Reevaluating the jet breakup regime diagram

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Nov. 24, 2019, 5:06 pm
APS DFD 2019
Seattle, WA

Why study regimes?

- Each regime must be modeled differently. Frequently inappropriate models are used!
- If researchers want to study a particular regime, they often consult a regime diagram to place their study. If this is wrong, then they won't be studying the regime they want to.

Conventional regimes of jet breakup

- **Rayleigh**
- first wind-induced
- second wind-induced
- atomization

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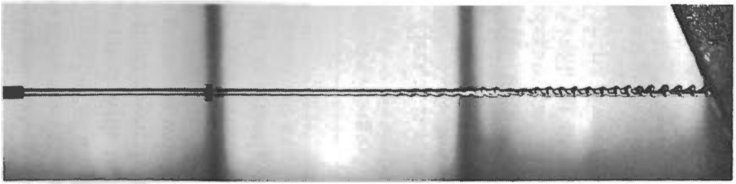

Preprint DOI: 10.31224/osf.io/nqhs5

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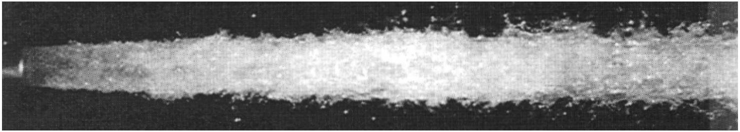

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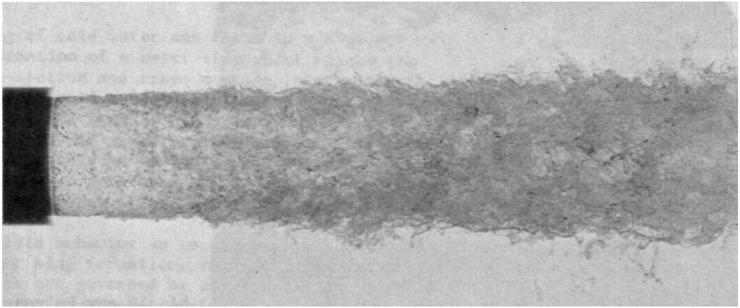
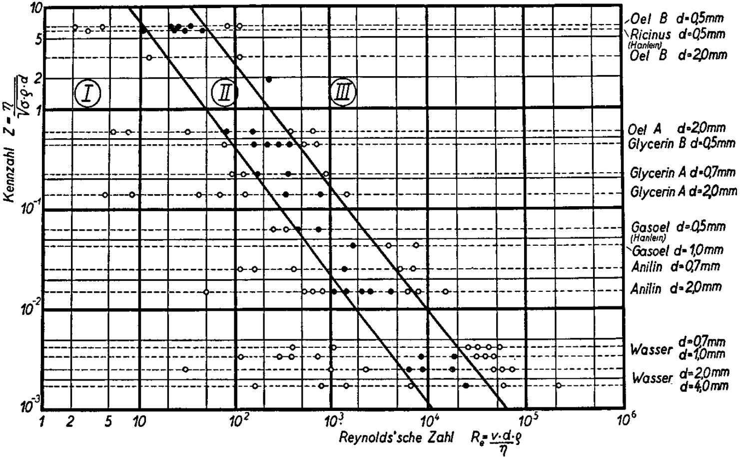


Ohnesorge diagram



Common criteria — and problems

$$\mathrm{We}_{\mathrm{g0}} \equiv \frac{\rho_\mathrm{g} \overline{U}_0^2 d_0}{\sigma}$$

$$\begin{aligned}
\text{Rayleigh if} \quad & \mathrm{We}_{\mathrm{g0}} < 0.4 \\
\text{first wind-induced if} \quad & 0.4 < \mathrm{We}_{\mathrm{g0}} < 13 \\
\text{second wind-induced if} \quad & 13 < \mathrm{We}_{\mathrm{g0}} < 40.3 \\
\text{atomization if} \quad & \mathrm{We}_{\mathrm{g0}} > 40.3.
\end{aligned}$$

Common criteria — and problems

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1. The critical Weber numbers of 0.4 and 13 (from Ranz) are based on no data at all!
2. The critical Weber number of 40.3 (from Reitz) was miscalculated and should be ≈ 12!
3. Some measure of the turbulence level should be a factor...

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Data compilation 1/2

- Using data compiled from many fully developed "pipe jet" studies because they are common and it is possible to credibly estimate the Weber number, Reynolds number, and turbulence intensity for these nozzles.
- Shortcoming: Low critical Reynolds number
- Can estimate turbulence intensity from friction factor:

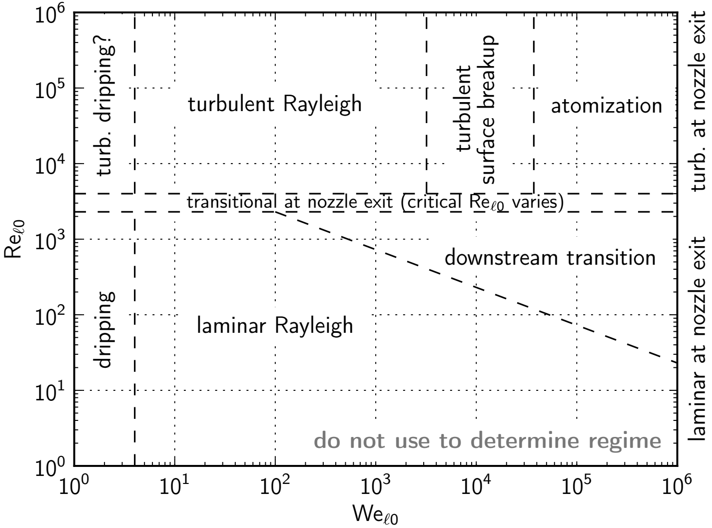
$$\overline{\mathrm{Tu}}_0 = \frac{\sqrt{\frac{2}{3}\overline{k}_0}}{\overline{U}_0} = \frac{\sqrt{\overline{{u'_0}^2}}}{\overline{U}_0} = 0.366 f^{0.459}$$

- Idea from Skrebkov (1966), but regression is my own.

Data compilation 2/2

	photos	$\langle x_b \rangle$	total
Ohnesorge (2019)	63	0	63
Miesse (1955, fig. 8)	66	0	66
Ranz (1956, pp. 61–62)	0	0	0
Grant and Middleman (1966)	26	127	132
Sterling and Sleicher (1975)	0	106	106
Torda (1973, fig. 14)	12	0	12
Reitz (1978, pp. 133–137)	67	0	67
Wu, Miranda, and Faeth (1995, fig. 7)	110	0	110
Schillaci et al. (2019)	11	0	11
This work	120	1094	1188

New schematic regime diagram



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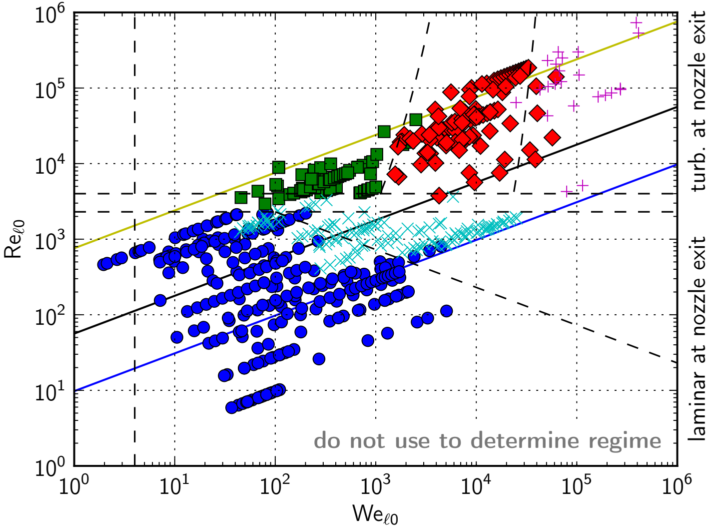
Regime diagram for smooth pipe jets at ~ 1 atm.



Questions?

Reevaluating the jet breakup regime diagram

Session G15: Jets: General

Presenter:

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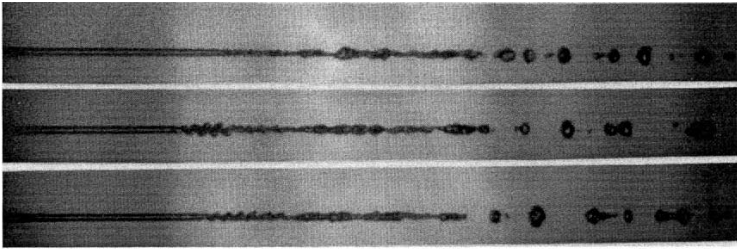
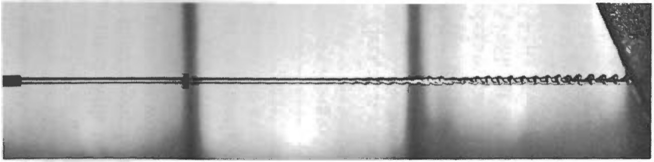
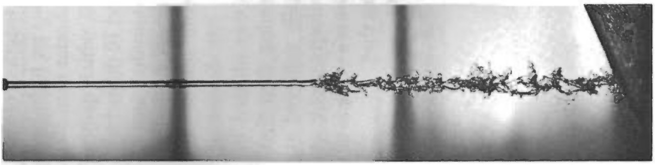
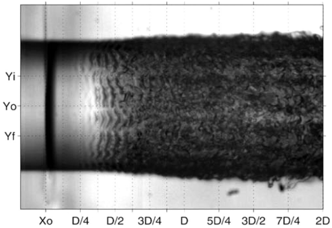
Turbulent Rayleigh regime



Varieties of the “downstream transition” regime







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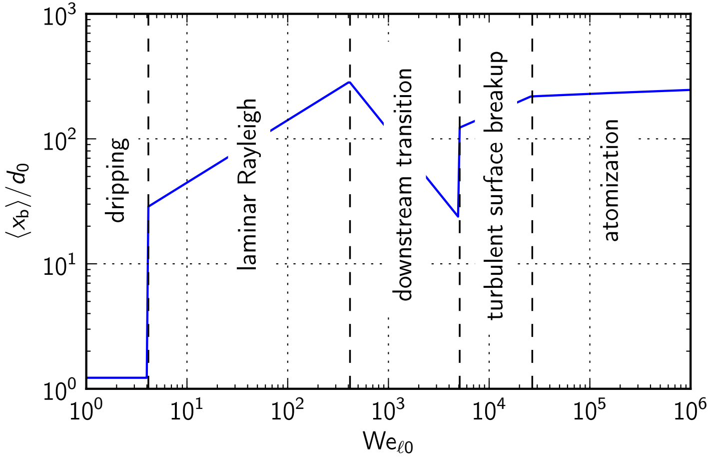
Conventional regime progression



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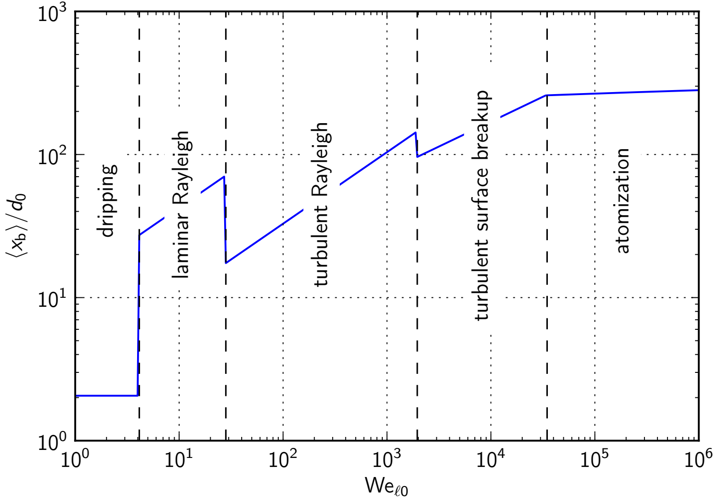
Large-nozzle/weak-viscosity regime progression



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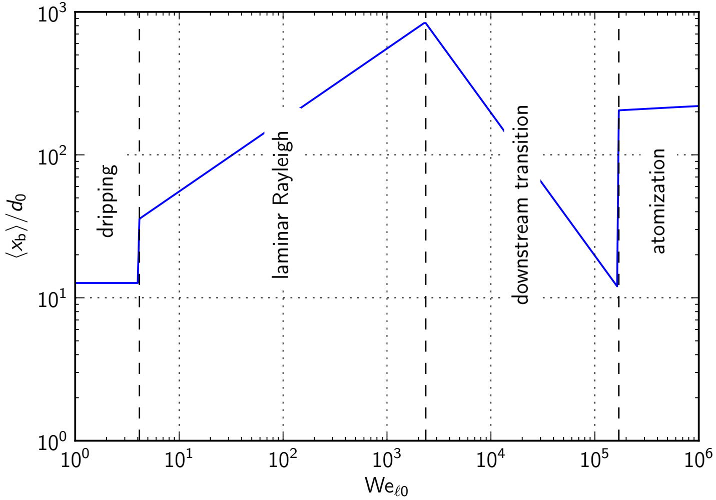
Small-nozzle/viscous regime progression



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Conversion table

New regime name	Old regime name
dripping	dripping
laminar Rayleigh	Rayleigh
downstream transition	first wind-induced
turbulent Rayleigh	—
turbulent surface breakup	second wind-induced
(turbulent) atomization	atomization

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