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Technical Note

Windward Fraction of the Total Mass or Heat Transport for Flow past a Circular Cylinder

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The preferential deposition of material on the windward side of a bluff aerodynamic object is sometimes taken as evidence that the dominant mechanism of mass transport is the *inertial impaction* of large particles¹ rather than the *convective diffusion* of vapors or small particles (e.g., Fuchs, 1964). However, although the latter mechanism is able to deliver material efficiently to the leeward portion of a bluff object (through the turbulence and recirculation), it is also true that below a particular Reynolds number ($\sim 10^5$ for a cylinder in crossflow) even convective

diffusion delivers more than half of the material to the windward portion of a cylinder. To quantify this we have reexamined the available experimental data for the angular distribution of the dimensionless (Nusselt) transfer coefficient,² $Nu(\theta; Re)$, and calculated the Re dependence of the windward surface fraction (the fraction of the total

¹Even particles in the inertial range can find their way to the leeward surface through entrainment in the recirculation eddy or by "saltation" (Owen, 1964).

²Since most of these data are for heat transfer in air or naphthalene vapor transport in air, the results (Figure 1) explicitly pertain to Schmidt numbers of order unity. Insufficient data are available to display the Schmidt number and Mach number dependence of the windward fraction. The error bars shown in Figure 1 reflect our estimate of the uncertainties in reading the data off graphs and carrying out the required numerical integrations. The scatter of the points shown probably reflects differences in mainstream turbulence intensity and scale, diffusivity ratio, etc. (e.g., Lowery and Vachon 1975).

FIGURE 1. Reynolds number dependence of the windward fraction of the total mass or heat transfer for a circular cylinder in crossflow for a molecular diffusivity ratio of order unity. O, Giedt (1949); ●, Eckert and Soehngen (1952); △, Yardi and Sukhatme (1978); ▲, Giedt (1951); □, Kruzhilin and Shvab (1935); ■, Meel (1962); ◇, Krall and Eckert (1970); ◆, Schmidt and Wenner (1941).

mass collected for $-90^\circ \leq \theta \leq 90^\circ$) over the Re range $2 \times 10^1 < \text{Re} < 4 \times 10^5$. The results (Figure 1), obtained from polar integrations of data from eight sources reveal that, first, for Reynolds numbers up to about 2×10^3 more than 70% of the total transfer occurs on the windward surface and, second, only at Re values above about 10^5 does the windward percentage fall beneath 50%. Thus, unless the windward fraction of the total transport to a circular cylinder in crossflow is significantly larger than, say, 72% or the Reynolds number is much larger than 10^5 , preferential windward surface mass transfer is *not* sufficient evidence of the dominance of inertial capture mechanisms over diffusional ones.

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