NucE 511

NUCLEAR REACTOR KINETICS AND DYNAMICS

Class 1: Basic Topics and Nomenclature

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Basic Time-Dependent Phenomena in Nuclear Reactors

Time-dependent phenomena in nuclear reactors may be subdivided into three distinctly different classes:

- The time constants of the individual phenomena in the three classes differ by orders of magnitude.

- Different physical phenomena require different set of equations and solution approaches - not just a case of the same phenomenon occurring at different speeds.
Basic Time-Dependent Phenomena in Nuclear Reactors

1. **Short time phenomena**, which typically occur in time intervals of milliseconds to seconds; in special cases, the time intervals may extend to many minutes.

2. **Medium time phenomena**, which occur over hours or days corresponding to the mean buildup and decay times of certain fission products that strongly affect the reactivity.

3. **Long time phenomena**, with variations developing over several months or years.
Basic Time-Dependent Phenomena in Nuclear Reactors

These time-dependent phenomena basically include changes in the neutron flux as well as causally related changes in the reactor system, i.e., composition or temperature.

The causal relationship between the neutron flux and the physical reactor system may occur in either direction:

1. changes in the composition or temperature of the system may cause a change in the flux

2. changes in the flux may alter the composition or temperature and thus the density and absorption characteristics of the system
Changes in the system can also be externally induced (for example, by the motion of an independent neutron source, or of control rods, resulting in neutron flux changes).

If the flux changes cause changes in the reactor and these changes subsequently "act back" on the flux, the phenomenon is termed "feedback."
Basic Time-Dependent Phenomena in Nuclear Reactors

The "short time phenomena" include more or less rapid changes in the neutron flux due to intended or accidental changes in the system.

- The latter changes may influence the flux through feedback.

- Short time phenomena include flux transients important for:
  1. Accident analysis and safety
  2. Experiments with time-dependent neutron fluxes
  3. Reactor operation, such as startup, load change, and shutdown (even though some startup procedures may take hours)
  4. Analysis of stability with respect to neutron flux changes
"Medium time phenomena" are generally associated with the buildup, burnup, and beta decay of two fission products (\(^{135}\text{Xe}\) and \(^{149}\text{Sm}\)) in thermal reactors.

- These two fission products have very high thermal neutron capture cross sections and thus require special attention in thermal reactors.

- Since the treatment of medium time phenomena is methodologically different from kinetics it is treated in a separate class.
Basic Time-Dependent Phenomena in Nuclear Reactors

"Long time phenomena" include particularly the burnup and buildup of fissionable isotopes, as well as the buildup, beta decay, and burnup of most of the fission products.

- In the fast neutron energy range, the cross sections of all fission products are so small that they do not affect the flux and the reactivity as strongly as in thermal reactors.

- Other long time phenomena occurring in reactors that have only a minimal effect on the neutron flux include swelling of the structural material, changes in the fuel pellets due to burnup, etc.
Since short, medium, and long time phenomena are physically different phenomena resulting in different sets of equations, different concepts and solution approaches are utilized.

These are the strongest reasons for separating these time phenomena into three different categories with different names.
Kinetics Versus Dynamics

The nomenclature used for the different categories of time-dependent phenomena in nuclear reactors is not unique.

The two basic names in use are kinetics and dynamics:

- A few authors subsume all time-dependent phenomena under "dynamics," including burnup and buildup of isotopes.
- Most authors, however, consider long time phenomena to represent a separate category, namely "fuel cycle problems."
Essentially three names are in use for the class of short time phenomena:

1. **Kinetics**, for the entire class of short time phenomena

2. **Dynamics**, also for the entire class of short time phenomena

3. **Dynamics**, as a general heading for the entire class of short time phenomena, with two subheadings:
   
   a) **kinetics**, for short time phenomena without feedback
   
   b) **dynamics**, in the narrower sense, for short time phenomena with feedback
Kinetics Versus Dynamics

It is convenient to have a special name for the range of problems (kinetics problems, kinetics equations) in which only the time behavior of neutrons need be considered.

If feedback is important, the system of kinetics equations must be completed by another set of equations describing the various feedback effects.
Kinetics Versus Dynamics

- It is also convenient to have a different name for the completed set of equations (dynamics equations, dynamics problems)

- Since the completed set of equations describes the general problem, dynamics is also used as a general heading

- This course is concerned with the short time variations of the neutron flux as a function of time, i.e., with the typical topics of kinetics and dynamics
Next Class

*Dynamic Equation*

*Simplified Neutron Cycle*
1. Describe briefly the three categories of time dependencies occurring in nuclear reactors.

Short term phenomena – milliseconds to minutes
   control changes + TH feedback
   time-dependent neutronics

Medium term phenomena – hours to days
   fission products
   time-dependent neutronics

Long term phenomena – months to years
   burnup; structural changes in the fuel pellet
   steady state neutronics + time-dependent nuclide concentration
Review Questions

2. State three areas of kinetics or dynamics applications.

1. Accident analysis and safety
2. Experiments with time-dependent neutron fluxes
3. Analysis of stability with respect to neutron flux changes
3. Considering the nomenclature, what do various authors consider to be the subject of "dynamics" or "kinetics"?

   Kinetics – time-dependent neutronics

   Dynamics – time-dependent neutronics + feedback model
4. What is the main difference in the balance equations for the neutron flux in reactor dynamics and fuel cycle analysis?

reactor dynamics – time-dependent neutronics + feedback model

fuel cycle analysis - steady state neutronics + time-dependent nuclide concentration