# A KIVA code penetration model incorporating jet breakup

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# Outline

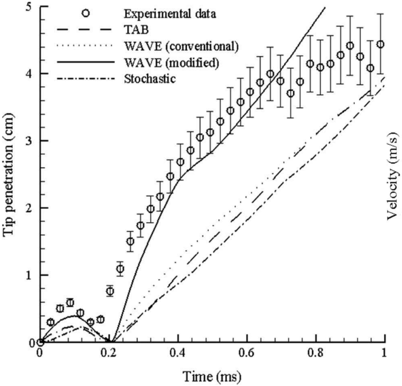
1. Current breakup models
2. Inclusion of jet breakup
3. Conclusions

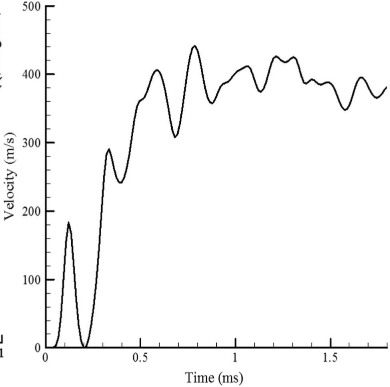
Current CFD models and the breakup models they contain, focus on spray breakup.

This is the breakup of large droplets into a series of smaller droplets.

The results from these models have been shown to agree well with experimental spray penetration results, but have been shown to underestimate the penetration length for experimental results generated within this group.

## Single holed injector at high injection pressure





# Questions asked

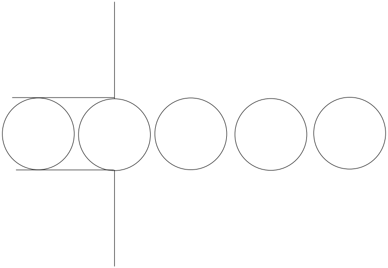
Is this difference between the experiment and simulations due to the neglected unsteady effects in the model?

We believe not. (see submitted paper)

If it's not the unsteady effects, then what feature is missing from the current droplet models?

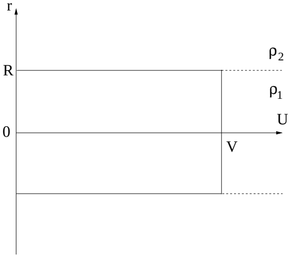
Is the missing element due to to the existence of a jet initially emerging from the nozzle?

# Current CFD and breakup models



There are three current breakup models used in this KIVA code.
1- Taylor Analogy Breakup (TAB) model (Default model in KIVA)
2- WAVE model
3- Stochastic model

# WAVE model



$$\frac{dr}{dt} = -\frac{r - r_s}{\tau_{bu}},$$

$$r_s = \begin{cases} B_0\Lambda & B_0\Lambda \leq r, \\ \min\left( \begin{array}{l} (3\pi r^2 U/2\Omega)^{0.33} \\ (3r^2\Lambda/4)^{0.33} \end{array} \right) & B_0\Lambda > r, \end{cases}$$

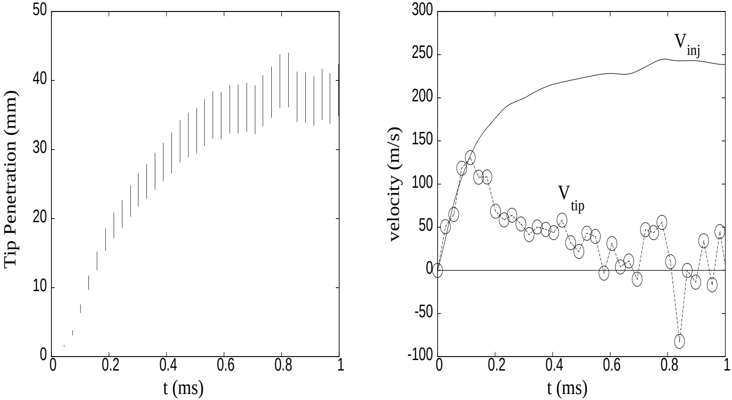
$$\Lambda = 9.02R\frac{(1+0.45Z^{1/2})(1+0.4T^{7/10})}{(1+0.87We_2^{5/3})^{6/10}},$$
$$\Omega = \left(\frac{\sigma}{\rho_1 R^3}\right)^{1/2}\frac{(0.34+0.38We_2^{3/2})}{(1+Z)(1+1.4T^{6/10})},$$

These quantities come from a numerical fit of the linear stability results for $q = \rho_2/\rho_1 < 1/10$. Here we consider $T = Z = 0$, inviscid solutions.

$$\tau_{bu} = 3.7626\frac{B_1 R}{\Lambda\Omega},$$

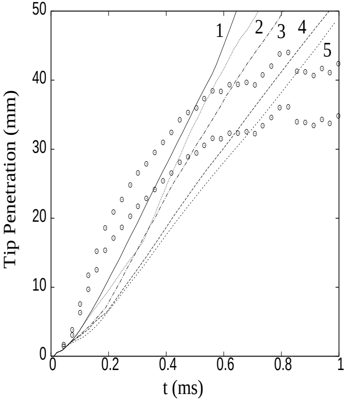
This breakup time comes from fitting to experimental data, and $B_1$ is an adjustable model constant in the range $[1.73, 10]$.

This is the experimental data we hope to validate our model on.



This is a 7 hole injector injecting with pressure 60MPa and injecting into air at 2MPa.

This is the classic breakup models result.



1- no breakup model

2- the WAVE model with $B_1 = 10$

3- the WAVE model with $B_1 = 1.73$

4- the TAB model

5- the stochastic model.

# Outline

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While the WAVE model described earlier seems to predict secondary breakup well, the previous result shows that it fails to predict the primary breakup of the jet into droplets.

Here we introduce a primary breakup model to incorporate with the current WAVE (or TAB or Stochastic) model to give better results with the experimental penetration results produced at Brighton.

The jet model we introduce uses no new information at this stage, and uses all the same assumptions as used in the WAVE model, because although these assumptions can be improved, they are widely accepted in the engineering community.

There are two parts to calculating the jet breakup length. First of all there is the length before any breakup has occurred. Here the jet is modeled as a solid body.

$$L_{solid} = \int_0^t V(t')\,dt'.$$

Then there is the breakup length of a disturbance wave packet released at $t = t_0$.

$$L_{bu} = \int_{t_0}^{t_0+\tau_b(V)} \frac{\partial\omega}{\partial\alpha} V(t')\,dt'$$

with

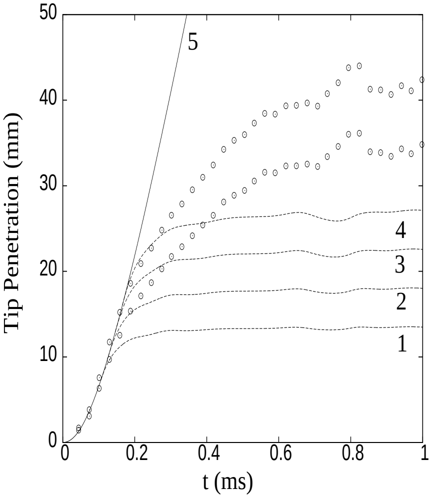
$$\tau_b = B_1' \frac{R}{V} q^{-1/2},$$

# Jet breakup questions

What value does $B_1'$ take?

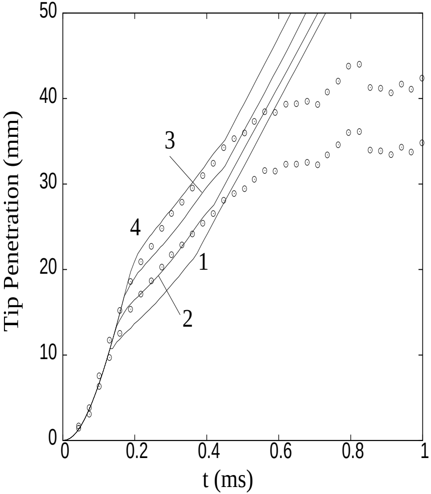
Is this the correct form of the breakup time?

What is the group velocity for the jet?



$B'_1 = 3, 4, 5, 6$

Let us include the WAVE breakup model on top of this jet breakup model into a composite model.



# Questions/problems about composite model

Does it give the correct droplet distribution?

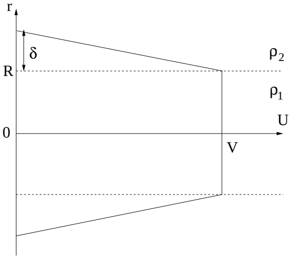
No, and droplets appear to be too small compared to experimental measurements.

Is the jet breakup model realistic?

No, because it assumes an inviscid gas layer. However, the overall effect of viscosity in these problems is small.

# How can we overcome these problems?

Try a new model for jet stability, with a viscous gas layer profile (still with an inviscid stability analysis).



This gives larger droplets for the initial condition to the droplet code, and hence gives larger droplets downstream.

But should we use this new breakup mechanism in the WAVE model too?

This new model also reduces the disturbance group velocity, so we would need to amend the solid jet part of the code.

Putting a spray cone angle at the jet tip gives a better droplet distribution.

# Outline

This new composite model that combines primary breakup using disturbance group velocities appears to give good agreement with the experiments, by using no new experimental data.

This model incorporates the existence of a coherent jet emerging from the nozzle in a sensible way, without the need for adhoc approaches.

The model could be improved, and this allows experimental studies to pin down some of the new model constants, and answer some of the questions raised in this talk.