The Rayleigh-Taylor Instability at a Water/Magnetorheological Fluid Interface

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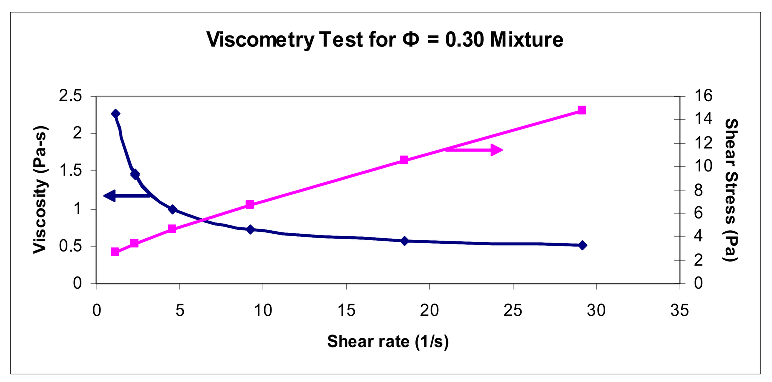
Magnetorheological Fluids

- Three different Magnetorheological (MR) fluids being studied
- Each Mixture contains light grade mineral oil, oleic acid, carbonyl iron powder
  - Oleic acid stabilizes fluid by preventing agglomeration of iron particles
- Mixtures studied have 15, 20, and 30% by volume of carbonyl iron powder
  - Φ represents this volume percentage (15% → Φ = 0.15)
- Ratio of oleic acid to mineral oil kept constant
- Interfacial tension (T) taken as that between mineral oil and water for all cases
- A represents the atwood number

Table 1: MR fluid properties

Φ	ρ (kg/m^3)	μ (Pa-s)	T (N/m)	A
0.15	1782.2	0.0229	0.051	0.28206
0.2	2050	0.100	0.051	0.34514
0.3	2772.3	0.643	0.051	0.47059

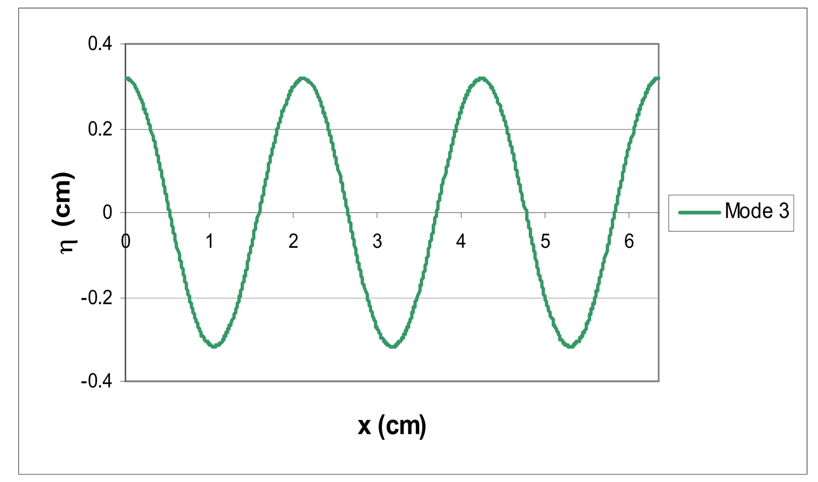


Interface Shapes

Single Mode

$$\eta_3 = (0.3175\ cm)\cos\left(\frac{2\pi}{\lambda_3}x\right)$$

$$\lambda_3 = 2.12cm$$



Multimode

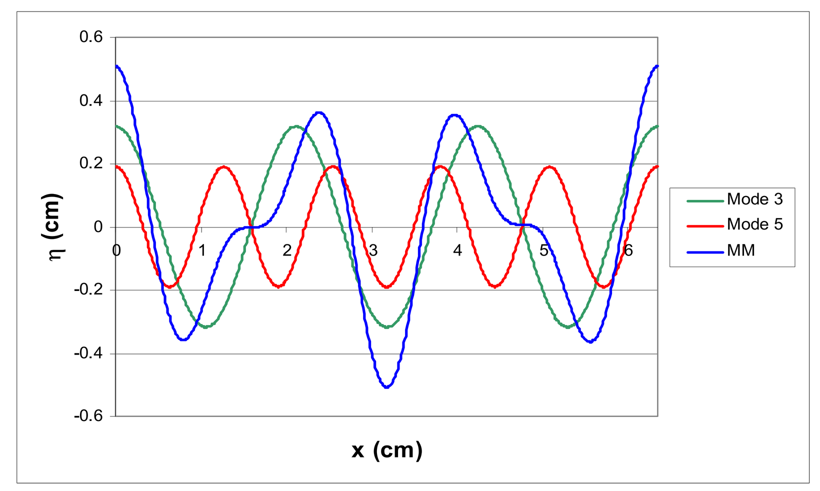
$$\eta_3 = (0.3175\ cm)\cos\left(\frac{2\pi}{\lambda_3}x\right)$$

$$\eta_5 = (0.1905\ cm)\cos\left(\frac{2\pi}{\lambda_5}x\right)$$

$$\eta_{MM} = \eta_3 + \eta_5$$

$$\lambda_3 = 2.12cm$$

$$\lambda_5 = 1.27cm$$



Experimental Procedure

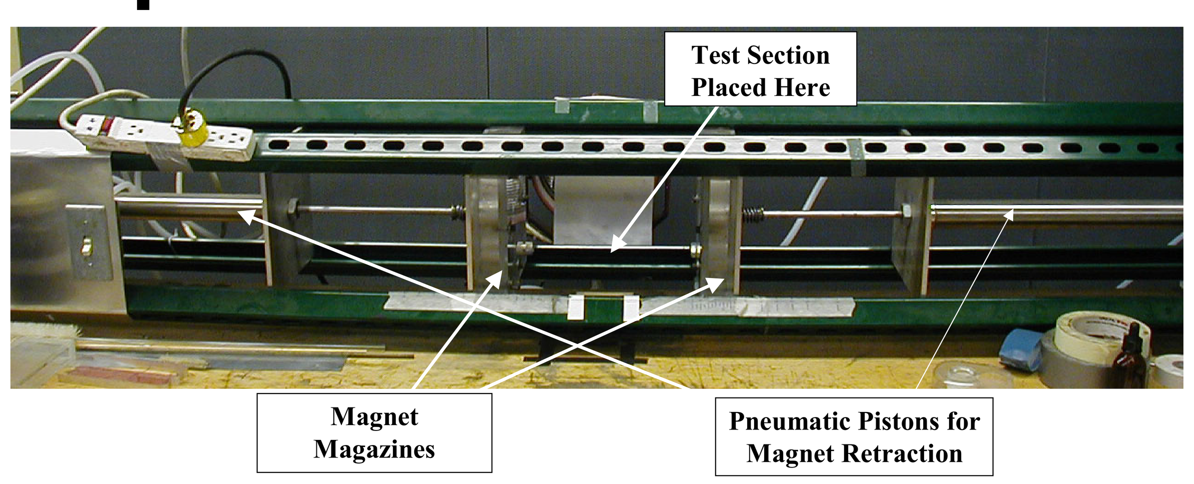


Figure 1: Experiment Setup without Imaging Hardware

1) Insert plunger in test section and partially fill with water.
2) Press aluminum strip between shaping blocks (Fig. 2); insert into water-filled side of test section (Fig. 3).
3) Siphon off water above aluminum strip; freeze test section.
4) Remove shaping strip; fill test section with MR fluid over ice; seal test section.
5) Flip over test section; place between magnet magazines to freeze MR fluid (Fig. 1).
6) Remove plunger; pour water to melt the ice.
7) Replace ice with liquid water.
8) Flip the test section so that MR fluid is above water; ensure to keep test section between magnet magazines to maintain magnetically-frozen interface shape.
9) Turn on backlight.
10) Pressurize gas lines for pneumatic pistons.
11) Start acquiring images and initiate magnet bank retraction.

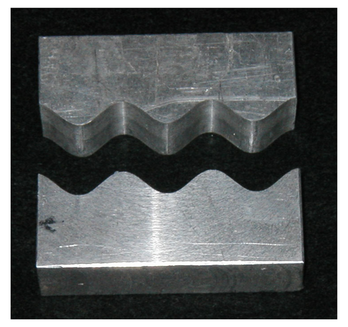


Figure 2: Interface Shaping Blocks

Figure 3: Test Section Before Freezing interface Shape

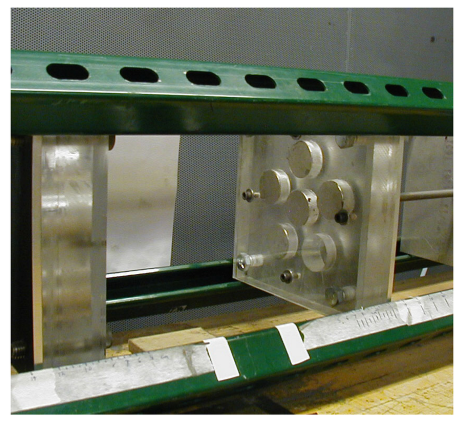


Figure 6: Magnet Magazines

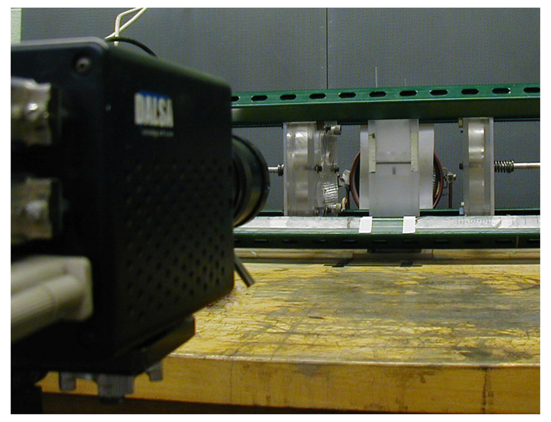


Figure 5: Imaging Setup

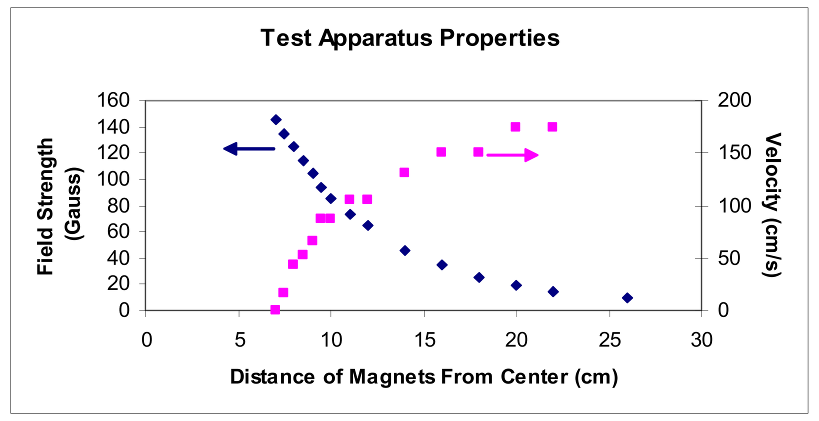
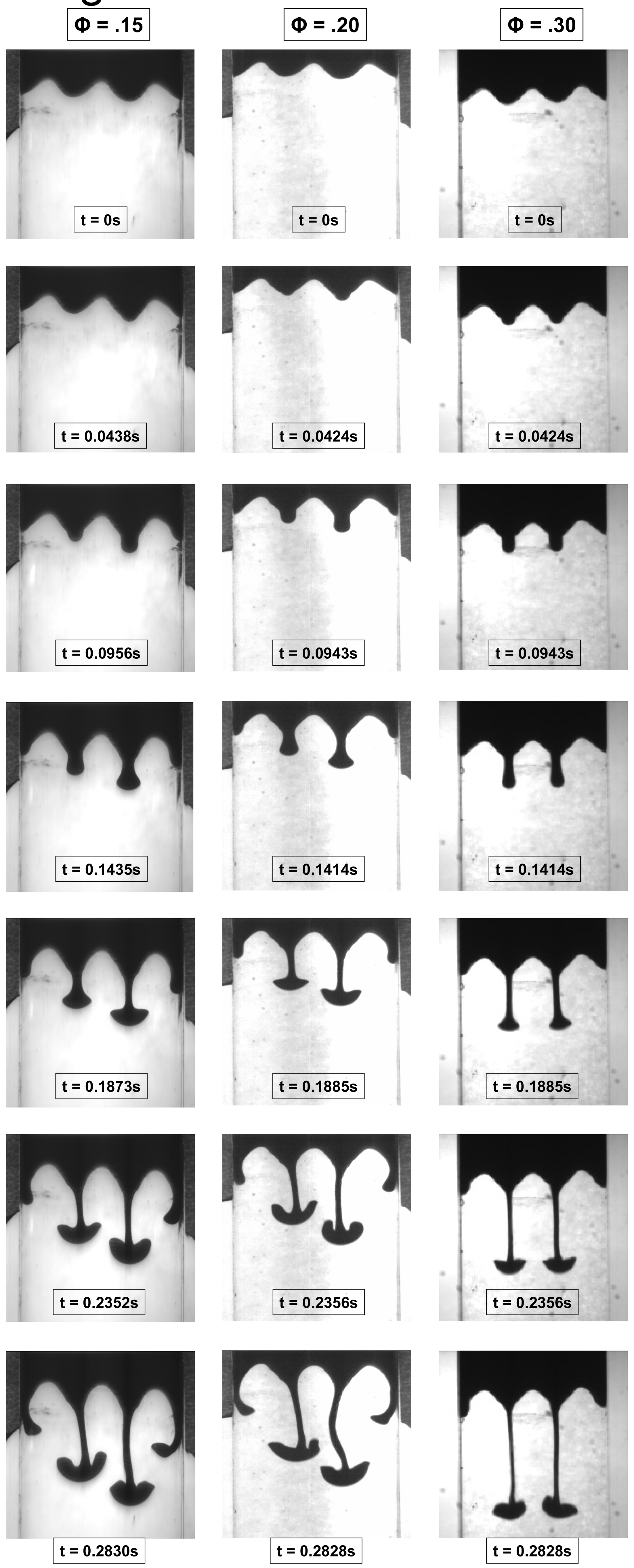
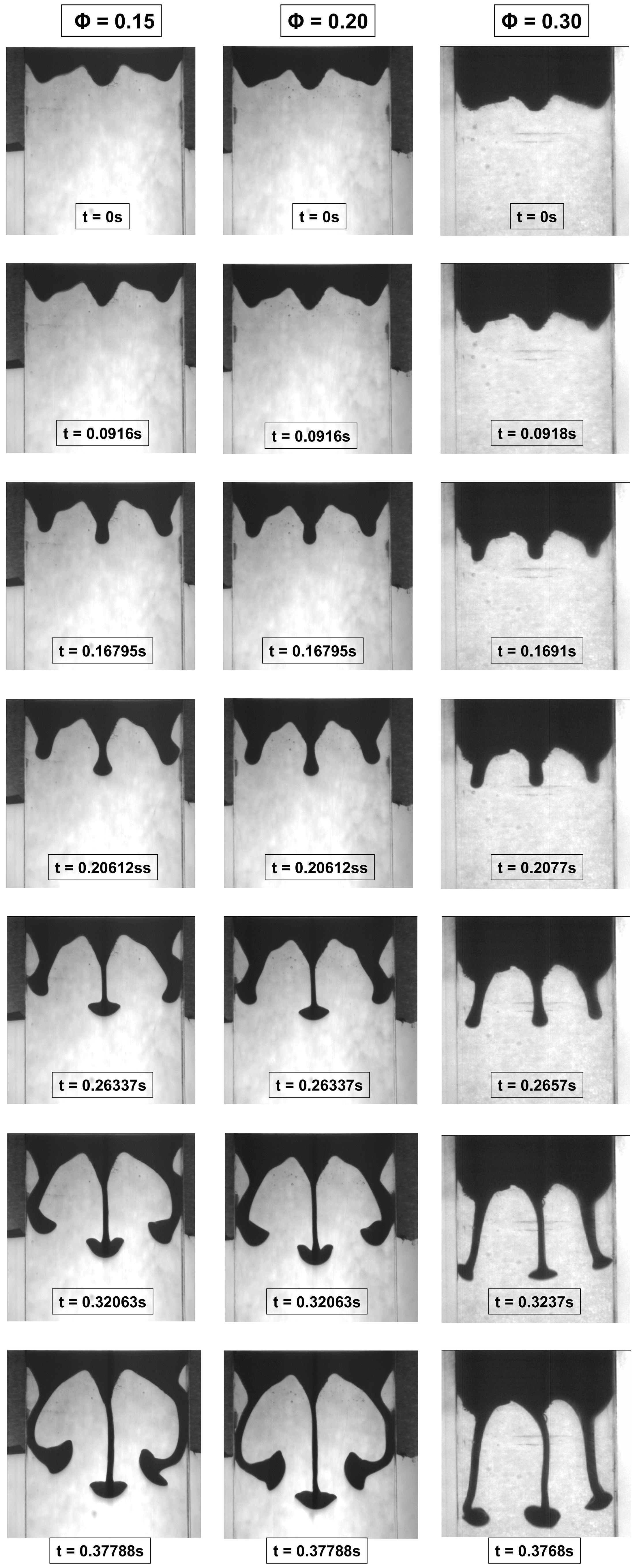


Figure 4: Magnetic field strength vs. distance of magnets from center of test section and velocity of the magnets as a function of the same distance.

Single Mode Perturbation



Multimode Perturbation



Results

The following figures show growth rate data for tests run with each of the three MR fluid mixtures. Figure 11 shows a comparison of the growth rates for one test using each fluid. Figure 12 shows the same experimental runs with normalized axes. The amplitude is normalized with respect to the width of the interface (L=6.35 cm), while the time is normalized by $\tau = \sqrt{L/Ag}$. Figures 13 and 14 show the modal growth rates for the multimode case where Φ = 0.15, both dimensioned and normalized. Figures 7, 8 and 9 show comparisons of each fluid case to theoretical values based on linear stability theory. Three theoretical values are shown: the inviscid case; the inviscid case with interfacial tension (IFT); and the viscous case with IFT. Figure 10 represents the statistical scatter of the data from 10 separate tests. This figure shows that the repeatability of these tests is quite good with the current experimental procedure.

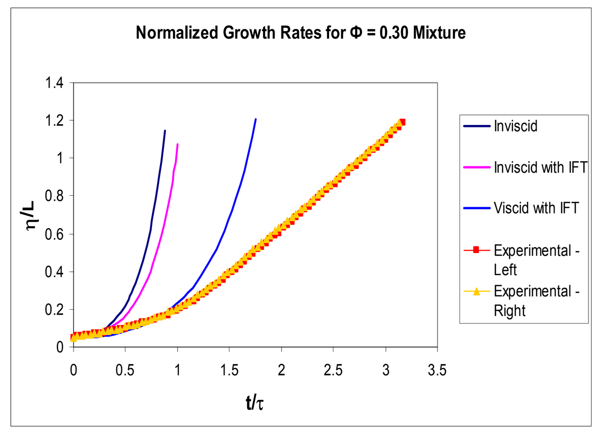


Figure 7

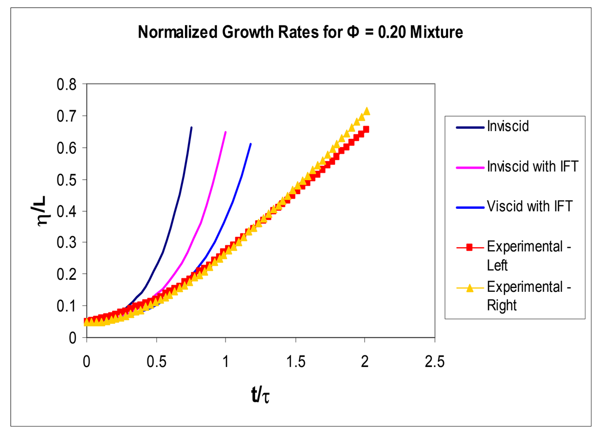


Figure 8

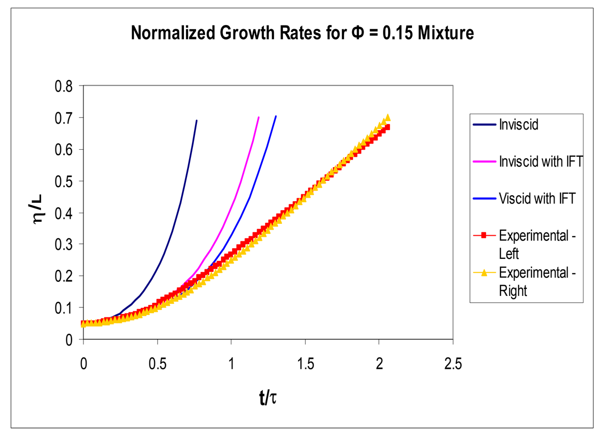


Figure 9

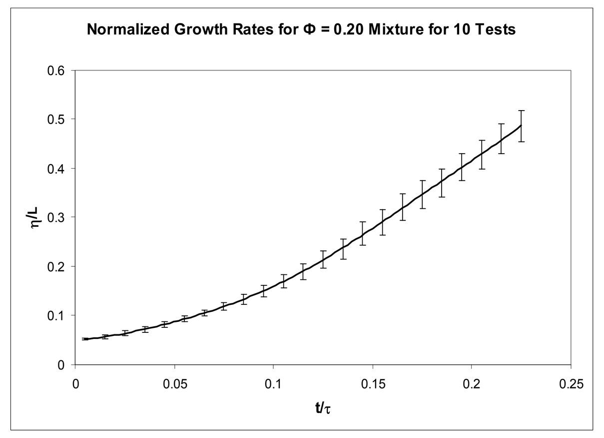


Figure 10

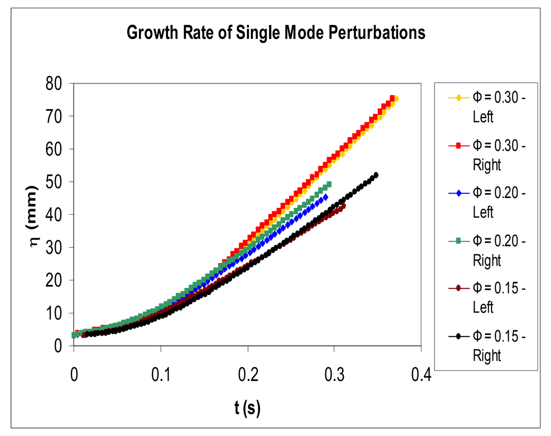


Figure 11

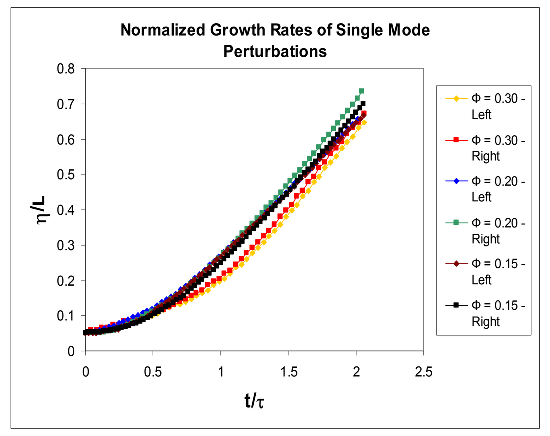


Figure 12

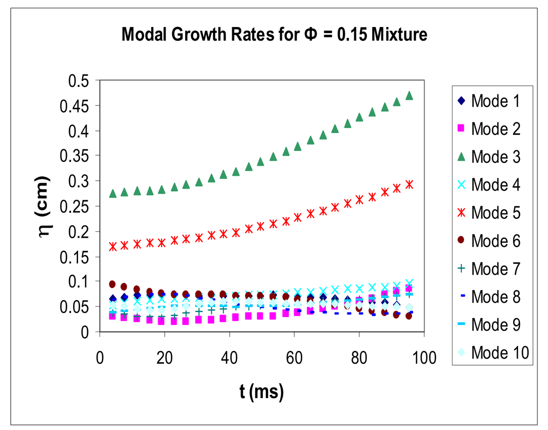


Figure 13

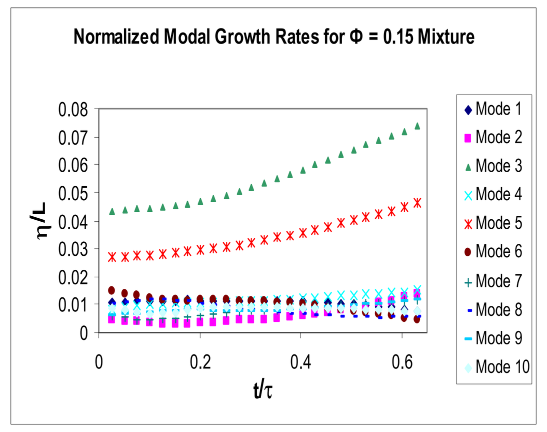


Figure 14