THE SIGNIFICANCE OF APPLIED MECHANICS IN DESIGNING THE FAST TEST REACTOR

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The influence of applied mechanics analysis has had a significant effect in designing the Fast Test Reactor (FTR), a Sodium-cooled Fast Flux Reactor being constructed for testing candidate materials and fuels for the U.S. Liquid Metal Fast Breeder Reactor (LMFBR) program. This mechanics influence is more evident in the design of a liquid metal cooled reactor such as the FTR than in the more conventional water-cooled designs.

While applied mechanics have played a major role in all reactor designs, the combination of environmental conditions in a liquid metal reactor results in an interplay between the mechanics analyst and the reactor designer to a degree as never before required. Specifically, these environments include a fast neutron spectra, high neutron fluence (flux-time) exposures, an elevated thermal environment, and a high conductivity coolant.

The fast neutron spectrum (65% greater than 0.1 Mev) and high flux exposures (greater than 10^{23} nv) when coupled with the thermal environment (1100°F in the active core), causes a metal growth phenomenon and a radiation-induced creep effect, particularly in the active core region.

The high flux and fast spectra also cause metal embrittlement which must be factored-in to the elastic design of the more permanent, nonremovable structure within the reactor.

The combination of an elevated temperature, a high conductivity coolant (sodium) and (in the case of the FTR) the diverse structures required in a test reactor, creates unique thermal stress conditions not previously encountered in water reactors.

Current criteria being utilized for structural design include residual ductility requirements for permanent structures; strain-limited design requirements for removable highly irradiated components such as the cladding; and an intermediate combined criterion for such items as the in-core component ducts.

Areas where the analysis/design interplay are particularly required include:

- Duct and core restraint design and duct distortion/dilation analysis.
- Inlet tubesheet elastic design and neutron embrittlement considerations.
- Outlet instrumentation structures and thermal stress analysis of these structures under postulated transient conditions.

This paper discusses the significant effect of these phenomena on reactor design, describes the analytic methods being utilized in formulating design solutions, and covers the resultant unique FTR design features evolving from the analysis/design iterations.

DISCUSSION

V. BECKETT, U. K.

Q

You mentioned having trouble with the hexagonal ducts which tend to go circular due to pressure differentials and creep. Could you not reduce this problem by starting off with circular ducts ? This may mean a slightly larger core for the same fuel inventory perhaps but not, I think, by a very large amount.

G. R. WAYMIRE, U. S. A.

A

We had considered circular ducts early in the conceptual design, which was before the advent of irradiation induced creep. The reason then for considering circular elements was because it would be easier to fabricate the assembly. Because of reduced power density, however, and because of the desire to achieve a high flux, the circular duct was not considered practical for the FTR or for subsequent power reactors. This, I am sure, would still be the case even with the problems associated with irradiation induced creep.

M. BENDER, U. S. A.

Q

Could you comment on the thermal expansion effects in the FTR core ? How are the strain limits influenced by thermal strain cycling of core components ?

G. R. WAYMIRE, U. S. A.

A

Thermal expansion considerations or, if prevented, the resultant thermal loading, is a major consideration in the FTR design, as I indicated in the section of the paper dealing with specific problems, e. g. , the instrument tree design. We are using conservative postulated cyclic histories in performing the analysis on components to assure that the strain limits I mentioned are not exceeded.

J. VAN MIEGROET, Belgium

Q

Could you describe the procedure you use to start the reactor, going from cold to hot state, as far as core compaction is concerned. Is this compaction a stiff one or only a displacement limitation allowing for some limited subassemblies displacement and reducing thus the degree of interaction between clamping system and subassemblies shrouds ?

G. R. WAYMIRE, U. S. A.

A

During startup, the core restraint is first activated to assure core compaction to some limit near theoretical compaction which will assure a safe startup condition. The instrument trees are then repositioned over the core and the safety and control rods are

reconnected.

Flow is then monitored to assure adequate coding and the rods are withdrawn.

The core restraint system allows sufficient opening during refueling to assure that handling damage does not occur. Prior to startup, the core is compacted to a tight geometry. During operation a new constant load variable displacement lateral support is maintained.

Q

M. SCHMIDT, Germany

You showed us formulas for swelling and creep which are valid for 20% cold worked material. I suppose the main reason therefore was the anticipated lower amount of swelling of c. w. materials. On the other hand, I have read in an FFTF paper about the difficulties as to manufacturing of properly cold worked components, as for instance core ducts. Could you comment on this item, and above all, are you now confident to be able to overcome these problems, viz. to get at least better results than with solution treated material ?

A

G. R. WAYMIRE, U. S. A.

We were concerned earlier with distortions in the duct due to variations in cold work, for example, at the hexagon corners, which would occur during manufacture. We do now have some fabrication development experience under our belt and we feel quite confident that these problems are not of great enough magnitude to cause distortions in excess of those which can be allowed with present duct tolerances. Additional development work will of course be required to assure our current feelings. We do feel that a significant reduction in swelling can be obtained with 20% cold worked material.

Q

H. HOLTBECKER, JRC Ispra, Italy

1. Could you comment on emergency core cooling under post accident conditions: Is a core-catcher system foreseen ?
2. What kind of emergency core cooling system is foreseen for decay heat removal ?

A

G. R. WAYMIRE, U. S. A.

First, I would like to say that my part is not reactor safety, and then taking your questions in order:

1. The ECC mode, of course, is dependent upon the postulated accident. For example, in the case of a primary system rupture, the guard vessel and system elevations (thermal center elevations) assume core coverage and natural convection cooling which will maintain the fuel in a safe condition.

There is no core catcher within the vessel. There is a meltdown section located below the guard vessel.

2. The emergency core cooling is afforded by using a guard vessel around the reactor vessel,

which assures adequate coverage of the core for convection cooling.

Q J. WENGLER, Germany

1. Do you assume that the core cannot melt ? If it melts were does the molten material go to and is it cooled ?
2. How is your concept for emergency cooling ?
3. Do you plan to install in the testing position a facility for doing gas-loop experiments for gas-breeder-elements ?

A G. R. WAYMIRE, U. S. A.

Again let me preface my answer with the comment that I do not claim any expertise in safety.

1. We do assume core melting under the hypothetical core disrupture accident. I am not sure of the molten materials postulated flow path. There is a meltdown structure below the guard vessel which I assume is designed to contain the molten mass.
2. Emergency cooling is assured by sodium coverage of the core under all conditions combined with a natural convection cooling path. In the extreme, this method will assure that the cladding will not be breached, although significant fuel melting does occur.
3. Early conceptual studies examined gas cooled loops and found them feasible. Because of funding limitations, however, there are no current plans for designing a gas cooled loop for FTR.