Data Bank for Experiments on Aerodynamic Dissemination

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The problem of aerodynamic dissemination has a long history at Army laboratories. More recently expensive experiments have been carried out here and elsewhere. We have the impression that the results of these experiments are inconclusive because the totality of them are not archived, processed and intelligently compared.

Our proposal is to create a data bank for all relevant experiments, good and bad, which can be interrogated for the factors which determine drop size distributions and other outcomes that interest us. Those factors are buried in the data.

We believe that the drop size distribution is determined by dimensionless parameters like the Weber number, Reynolds number of the gas, viscosity ratio, density ratio and viscoelastic parameters like the Deborah number. We want to correlate drop size distributions and other relevant outcomes with the values of these parameters.

The data bank we propose to create is structured as columns on a spreadsheet. The first columns list material parameters, densities, viscosities, relaxation times, surface tension, thermodynamic data like solubility of vapor (this may be called from a separate thermodynamic data file), etc. The second group of columns on the spreadsheet are operating parameters, initial drop size, gas speed, pressure, density, temperature and dynamic pressure environment of the drop at breakup. The shock parameters are important when there is a shock only as an index to the aforementioned breakup environment. The third group of columns are dimensionless parameters composed from previous columns: Weber number, Reynolds number Deborah number, viscosity ratio, etc. WE are searching for correlating parameters so that these columns are candidates only. The final columns are outcomes: MMD, drop acceleration, wavelength at instability, missing mass fractions, etc. We would like to see outcomes expressed in dimensionless form.

Each row on a spreadsheet is an experiment. We process an experiment by plotting dimensionless parameters against outcomes, two at a time and preferably in log-log plots looking for power laws.

We have correlated data for a variety of numerical and real experiments in solid-liquid flow and in gas liquid flow. A file of papers on this method of correlations can be downloaded from *http://www.aem.umn.edu/people/faculty/joseph/PL-correlations/*. The correlation for bed load transport given below involves five dimensionless parameters and we think to be a huge success. There is nothing really new in this tried and true method of correlations. Engineers always have and always will rely on correlations. What is really new here is that digital technology allows us to store a lot of data and to process and manipulate it with a click of the mouse.

The method described here does not use models; it looks for the secrets buried in the data. But if the results are good the data can be used as a standard for testing predictions of models. We introduced new ideas to the discussion of drop breakup and aerodynamic dissemination: the central role of dynamic pressure previously not considered; the importance of Rayleigh-Taylor (RT) instability in breakup and the prediction of the wave length at instability (see figure 1 for a spectacular new demonstration); the importance of acceleration in the RT instability and its correlation with dynamic pressure; the role of outgassing at high altitudes; the shock tube and the first movies of drop breakup (see *http://www.aem.umn.edu/research/Aerodynamic_Breakup/*). Our results are published in various reports and in four papers below which may be downloaded from the hyperlinks[1].

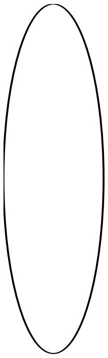

Figure 1. The spectacular demonstration…

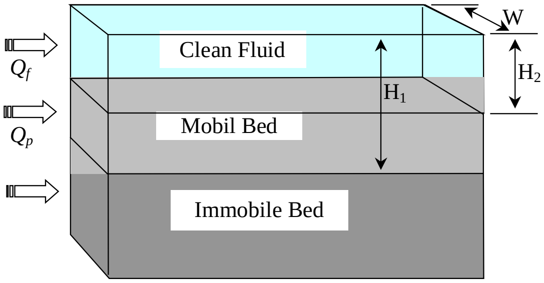

Figure 2. Proppant transport at steady state. Data from slot experiments done at STIM-LAB using many different sands.

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[1] D.D. Joseph, G.S. Beavers, T. Funada, 2002. Rayleigh-Taylor instability of viscoelastic drops at high Weber numbers, *J. Fluid Mech.*, **453**, 109-132.

- *http://www.aem.umn.edu/people/faculty/joseph/papers/RTI_We2001.pdf*

T. Funada, D.D. Joseph, 2001. Viscous potential flow analysis of Kelvin-Helmholtz instability in a channel, *J. Fluid Mech.*, **445**, 263-283.

- *http://www.aem.umn.edu/people/faculty/joseph/papers/khinstabS.pdf*

D.D. Joseph, J. Belanger, G.S. Beavers, 1999. Breakup of a liquid drop suddenly exposed to a high-speed airstream, *Int. J. Multiphase Flow*, **25**, 1263-1303.

- *http://www.aem.umn.edu/people/faculty/joseph/papers/breakup99.pdf*
- *http://www.aem.umn.edu/people/faculty/joseph/papers/brkp99s2.pdf*

D.D. Joseph, A. Huang, G.V. Candler, 1996. Vaporization of a liquid drop suddenly exposed to a high-speed airstream, *J. Fluid Mech.*, **318**, 223-236.

- *http://www.aem.umn.edu/people/faculty/joseph/papers/96_2.pdf*

$$\frac{H_1}{W}=\left[-0.000230\ln(R_G)+0.00292\right]R_f^{\,1.2-0.00126\lambda^{-0.428}[15.2-\ln(R_G)]}R_p^{\,[-0.0172\ln(R_G)-0.120]},$$

$$\frac{H_2}{W}=\left[-0.000115\ln(R_G)+0.00133\right]R_f^{\,1.2-1.295\times10^{-6}\lambda^{-1.28}[11.67-\ln(R_G)]}R_p^{\,[-0.0072\ln(R_G)-0.304]},$$

Sedimentation number $R_G=\dfrac{\rho_f\left(\rho_p-\rho_f\right)gd^3}{\eta^2}$, $\lambda=\dfrac{\eta}{\rho_f W^{3/2}\sqrt{g}}$

Fluid Reynolds number based on channel width $R_f=\dfrac{\rho_f\tilde{V}W}{\eta}=\dfrac{\rho_f Q_f}{W\eta}$, where $\tilde{V}=\dfrac{Q_f}{W^2}$.

Proppant Reynolds number based on channel width $R_p=\dfrac{\rho_p\bar{V}W}{\eta}=\dfrac{\rho_p Q_p}{W\eta}$, where $\bar{V}=\dfrac{Q_p}{W^2}$.

Figure 3. Bi-power law correlations for bed load transport.

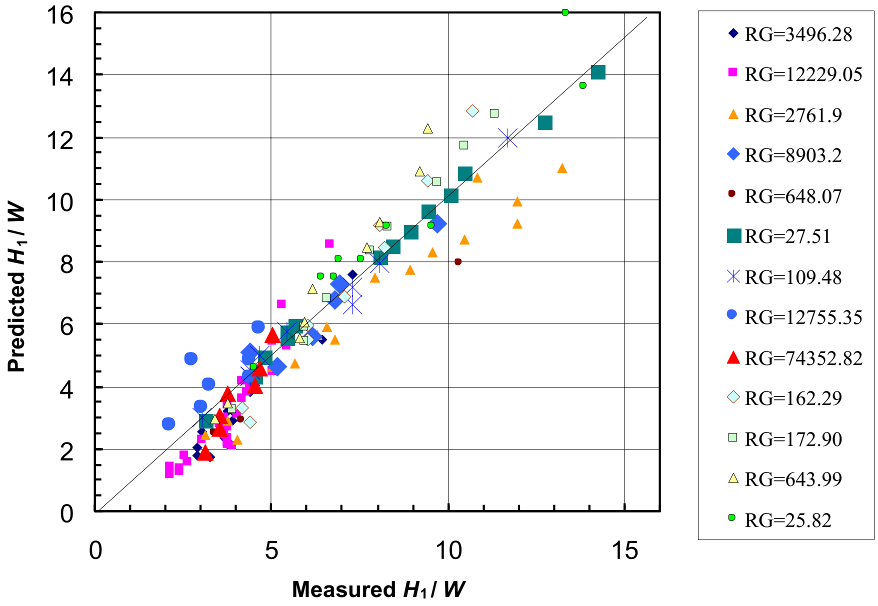

Figure 4.

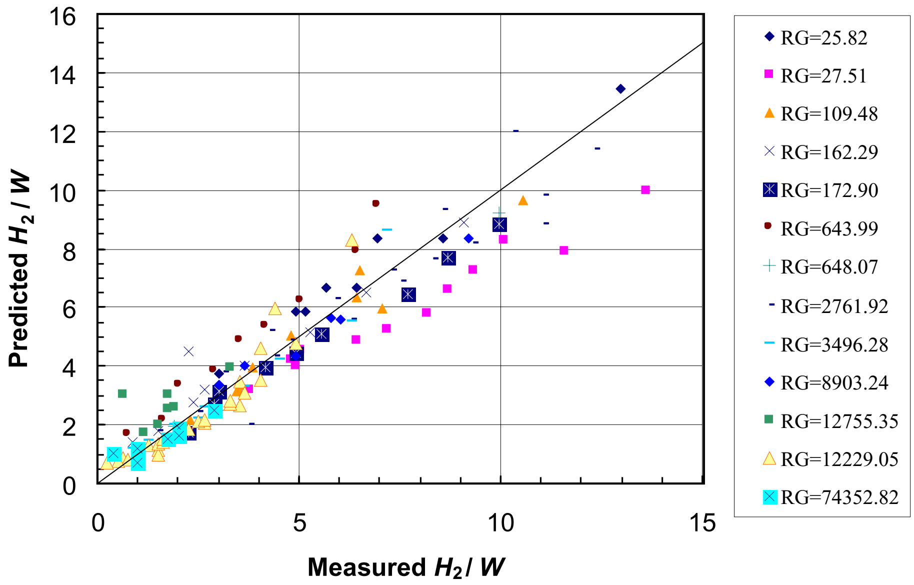
Predicted H_2 / W
16
14
12
10
8
6
4
2
0
0
5
10
15
Measured H_2 / W
RG=25.82
RG=27.51
RG=109.48
RG=162.29
RG=172.90
RG=643.99
RG=648.07
RG=2761.92
RG=3496.28
RG=8903.24
RG=12755.35
RG=12229.05
RG=74352.82

Figure 5.