n7107/fig_tab/nature05089_F1.html]

Fig. 1. Simple determination of turbulent flow

References

1. Hof, B., Westerweel, J., Schneider, T.M., Eckhardt, B. (2006). Finite lifetime of turbulence in shear flows. ¡span style=”font-style:italic;”¿Nature, 443¡/span¿(7107), 59-62. [DOI: 10.1038/nature05089]

2. Rotta, J. C. Experimenteller Beitrag zur Entstehung turbulenter Strmungen im Rohr. Ing. Archiv 24, 258281 (1956) [DOI: 10.1007/BF00536526]