24.536 Reactor Experiments and 407.403 Advanced Nuclear Lab

HW #6: "Reactivity Measurements" Pre-lab Exercises

Introduction

The purpose of Reactor Experiment #2 is to become familiar with various techniques for measuring reactivity changes and reactivity levels within a variety of reactor configurations. In particular, this lab exercise will address four different experimental techniques and show that a combination of these methods will allow the measurement of a range of reactivity changes, $\Delta\rho$, during both critical and subcritical operations, as well as the determination of the absolute reactivity level, ρ_o, of a subcritical configuration.

Upon completion of this experiment, the student should have a better understanding of various methods for measuring reactivity and the subcritical reactivity level, and be able to apply and interpret the four methods discussed. HW#6 emphasizes these topics and assures that everyone has the proper background for the actual lab experience. The specific tasks and deliverables for this pre-lab assignment are described below:

Task 0: Review/Study the Lecture Notes, Examples, and Associated Reference Materials

Before starting the formal tasks listed below, you should be sure that you have a good understanding of the main topics under study and be familiar with the overall experimental procedure to be followed for Reactor Lab #2. In particular, for this pre-lab HW, you should carefully review the following documents (these are available within the Dropbox share folder for this course):

1. J. R. White, "Reactivity Measurement Techniques," part of a series of Lecture Notes for the Nuclear Engineering Program at UMass-Lowell. Also included in this discussion is a series of Matlab routines to illustrate the four methods discussed here. These files are available within the class Dropbox folder within the ***measure_rho_simulations.zip*** file.
2. J. R. White, "Reactor Lab #2 Description/Procedure: Reactivity Measurement Techniques," part of a series of procedures used within the 24.536 Reactor Experiments course at UMass-Lowell.

Task 1: Answer several general questions concerning the background theory and the specific methods to be illustrated as part of the Reactivity Measurements lab.

Answer each of the following questions/problems fully and include your responses, calculations, and Matlab simulations, as needed, as part of your complete package for HW#6.

Problem 1: In class, it was stated that, "for large reactivity changes, the **Stable Period Method** breaks down for both positive and negative ρ." Clearly explain this statement in some detail.

Problem 2: Summarize briefly the region of applicability of the four methods discussed in the Lecture Notes -- that is, in what situation is each method applied?

Problem 3: The **Rod Drop** and **Source Jerk Methods** require numerical integration of the measured P(t) data. This exercise wants you to become familiar with the ***trapz*** routine in Matlab for performing the needed integrations. In particular, let's focus on a simple function that decays exponentially to zero as $t \rightarrow \infty$ -- say, for example, $f(t) = e^{-at}$, where a is a positive constant.

a. Integrate this function analytically from 0 to ∞ -- that is, what is the exact value of I, where

$$I = \int_0^\infty f(t)dt \qquad \text{for} \qquad f(t) = e^{-at}$$

for two different values of the constant a, say $a = a_1 = 0.5\ s^{-1}$ and $a = a_2 = 2.0\ s^{-1}$.

b. Now write a Matlab code to numerically integrate this function over the range $0 \le t \le 30$ seconds using the ***trapz*** function for the two different constants given above (note that the contribution to the integral beyond 30 seconds is negligible in both cases). Since ***trapz*** requires discrete vectors for the function, f(t), and independent variable, t, let's study the accuracy of the numerical integration versus the selected step size, Δt. In particular, let Δt take on the following four different values, **dt = [10 1 0.1 0.01]** seconds. Create discrete vectors for **t** and **f** and use ***trapz*** to perform the desired integral, I, for the four different step sizes and the two different values of the decay factor, a, and compare your results to the exact analytical solutions. Do things behave as expected? Explain your observations here…

Note that the sampling time for the data acquisition system in the UMLRR is 1 second. What does this say about our ability to measure fast negative transients within the UMLRR?

Problem 4: Here we want to illustrate the use of the **Stable Period Method**.

Using the **bw_display** GUI with the most recent blade worth data, estimate the reactivity change associated with the following two cases:

1. RegBlade moves from 10″ withdrawn to 13.0″ out
2. RegBlade moves from 10″ withdrawn to 5.5″ out

Now, use the ***rho_stable_period.m*** routine to simulate these reactivity perturbations in the UMLRR assuming that the system is initially critical, and use the simulated P(t) data within the **Stable Period Method** to "measure" the reactivity inserted, using the following parameters:

noise level: 5% short transient time: 90 seconds

Show and explain your results…

Problem 5: Here we want to illustrate the use of the **Rod Drop Method**.

For a noise level of 5%, assume that **Control Blade 1** drops instantaneously from a position of 17.5″ withdrawn within a steady-state critical system. Simulate this event using the Matlab ***rho_rod_drop.m*** code and compare the "measured" worth relative to the actual reactivity used to initiate the transient. Show your results and briefly explain what was done here. Do your results make sense? Again use the **bw_display** GUI, as needed.

Problem 6: Here we illustrate the use of the **Subcritical Multiplication Factor Method**.

Assume that the UMLRR is subcritical by the amount of worth inserted by **Blade 1** in the previous problem (i.e. the worth of going from 17.5″ out to fully inserted). **Blade 1** is then pulled out quickly to 15″ withdrawn. Use the **bw_display** GUI and the ***rho_subcriticalM.m*** code to simulate and analyze this situation and to "measure" the worth associated with the movement of **Blade 1** from 0 to 15″ withdrawn. Again, show and explain your results. Assume a 20% noise level and that the ratio of count rates for the two steady-state subcritical configurations is the same as the power ratio in these states.

Problem 7: Here we want to illustrate the use of the **Source Jerk Method**.

Assume that the UMLRR is at steady state subcritical with **Blade 1** at 15″ withdrawn (that is, the endpoint of the previous problem simulation). Now the source is pulled out of the core very quickly. Use the ***rho_source_jerk.m*** code to simulate and analyze this situation and to "measure" the subcriticality level of the system with **Blade 1** at 15″ out. Again, show and explain your results and make the same assumptions as in the previous problem (i.e. a 20% noise level and that $C_1/C_0 = P_1/P_0$).

Note: Problems 5-7 are related in that the end condition of one problem is the starting point of the next problem. In particular, the system is assumed to be just critical when **Blade 1** is dropped from 17.5″ to fully inserted (Problem 5). Then **Blade 1** is moved out to 15″ withdrawn (Problem 6). And, assuming steady-state at this condition, the source is pulled from the core (Problem 7). Understanding these relationships makes these problem easier to interpret -- and this will be roughly the sequence of events that we perform in the live reactor lab during our upcoming Reactivity Measurements lab…

Documentation and Submission of HWs

In general, I expect a professional, well-written, semi-formal report for each HW assignment in this course. Please refer to HW#1 regarding the format for each HW assignment in this course -- **they should all be done and submitted in a similar fashion!!!**

For this HW, you will need to include your discussions for Problems #1 and #2, and the Matlab code, results, and discussions for Problem #3. For Problems #4 - #7, show and discuss your results and include the modified versions of the sample codes given to you as part of your overall HW submission. These last four problems, in particular, actually simulate roughly what will be done in the reactor lab, so success with these problems will give you a good understanding of the upcoming Reactor Measurements lab. As done previously, please put everything together, including all your Matlab m-files, in a single zip file -- **only one zip file per HW please** -- and **email this to me before 4 pm (UML time) on the Sunday** before our next class.

Good luck…