UCI Samueli School of Engineering

The effects of Impeller Size and Speed on Fluid Mixing

Experiment 10 – *team ten*

Bo Bramer, Clark Wey, Jose Leal, Angel Rodriquez

Topics Covered

- Introduction (background, ethics, objectives)
- Materials and Methods
- Theory
- Results
- Discussion
- Conclusion

Introduction – Background

- Common in industrial applications
  - Oil and gas industry
  - Food industry
- Convert heterogeneous to homogeneous
  - Single or multiphase
  - One or many components

Introduction – Background

- Difficult process
  - Every system has different design variables
- No “one-size-fits-all” mixing system
- Important to know how any variable affects the mixing process

Introduction – Ethics

- Important to have thorough mixing
  - Increased cost, increased time
- When not mixed thoroughly, problems arise
  - Endanger both environment and process
- AIChE code of ethics
  - "hold paramount the safety, health and welfare of the public and protect the environment in performance of their professional duties"

UCI Samueli School of Engineering

Introduction – Ethics

- Thermal Runaway
  - Catastrophic effect on environment and process
    - Destroying environment
    - Low product yield

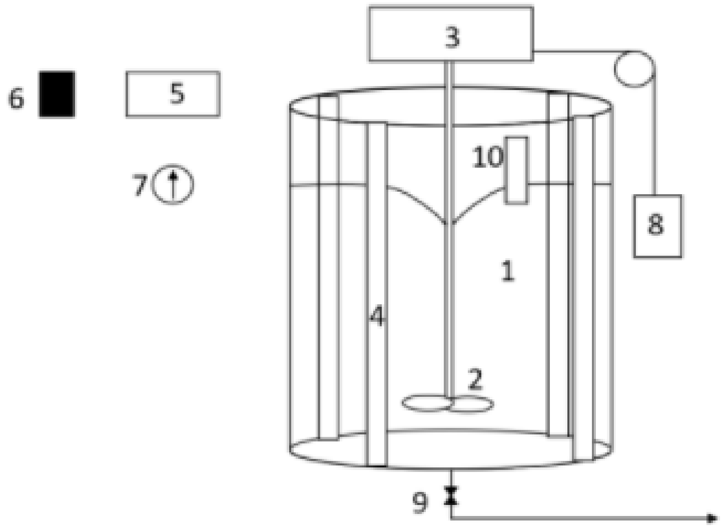
- Dec 19th, 2007
  - T2 Laboratories in Florida
  - 4 deaths, 32 injuries

Introduction – Objectives

- Know how different variables affect mixing process
    - Density, components, mixing speed, etc.
- Characterize mixing in acrylic tank of water with different variables
    - Blade size, mixing speed, presence of baffles

Materials and Methods

- Different sized impeller blades
  - 2.1x6.2, 4.3x6.2, 6.5x6.2 cm
  - Different widths, same lengths
- Different impeller speeds
  - 150, 250, 350 RPM
- Conductivity probe to determine mixing time
- Force meter to determine torque on motor



Theory

- Reynolds number
  - $Re = \frac{\rho N D^2}{\mu}$
- Power number
  - $N_p = \frac{P}{\rho N^3 D^5}$
- Froude number
  - $Fr = \frac{D N^2}{g}$

ρ: Fluid density

N: Impeller rotational speed

D: Impeller Diameter

μ: Fluid dynamic viscosity

P: Mixing power

g: Gravitational acceleration

Theory

- Blending time number t_b: blending time
  - $N_b = t_b \cdot N$

Theory

- Expected Reynolds number vs. mixing time number plots

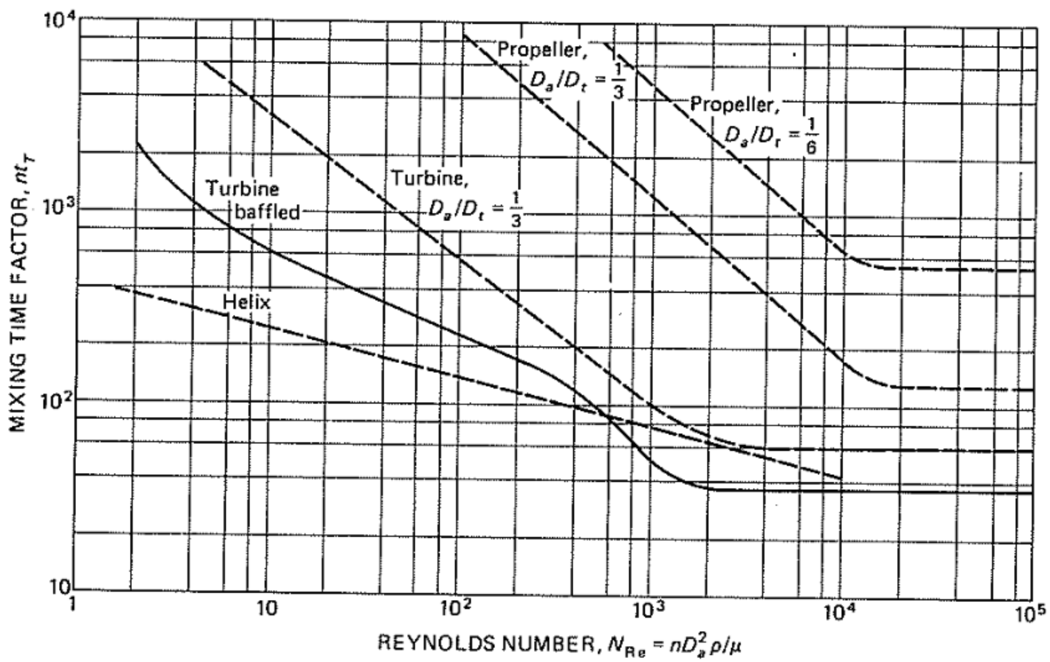


FIGURE 9.15
Mixing times in agitated vessels. Dashed lines are for unbaffled tanks; solid line is for an unbaffled tank.

Theory

- Expected Reynolds number vs. power number plot

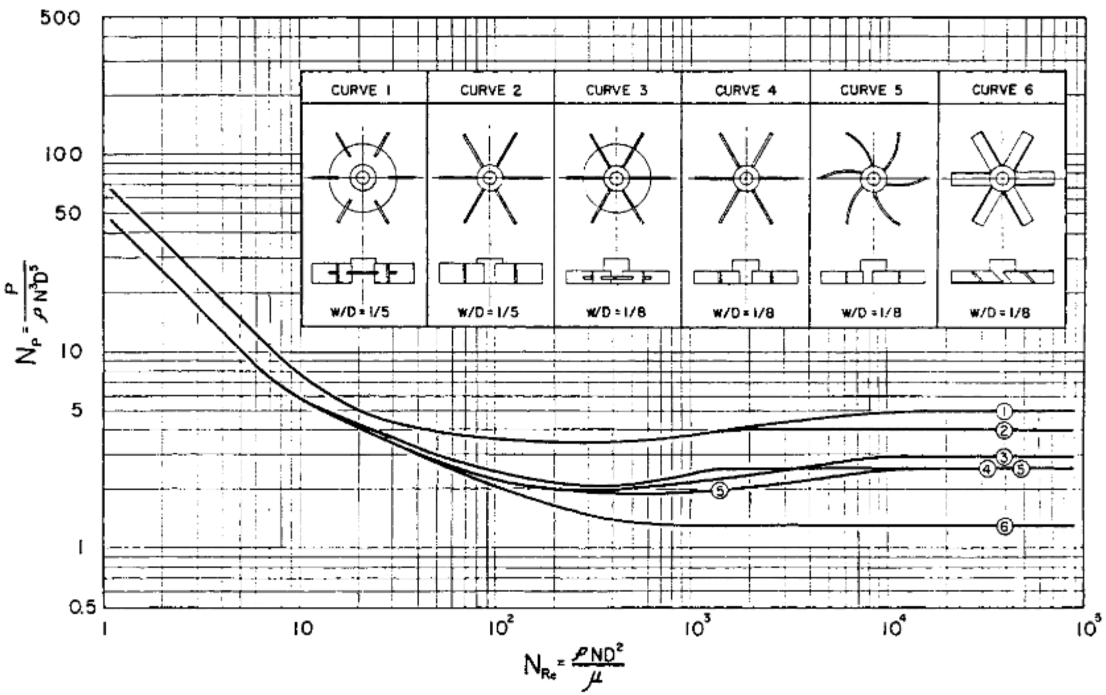
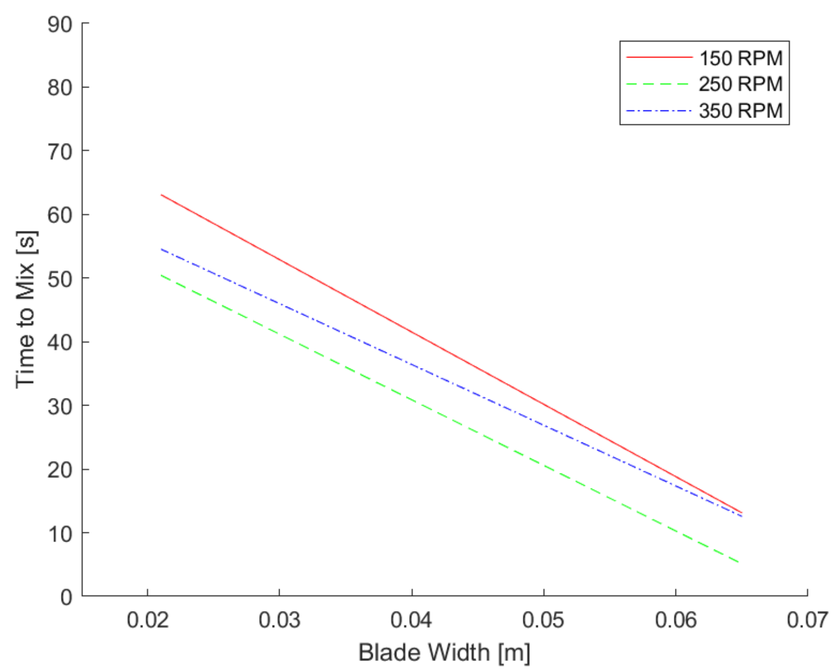


FIG. 6-40 Dimensionless power number in stirred tanks. (*Reprinted with permission from Bates, Fondy, and Corpstein,* Ind. Eng. Chem. Process Design Develop., **2,** *310* [*1963*].)

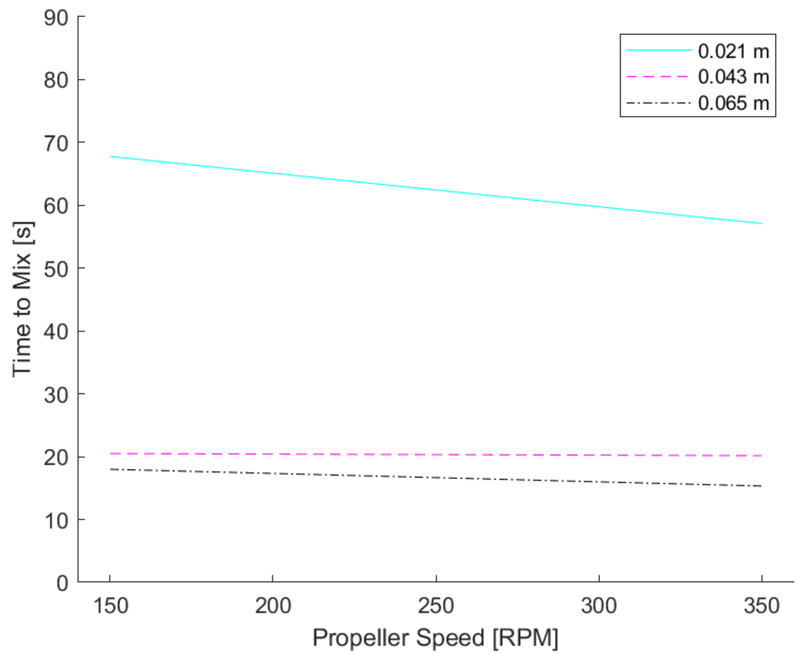
Results

- Blade width vs. time to mix while holding rotation speed constant shows negative correlation



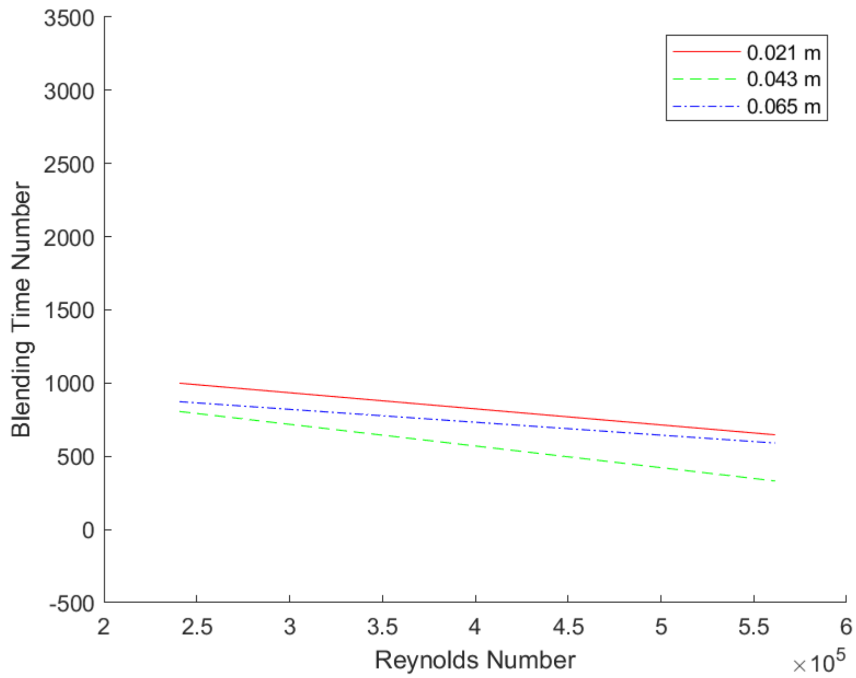
Results

- Rotation speed vs. time to mix while holding blade width constant shows no significant correlation



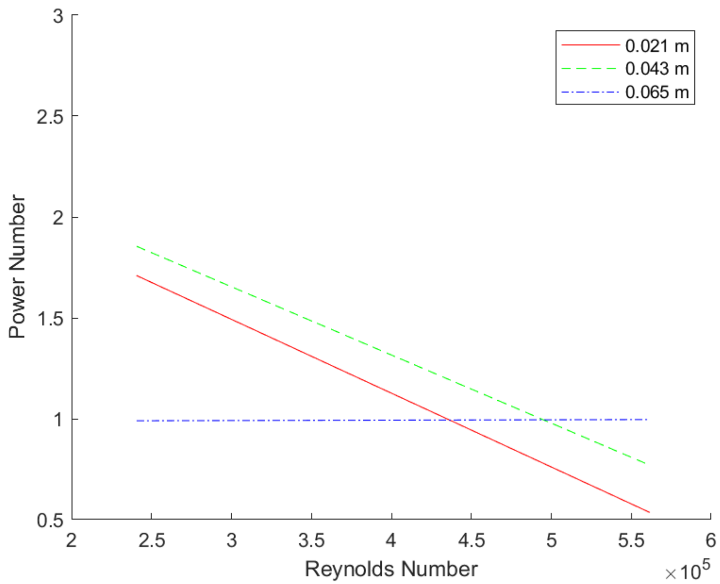
Results

- Reynolds number vs. blending time number shows weakly negative correlation



Results

- Reynolds number vs. power number shows that over increasing Reynolds number, increase in blade width to blade length ratio led to decrease in power number



Discussion

- Increasing blade width decreased time to mix
- Increasing blade speed did not decrease time to mix
- Increasing Reynolds number had a weakly negative correlation with blending time number
- Increasing Reynolds number led to a decrease in power number

Discussion

Reynolds number vs. blending time number

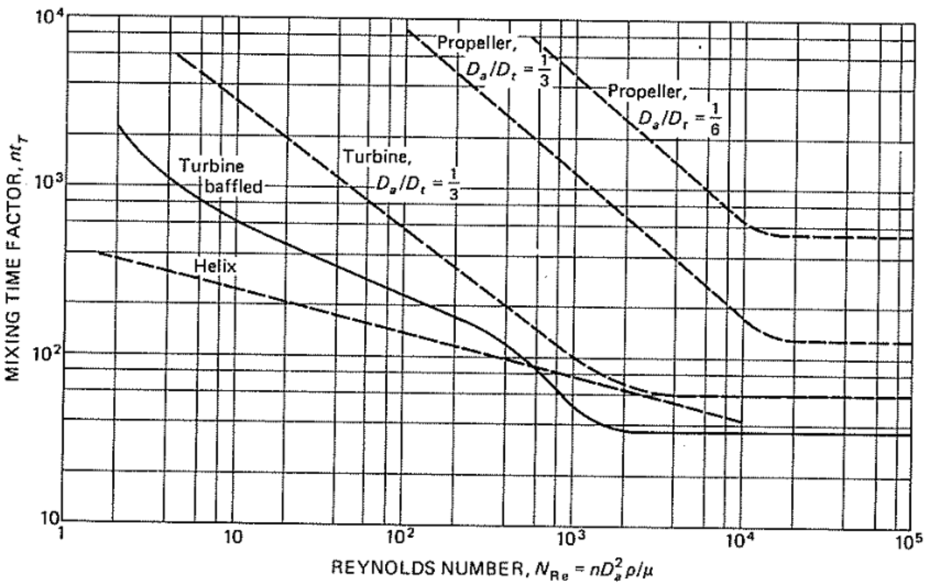
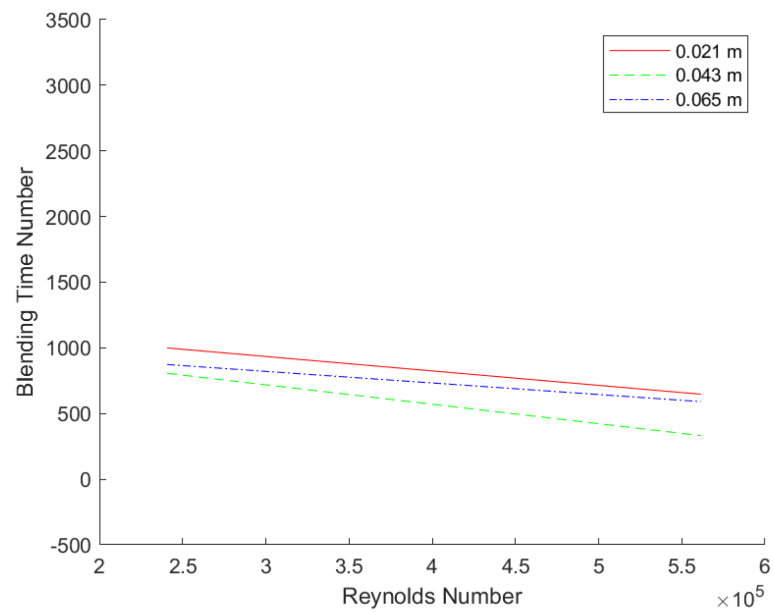


FIGURE 9.15
Mixing times in agitated vessels. Dashed lines are for unbaffled tanks; solid line is for an unbaffled tank.



Discussion

Reynolds number vs. power number

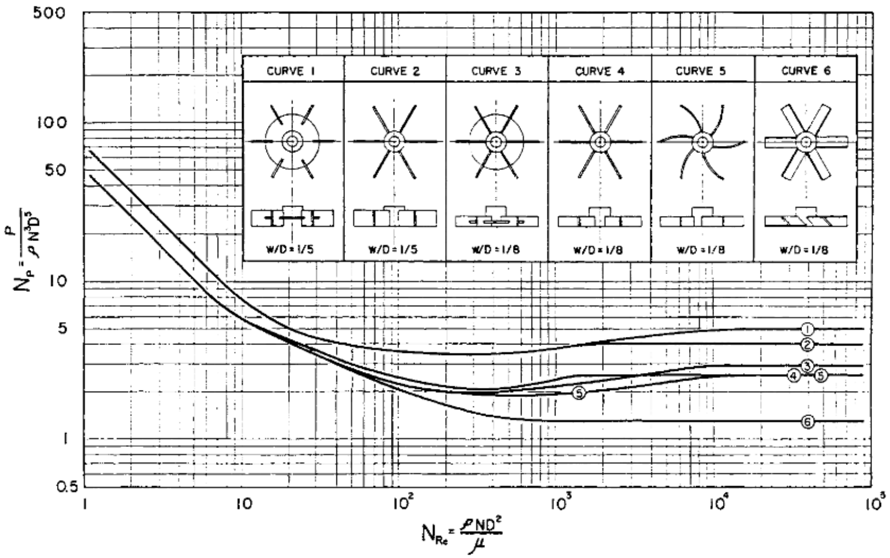
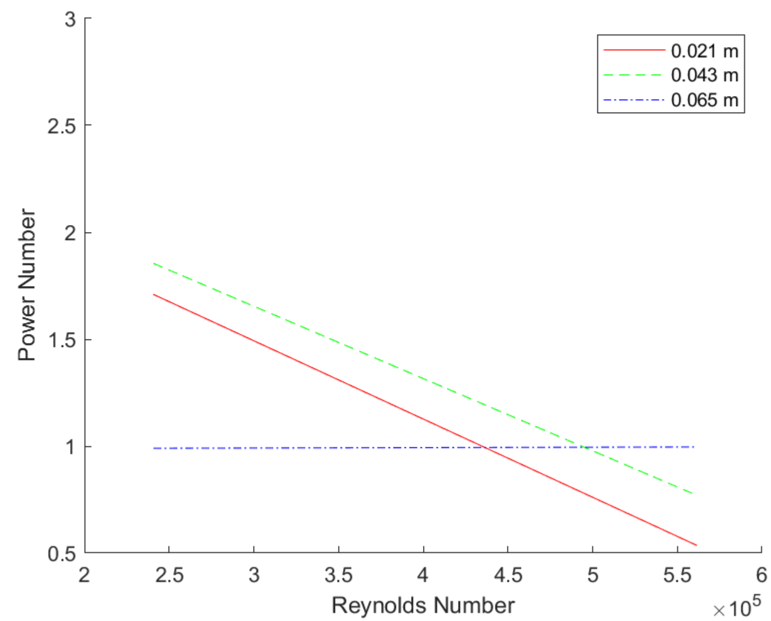


FIG. 6-40 Dimensionless power number in stirred tanks. (*Reprinted with permission from Bates, Fondy, and Corpstein,* Ind. Eng. Chem. Process Design Develop., **2,** *310* [*1963*].)



Conclusion

- Increasing blade widths significantly decreased mixing time
- Increasing impeller speeds did not
- Higher Reynolds numbers lead to better performance
  - Mixing time number, power number

Conclusion

- Approach for scaling up
  - Holding power number constant
  - $\frac{N_2}{N_1} = \left(\frac{D_1}{D_2}\right)^{\frac{2}{3}}$
- Future steps
  - Changing angles of blades
  - Expect angles closer to vertical to have lower blending time but higher power number

Citations

- J. B. McClintock, R. A. Angus, M. R. Mcdonald, C. D. Amsler, S. A. Catledge, and Y. K. Vohra, ``Rapid dissolution of shells of weakly calcified Antarctic Benthic macroorganisms indicates high vulnerability to ocean acidification: Antarctic Science,'' Cambridge Core, 01-Oct-2009. [Online]. Available: https://www.cambridge.org/core/journals/antarctic-science/article/abs/rapid-dissolution-of-shells-of-weakly-calcified-antarctic-benthic-macroorganisms-indicates-high-vulnerability-to-ocean-acidification/DC9B2354DAACA88BC5305C1D69BB578D. [Accessed: 19-Oct-2021].
- "Code of Ethics." AIChE's, 21 Aug. 2020, https://www.aiche.org/about/governance/policies/code-ethics.
- "T2 Laboratories Inc.. Reactive Chemical Explosion." CSB, https://www.csb.gov/t2-laboratories-inc-reactive-chemical-explosion/.
- Kummer, Alex, and Tamás Varga. "What Do We Know Already about Reactor Runaway? - A Review." Process Safety and Environmental Protection, vol. 147, 2021, pp. 460–476.