Experimental Investigation of Richtmyer-Meshkov Instability after a Second Interaction with a Reflected Shock Wave

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Reynolds Number

\[
Re = \frac{U \ell}{\nu}
\]

Let, \( \ell \sim h = 2a, \quad U \sim \frac{dh}{dt}, \quad \nu = \text{average viscosity} \)

At time of transition,

\[
Re \sim \frac{h \dot{h}}{\nu} \approx 50,000
\]

Alternatively let,

\[
Re = \frac{\Gamma}{\nu}
\]

Linear stability theory gives, \( \Gamma = \frac{2}{\pi} \lambda \dot{a}_0 \)

Then,

\[
Re = \frac{2}{\pi} \frac{\lambda \dot{a}_0}{\nu} \approx 42,000
\]
Nonlinear Models

Zhang & Sohn (1997)

\[ v_{b/s} = \frac{v_0}{1 + v_0 a_0 k^2 t + \max[0, a_0^2 k^2 - A^2 + \frac{1}{2}]v_0^2 k^2 t^2} \]
\[ \mp \frac{A v_0^2 k t}{1 + 2 k^2 a_0 v_0 t + 4 k^2 v_0^2 [a_0^2 k^2 + \frac{1}{3}(1 - A^2)]t^2} \]

when \( A^2 \leq \frac{1}{2} + a_0^2 k^2 \)

\[ v = \frac{1}{2} (v_b + v_s) \rightarrow \frac{v_0}{[a_0^2 k^2 - A^2 + \frac{1}{2}]v_0^2 k^2 t^2} \propto \frac{1}{t^2} \text{ as } t \to \infty \]

Sadot el al. (1998)

\[ v_{b/s} = \frac{v_0 (1 + v_0 k t)}{1 + (1 \pm A)v_0 k t + \frac{1\pm A}{1+A} \left[ \frac{1}{2\pi C} \right] \frac{1}{v_0^2 k^2 t^2}} \]

where
\[ C = \begin{cases} 
1/3\pi & A \geq 0.5 \\
1/2\pi & A \to 0 
\end{cases} \]

\[ v \rightarrow \left( \frac{1}{1-A} \right) C \lambda \propto \frac{1}{t} \text{ as } t \to \infty \]
Late Time Growth

Sadot et al.

Zhang & Sohn
Bubble and Spike Amplitudes

- Spike
- Bubble
- Zhang & Sohn
- Sadot et al.

$k(a-a_0)$ vs. $kv_0t$
Wave Diagram; $M = 1.11; A = 0.656$
Reshock Amplitude

Amplitude (mm)

$A a_0 V t$

ka_R = 1.2
ka_R = 1.8
ka_R = 2.6
Growth Rate after Reshock

\[ k(a - a_i) \]

\[ (a_0^+ + a_0^-) \Delta V t A k^2/2 \]

linear theory

- Single shock
- Single shock
- Single shock
- Reshock, \( k a_R = 1.2 \)
- Reshock, \( k a_R = 1.8 \)
- Reshock, \( k a_R = 2.6 \)
10% to 70% Mixed Fraction

$ka_R = 1.2$

$ka_R = 1.8$

$ka_R = 2.6$

Mixed Fraction

A $a_0t V$

Single Shock

Reshock
Conclusions

Single-mode RM experiments show a transition to turbulence in the vortex cores at $Re \approx 50,000$.

Late-time amplitude measurements show excellent agreement with the model of Sadot et al. (1998).

Penetration depth measurements for the three reshock conditions collapse when plotted in dimensionless form and have a growth rate approximately $1/3$ that given by linear stability theory.

Reshock at early stages of the instability show similar evolution to that of single interaction with little increase in the mixing rate.

Reshock at late stages of the instability produces a complex interface pattern and a significant increase in the mixing rate.