Session 2067

APPLICATION OF INTERACTIVE INSTRUCTIONAL COMPUTER MODULES IN ENGINEERING LABORATORY ENVIRONMENTS

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Abstract

This paper demonstrates a way of applying JAVA, a platform independent computer language, for Computer Aided instruction in Engineering. An interactive instructional computer module related to Unit Operations in Engineering is formulated for in a game like environment. The modules are tested for their flexibility, portability, and security. The results indicate that JAVA-based instructional/simulation modules can become one the chief teaching/training tools of the decade.

Project Objectives

The main object of this paper is to demonstrate the suitability of JAVA to develop platform independent interactive teaching modules. The case-study selected to illustrate this concept focuses on technical calculations, analysis, improvement, scaling-up and development of mixing processes and equipment. The product enables chemical and process engineers to visualize mixing processes and to calculate process parameters for single- and two- phase systems, power consumption and circulation rates. The module is developed with two goals in mind: be interactive to keep the students attention while demonstrating important design concepts, and be flexible enough to fit different teaching styles and be practical to across-the-discipline instructors.

Methodology

Several dimensionless groups that are commonly used to characterize fluid flow and heat transfer phenomena in mixing operations. These dimensionless variables are ultimately combined to yield a general set of design equations for mixers.

When designing agitated vessels, an important dimensionless quantity that needs to be considered is the Reynolds number, $N_{Re,mix}$

$$N_{\mathrm{Re},mix} = \frac{\rho N D^2}{\mu}$$

The Reynolds number ($N_{Re,mix}$) is the ratio of inertia and viscous forces and is commonly used to determine whether laminar or turbulent flow exists in a system. In agitated vessels, it is common to define the reference length as the impeller diameter (D) and the reference velocity as agitator tip speed or the product of impeller diameter and impeller revolutions per minute (N D). Inclusion of the fluid density (ρ) and viscosity (μ) terms yields the Reynolds number equation below for agitated systems.

Additionally, it is important to describe the vortexing that can result from agitation by a rotating impeller. The dimensionless Froude number (N_{Fr}) is used to describe the extent to which vortexing occurs and is a measure of the ratio of inertial stress, which is the flow of momentum created by bulk fluid motion, and gravitational force per unit area acting on the fluid. Specifically, the Froude number is a function of impeller diameter, impeller RPM, and the acceleration due to gravity (g).

$$N_{Fr} = \frac{N^2 D}{g}$$

Power Analysis

In the beginning, the impracticability of a direct mathematical attack on agitator power correlation led to employment of an empirical approach. The subject however has much in common with the well- substantial method of analysis in fluid dynamics and, with the aid of dimensional analysis and the theory of models, a framework has been developed which satisfactorily encompasses most of the variables.

The power number (N_P) is used to estimate the energy required to rotate an impeller at a given speed and is analogous to a friction factor. The dimensionless power number is proportional to the ratio of drag forces acting per unit area of impeller surface and inertial stresses and is defined in terms of motor power (P), the gravitational constant (g_c), fluid density, agitator RPM, and impeller diameter.

$$N_P = \frac{P g_c}{\rho D^5 N^3}$$

Although these equations can be solved numerically, a solution is more suitable to illustrate the effect of the different operating parameters. This is achieved by using a JAVA applet embedded in an HTML document. The student chooses conditions and feeds in the input parameters and presses the "Calculate" button. Incase he doest know the input parameter value a default value button will be provided for solving the problem. The "calculate" button activates and displays the output in the applet (Figures 3 and 4). Altering any of the reactor parameters will change the output, allowing the student to optimize the operating conditions to meet a given objective or to visualize the effect of the different operating parameters.

Illustrative Example

A Flat-blade (Figure 1) turbine with six blades is installed centrally in a vertical tank. This tank is 6 ft (1.83 m) in diameter. The turbine is 2 ft (0.61m) in diameter and is positioned 2 ft (0.61m) from the bottom of the tank. The turbine blades are 6 in. wide. The tank is filled to a depth of 6 ft (1.83m) with a solution of 50% caustic soda at 150 °F (65.6°C) which has a viscosity of 12 CP and a density of 93.5 lb/ft^3 (1498 kg/m^3). The turbine is operated at 90 rpm. The tank is baffled. What power will be required to operate the mixer?

Solution[1]

Curve A in Figure 2 applies under the conditions of this problem.
The Reynolds number is calculated. The quantities for substitution are in consistent units

$D = 2$ ft

$N = 90/60$ rps $= 1.5$ rps

$\mu = 12 \times 6.72 \times 10^{-4} = 8.06 \times 10^{-3}$ lb ft^{-1} s^{-1}

$\rho = 93.5$ lb ft^{-3}

$g = 32.17$ ft sec^{-2}

Thus

$$N_{\mathrm{Re},mix} = \frac{\rho N D^2}{\mu} = 69{,}600$$

From Figure 2, we can then read the power number as $N_P = 6.0$

Then the power, in ft lb$_f$ s^{-1}, will be

$$P = \frac{N_P D^5 N^3 \rho}{g_c} = \frac{6 \times (2)^5 \times (1.5)^3 \times 93.5}{32.17} = 1{,}883$$

Thus, the power requirement is 1883/550 = 3.42 hp (2.55 kW).

Conclusions

A reliable online JAVA applet, which can be accessed on the Internet acting as the control console of a Mixer has been developed. This applet is a solver for equations governing mixing occurring in an agitated vessel. The JAVA code is compact, secure, and platform-independent. The applet can be easily embedded in an HTML document to be run in any computer with public-domain browsers (e.g., Netscape Communicator or Microsoft Internet Explorer). The program can be distributed in magnetic media (e.g. CD-ROM) or via the Internet (World Wide Web). The application is secure from adulteration because it exists in JAVA bytecode, which is makes it undecipherable without a decompiler. Another level of security is added by making the code virtually inaccessible by distributing the program and associated files in a compressed format. Defining a set of parameters that can be specified in the <APPLET> tags in the HTML code that invokes the applet ensures versatility. These parameters can be defined by the user/instructor without having to access or edit the code, adding flexibility to the module to set up a variety of mixer Design/configuration problems.

Significance

This project focused on tools to facilitate the educational process as applied to mixer design principles. The students in Engineering will find it helpful in improving their knowledge on mixing and improving agitated vessel design performance. It will provide the ability to perform technical calculations of the most recent research and mathematical modeling of mixing process. The project enables engineers to visualize the mixing process and calculate a number of most important process parameters for a single and two phase system. These include power consumption, circulation rates, flow regimes etc. A graphical user interface is provided for the step-by-step guidance through the stages needed to create the model for the chosen mixer. These modules had to meet security and portability standards, and be suitable for web-based delivery. The modules were to be developed with two goals in mind: be interactive to keep the students attention while demonstrating important design concepts, and be versatile enough to fit different teaching styles and be useful across-the disciplines instructors.

There exist a number of applications where a "Mixer Design" can be used: in-classroom teaching, web-based instruction, distance learning, self-paced tutorials, etc. Laboratory setups to simulate mixers using certain impellers are simple to develop. However, certain impellers and design conditions are difficult to setup for which the applet is very useful. Portability, security, and compactness make this type of module especially useful as training or testing tool. They require small disk storage, do not interfere with the operating system, and can be executed in any computer with a browser. It will not be long before these applets could be executed in portable devices (PDA), thus the engineer would carry the PDA with her/him. Therefore, the engineer will be able to simulate any alternative condition before setting the final process parameters that could impose risks on the plant, ship, or crew. This module has been used as an interactive simulator in Chemical Reactor Design, a Junior-level class. The students are given a number of open-ended problems and they are asked to formulate solutions and use the simulator to verify their solution

Acknowledgements

The authors want to acknowledge the financial support provided by Cleveland State University (CSU). This project has been made possible by an instructional improvement grant from the University Center for Teaching and Learning (UCTL) at CSU. Additional finances were provided the Department of Chemical Engineering and Cleveland State. Computational resources provided by the Fenn College of Engineering are also acknowledged.

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JORGE E. GATICA holds a Ph.D. degree from the State University of New York (SUNY) at Buffalo. Jorge Gatica manages programs involving the application of Reaction Engineering principles to Materials Manufacturing and Processing. His interests also include web-enhanced education and the integration of computers in Engineering curricula. He is an active member of the American Institute of Chemical Engineers (AIChE) and the American Society for Engineering Education (ASEE). He has over 70 technical presentations at national and international meetings, and more than 50 publications in refereed journals. He is a member of several editorial boards of Science and Technology publications, and is a frequent reviewer for several Chemical Engineering, Materials Science and Combustion publications, as well as a proposal reviewer for several federal agencies. His research on hybrid C-C composites was the first CSU project supported by the OAI Core Program. His research with NASA Glenn Research Center has resulted in a recent patent application for conversion/protective coating technology. Dr. Gatica serves as a mentor for undergraduate minority and high-school students, he is a member of the board of Esperanza (a non-profit organization dedicated to the academic advancement of North East Ohio Hispanic population), actively interacts with the Society of Hispanic Professional Engineers (SHPE), and he has also serves as an adviser for Project SEED (ACS) minority students.

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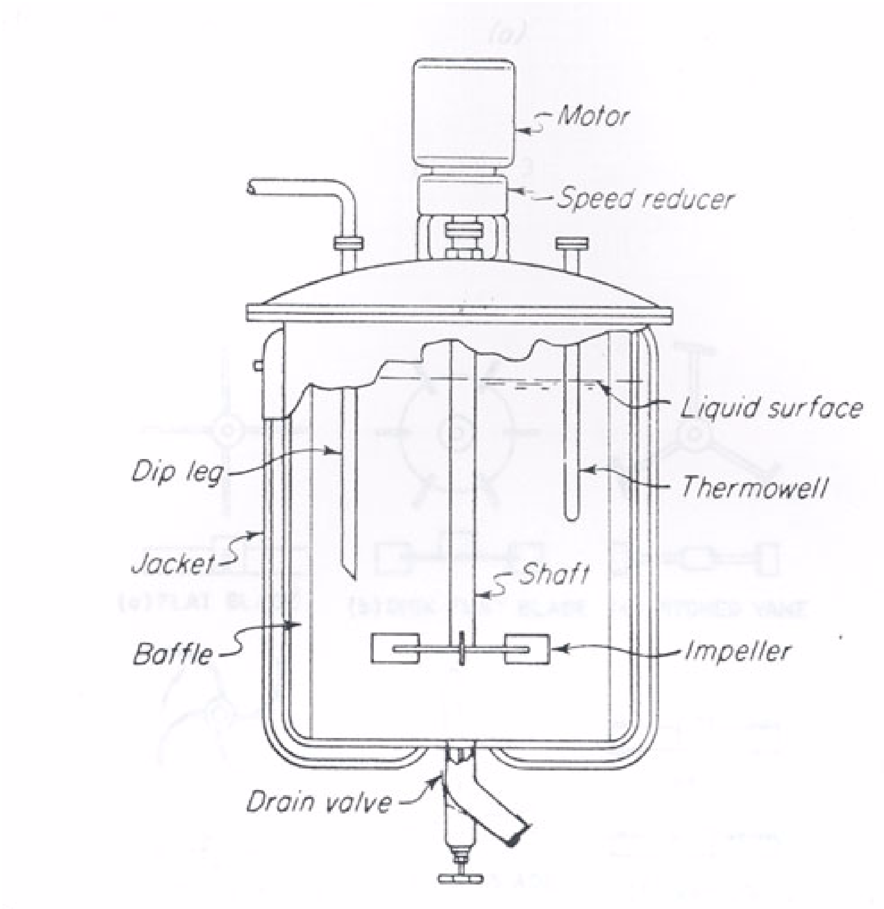

FIGURE 1: TYPICAL AGITATION PROCESS VESSEL

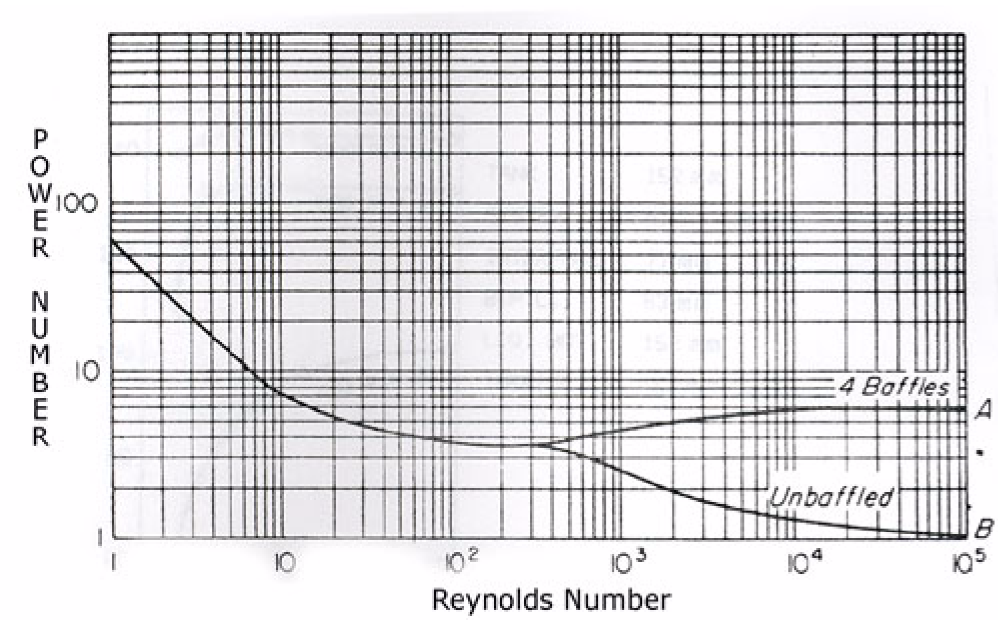

FIGURE 2: Example plot of Power number vs. Reynolds Number

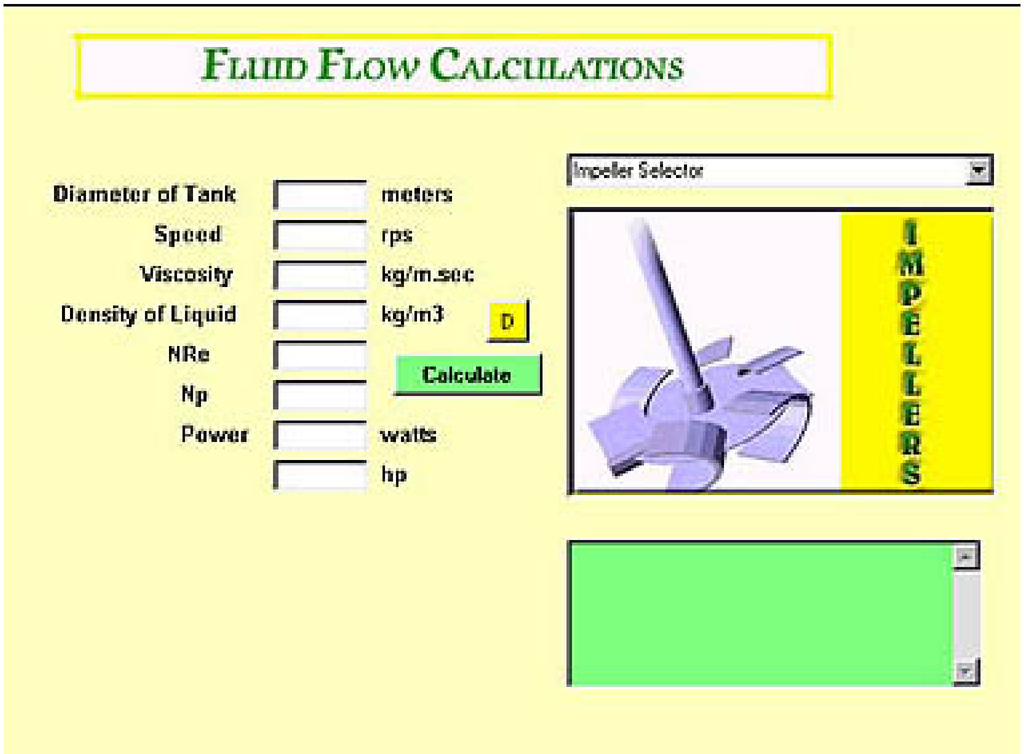

FIGURE 3: FLUID FLOW UNIT OPERATION BASED MODULE

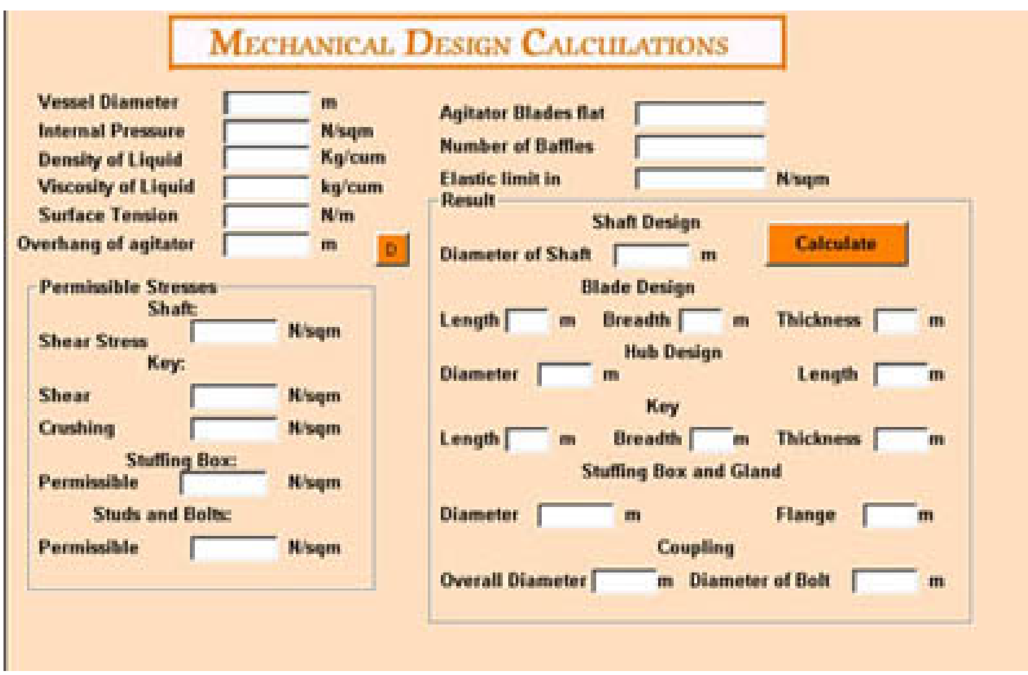

FIGURE 4: MECHANICAL DESIGN BASED MODULE