SUPPRESSION MEASURES AND EFFECTIVE TRIGGERING RETARDANT OF STEAM EXPLOSIONS

Masahiro Furuya*, Takahiro Arai
Central Research Institute of Electric Power Industry (CRIEPI)
2-11-1 Iwado-kita, Komae, Tokyo 201-8511, JAPAN
furuya@criepi.denken.or.jp

ABSTRACT

Steam explosion has been a potential threat during severe accident in light water reactors. We had reported that Polyethylene glycol (PEG) is a reliable retardant of steam explosions. Experiments were conducted to investigate the effects of concentration, molecular weight and salt additives on the controllability of steam explosions. Steam explosion was suppressed with a 0.03 wt% PEG solution for molecular weight of 4 million. This is because the cloudy-point phenomenon stabilizes vapor film and prevents the solution from mixing finely by the precipitated solute near the steam-water interface. The stabilizing effect of vapor film was confirmed in a solid stainless-steel sphere quenching experiment as well. The molecular weight must be selected in reference to the cloudy-point temperature to be lower than saturation temperature by a certain degrees at the target pressure. At atmospheric pressure, a molecular weight of 4 million is demonstrated to suppress steam explosions. The effective concentration became denser when large share stress and/or external force act on the vapor film. Steam explosion may occur in a PEG solution by adding 1wt% of sodium chloride, because such salts act as steam explosion promoter.

KEYWORDS
Steam explosion retardant, triggering, polyethylene glycol, additives, cloudy-point phenomenon

1. INTRODUCTION

Steam explosion has been causing disasters in chemical and metallurgy industries. In addition, Fletcher [1] reviewed the role of triggering in steam explosions in terms of nuclear reactor safety. Reliable countermeasures are crucial to cope with the industrial disasters by steam explosion. Large scale steam explosion is generally considered to proceed in the following four stages as shown in Fig. 1: (1) coarse mixing, (2) triggering, (3) propagation, and (4) expansion. Triggering is the event that initiates the rapid, local heat transfer and pressure rise that are necessary if a propagating wave is to develop. In spite of the industrial relevance, knowledge of the triggering mechanism is insufficient even for a simple molten-alloy droplet system since the experimental data are scattered even if initial conditions are set to be identical due to the random nature of steam explosions.

The authors [2] found that there are three factors that change triggering conditions sensitively during the premixing stage, resulting in the loss of reproducibility: (1) the heat transferred from a hot fluid to a cold fluid, (2) configuration and orientation of the interface where triggering occurs, and (3) the property of the surface, e.g., the oxide layer formation. The authors [3] have performed experiments in the droplet

---

* Corresponding author

11. L. S. Nelson, P. M. Duda, “Photographic Evidence for the Mechanism of Fragmentation of a Single Drop of Melt in Triggered Steam Explosion Experiments,” J. Non-Equilibrium Thermodynamics, Vol.13, pp.27-55, 1988.
12. R. Chapman, D. Pineau, M. Corradini, “Mitigation of Vapor Explosions in One-Dimensional Large-scale Geometry with Surfactant Coolant Additives,” Proc. AMIGO-IMI, pp.47-58, 1997.
13. J. H. Lienhard, “Correlation for the Limiting Liquid Superheat,” Chem. Engng. Sci., Vol.31, No.9, pp.847-855, 1997.
14. M. Furuya, I. Kinoshita, “Effects of Polymer, Surfactant, and Salt Additives to a Coolant on the Mitigation and the Severity of Vapor Explosions,” Experimental Thermal and Fluid Science, Vol.26, Issue2-4, pp.213-219, 2002.
15. M. Furuya, T. Arai, “Effect of Surface Property of Molten Metal Pools on Triggering of Vapor Explosions in Water Droplet Impingement,” Int. J. Heat and Mass Transfer, Vol.51, Issues 17-18, doi:10.1016/j.ijheatmasstransfer.2008.02.025, pp.4439-4446, 2008-8.
16. Y. IIda, T. Takashima, “Direct-Contact Heat Transfer Characteristics: Evaporation of a Drop Dropped onto a Hot Liquid Surface,” Int. J. Heat Mass Transfer, Vol.23, No.9, pp.1263-1271, 1980.
17. Y. IIda, T. Takashima, “Leidenfrost Film Boiling of a Droplet on the Free Surface of Hot Liquid,” ASME-JSME Thermal Engng. Joint Conf., Hawaii, pp.269-275, 1987.