

Review

Summary of severe accident issues of LBE-cooled reactors

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ABSTRACT

The safety analysis work is always a key issue for the nuclear power plant licensing. After Fukushima Accident of Japan, the severe accident safety analysis has been more concerned, which would be also very important and essential for the Research and Development (R&D) work of LBE-cooled reactors. So far, a great number of studies on severe accident of LBE-cooled reactors have been carried out. In this paper, a summary of severe accident of LBE-cooled reactors is conducted, which contains almost all the relevant issues on the hypothetical Core Disruptive Accidents (CDAs). Detailed contents of these issues are discussed. The systematic framework of severe accident safety analysis of LBE-cooled reactors is preliminarily given, which aims at providing a useful reference for the further safety analysis research work of this kind of advanced reactor.

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1. Introduction

The Lead-Bismuth Eutectic (LBE)-cooled Reactor (or Lead-cooled Reactor) is a kind of advanced reactor of inherent safety and could be used in electricity generation, fuel breeding and

long-life nuclear waste transmutation (Tucek et al., 2006; Sathiyasheela et al., 2011; Moiseyev and Sienicki, 2008). It is important for the sustainable development of nuclear energy source. LBE could be used as the primary coolant for both fast and accelerator-driven sub-critical system (ADS) reactors as it has good neutron properties, anti-irradiation performances, heat transfer properties and inherent safety characteristics (Sobolev, 2007). Fast reactor is the preferred reactor type in Generation IV

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reactors. The closed cycle of nuclear fuel supplied by fast reactor would be up to 60% or more utilization of Uranium resources (Sienicki, 2013). The partitioning and transmutation technology was proposed in 1960s, which was designed to be used in dealing with the long-life high-radioactive spent fuel. The ADS reactor is a potential option for spent fuel transmutation. In contrast with critical reactors, not only nuclear waste transmutation capacity of ADS is stronger, but the MA neutron economy is also better. The international typical LBE-cooled reactors are SVBR, MYRRHA, EFIT, PDS-XADS and CLEAR (Petrochenko et al., 2015; Zrodnikov et al., 2011; Wang et al., 2015; Tichelen et al., 2002; Liu et al., 2010; Suzuki et al., 2005; Gu et al., 2015).

For the future demonstration and commercialization of LBE-cooled reactors, many previous research and development (R&D) work were carried out. The safety assessment work is always a key issue for the nuclear power plant licensing, which evaluates accident conditions both from internal and external events. It is systematic and mature for the nuclear reactors which have been in operations successfully. But for LBE-cooled reactors, the safety assessment issue is still unsound. After Fukushima Accident of Japan, the severe accident safety analysis has been more concerned by nuclear regulatory authorities of all countries which are employing or developing nuclear power plants. IAEA requires severe accidents to be considered, with a combination of the probability and engineering judgement, assess reasonable mitigation measures (Ekelund, 2015). For the future nuclear power plants, severe accident might be systematically considered and analyzed in the preliminary and final safety analysis reports. Hence, for LBE-cooled reactors, the severe accident safety analysis work would be meaningful and necessary.

In recent years, many studies on severe accident safety analysis of LBE-cooled reactors have been conducted. For instance, the simulation of fuel dispersion in the MYRRHA-FASTEF primary coolant was carried out by Buckingham et al. with CFD and SIMMER-IV codes (Buckingham et al., 2015). Li et al. analyzed the fuel dispersion after pin failure in hypothetical blockage accidents for MYRRHA-FASTEF critical core (Li et al., 2015). Experimental study

on freezing behavior of molten metal on structure was carried out by Rahman et al. (2005). Our research group simulated the fuel dispersion in an LBE-cooled research reactor as a previous study (Wang et al., 2015) and carried out a review of recent simulation and experimental research progress on severe accident safety analysis of LBE-/lead-cooled fast reactors (Wang, 2017). The existing studies on severe accident of LBE-cooled reactors mainly include the postulated initiating event prediction, typical processes and phenomena simulation, re-criticality investigation, simulation code development, verification experiments, etc.

In this paper, based on the review of severe accident safety analysis experience of light water-cooled reactors (LWRs) and LMRs (including sodium-cooled, LBE-cooled and Lead-cooled reactors) (Tentner et al., 2010; Lia et al., 2015; Maschek et al., 2015; Natarajan and Ravichandran, 2001; Thilak et al., 2013; Sekimoto and Makino, 2002; Petrykowski, 2012; Maschek et al., 2011, 2003a,b,c, 2001; Kondo, 1994; Gu, 2018), a summary of severe accident of LBE-cooled reactors is carried out. Relevant issues on severe accident are discussed, which aims at providing a reference for the further safety analysis work of this kind of advanced reactor.

2. Definition of severe accident of LBE-cooled reactors

The research work of severe accident should be systematic and comprehensive. For LBE-cooled reactors, it mainly contains the relevant issues on severe accident as following:

- 1) The definition of the severe accident for LBE-cooled reactors
- 2) The events which may lead to severe accidents (postulated initiating events)
- 3) Main processes, typical phenomena and important consequences during severe accidents
- 4) The analysis methods of severe accidents
- 5) Severe accident prevention and consequence mitigation (severe accident management)

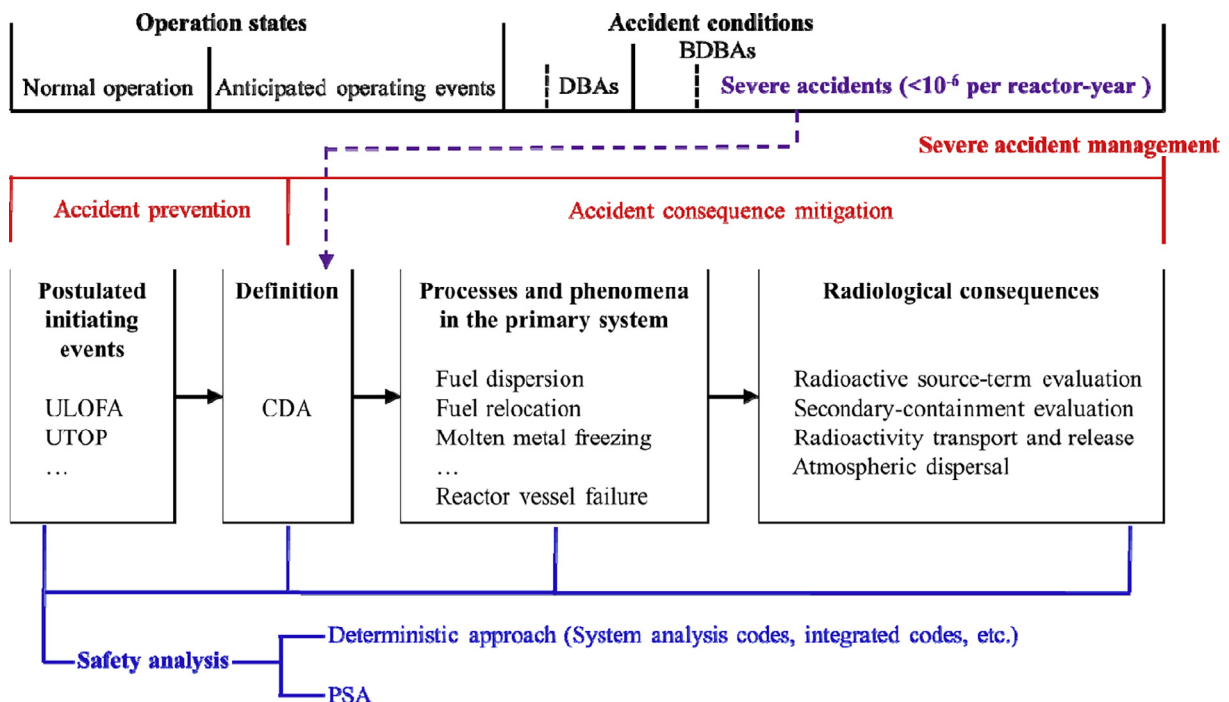


Fig. 1. Severe accident issues of LBE-cooled reactors.

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