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UC 79P

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Reports and Papers Published Under

MIT Fuel-Coolant Interaction Project

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Mujid, S. Kazimi, "Theoretical Studies on Some Aspects of Molten Fuel-Coolant Thermal Interaction," 31-109-38-2831-1 TR, MITNE-155, May 1973.

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Introduction

The objective of the continued work on this project at M.I.T. is to experimentally and analytically study the dominant mechanisms in fuel coolant thermal interactions which could lead to vapor explosions. Our exploration of mechanisms is focused in two areas:

a) Mechanisms responsible for fragmentation in molten metal droplet experiments (here we will include assessment of the validity of the proposed Spontaneous Nucleation Mechanism),

b) Thermal Stress Initiated Fracture as a fragmentation mechanism (this mechanism is not considered responsible for the fragmentation of molten metal drops - see Knapp's work).

Work is being performed in both these areas simultaneously and will be briefly described below.

I. Mechanisms Responsible for Fragmentation in Molten Metal Droplet Experiments

(Gautam Shiralker)

A. Gas Solubility Hypothesis

The primary effort in this task is to assess the validity of gas solubility hypothesis proposed by M. Epstein[1]. Preliminary experiments of tin heated in prepurified nitrogen gas (99.98% pure) in as short a time as possible (less than a minute) and dropped into water, indicated fragmentation similar to those experiments using air as an atmosphere.

It is believed, however, that water vapor coming off the furnace walls and present as an inpurity in the nitrogen could be responsible since it is possible for this gas to become dissolved in the tin during the required heating time.

To overcome this problem, design of an experiment whereby the heating could be carried out in a vacuum was undertaken. At the time of writing, the apparatus is ready and in working condition, suitable for dropping molten metal into cold liquids with low vapor pressure at ordinary (room) temperature. An adjustment will be made shortly to enable dropping metal into coolants with higher vapor pressure, such as water and a series of experiments will be initiated to check the hypothesis.

[1]Epstein, M., "Thermal Fragmentation--Gas Release Phenomenon", Nuclear Science & Engineering, Vol. 5, pps. 462-467. 1974.

B. Magnitude of the Pressure Pulses during Fragmentation

An experimental check was made of the formula relating the amplitudes of pressure traces recorded on tape, by a transducer placed some distance away in the water drom the drop entry, to the amplitude of the pressure extrapolated to the drop surface.

This formula is:

$$P_d = P_t(d/r)$$

where P_d - pressure at drop surface

P_t - pressure recorded by transducer

d - distance of transducer from drop at time of interaction

r - radius of drop.

The experiment was run using two recorders and two transducers simultaneously. The results indicate a fairly wide scatter around the values predicted by the above equation.

A simple calculation indicates that reflections of the pressure waves from the container sides should not be a problem. The consistency of the pressure traces also supports this view. This discrepancy will be investigated further in case check of future hypotheses are sensitive to the numerical magnitude of the pressure at the drop surface. However, the consistency of the interaction characteristics together with the important difference between pressure traces from liquid versus initially solid drops (which identify the "bigbang" as particular to liquid drops) indicate the value of even the qualitative pressure results of recordings.

II. Thermal Stress Initiated Fracture

(W. Fred Lenz)

At the November meeting at Argonne, the direction of the work being carried out at MIT on this aspect of the fuel coolant interaction program was shifted somewhat. Before the meeting, the work was directed towards carrying thru a mechanistic approach based upon the thermal stress mechanism to determine the final particle size distribution. The current work considers the thermal stress mechanism as a mechanism that may be shown to limit the rate of a fuel coolant interaction thus demonstrating why an energetic reaction is seen not to occur in most experiments carried out with UO_2 and Na.

The reason for this shift in direction was due to several factors. First of all, it was recognized by the meeting participants that a purely mechanistic approach based on following cracks as they grow and fork, represents a very complicated task. Secondly, due to wide range of experimental results, almost any final particle size determined by a mechanistic approach could be supported by experimental data.

In our effort to investigate the thermal stress mechanism as a limiting process, we will investigate those physical phenomenon which limit the stress induced fragmentation. Much of the work for this period has involved the development of computer codes to study one of these phenomenon, the effect of the solidification under various possible boundary condition assumptions. It is hoped that from study of these phenomena, small time scales for heat transfer in a fuel coolant interaction can be neglected as physically impossible resulting in lower expected interaction work energies.

The ANL fuel coolant interaction computer model written by Cho, et al., will be used to generate curves of constant work energy as a function of the mixing time constant and the final particle size with assumed parameters that will represent what is believed to be the worst case situation in the FFTF. Once this is accomplished, the results of solidification limited process will be used to effectively cut out certain areas of the graph that are physically impossible.

In an effort to establish if the stress induced fragmentation mechanism is capable of producing a particle size distribution found in the molten fuel-coolant experiments to date, some analyses will also be performed to determine if the stress levels in the solidifying fuel material are sufficient to produce characteristic particle sizes. This work should show the smallest particle size possible thereby verifying that the thermal stress induced fragmentation mechanism is capable of producing fragments within the final observed particle size distribution.