INTISARI

Pada reaktor nuklir jenis *pressurized water reactor* (PWR) terdapat kemungkinan kebocoran pada sirkuit primer yang menyebabkan reaktor kehilangan tekanan tiba-tiba dan terjadi perubahan fase cair menjadi uap jenuh yang disebut *loss-of-coolant-accident* (LOCA). Dalam skenario LOCA uap akan mengalir melalui *hot leg* menuju *steam generator* (SG). Ketika debit uap meningkat maka akan terjadi fenomena *countercurrent flow limitation* (CCFL) atau *onset of flooding*. Kondisi tersebut merupakan fenomena berbalik arahnya kondesat menuju SG kembali karena dorongan uap jenuh. Selanjutnya dengan debit uap jenuh yang semakin meningkat, mengakibatkan tidak mengalirnya cairan menuju RPV atau disebut *zero liquid penetration* (ZLP). Hal ini beresiko terhadap kegagalan pendinginan.

Penelitian ini mengkaji fenomena *onset of flooding* udara-cairan di simulator *hot leg* dengan analisis visual dan sinyal antarmuka dan tekanan pada cairan dengan tegangan permukaan rendah. Penelitian dilakukan pada simulator sirkuit primer reaktor PWR geometri tipe Konvoi Jerman skala 1/30 *hot leg* dengan panjang pipa horizontal 455 mm, diameter lingkaran dalam 25,4 mm, sudut kemiringan 50˚ terhadap horizontal, perbandingan I/D sama dengan 1,9 dan L/D = 24. Analisis fenomena *onset of flooding* dilakukan dengan visualisasi menggunakan *high-speed camera* serta akuisisi sinyal pada sensor *parallel wire* untuk fluktuasi antarmuka dan *differential pressure transducer* (DPT) untuk fluktuasi tekanan.

Analisis visual menyajikan visualisasi tiga buah kecepatan superfisial cairan (J_L) yaitu 0,023 m/s (12 gph); 0,056 m/s (24 gph); dan 0,088 m/s (36 gph) dengan kenaikan kecepatan superfisial udara (J_G). Visualisasi tersebut menunjukkan adanya fenomena aliran subkritis, aliran superkritis, *hydraulic jump*, aliran *stratified*, aliran *wavy*, aliran *slug*, dan aliran *churn* yang merupakan rangkaian dalam fenomena *flooding* hingga terjadinya *zero liquid penetration*. Hal tersebut didukung dengan grafik yang memperlihatkan terjadinya peningkatan tekanan tiba-tiba ketika *onset of flooding*. Pada J_L 0,023 m/s peristiwa *flooding* diinisiasi oleh antarmuka yang bergelombang di pipa horizontal dan diakhiri dengan aliran *slug* di belokan. Pada J_L 0,056 m/s aliran bergelombang menyebabkan aliran *slug* terjadi berulang kali di pipa horizontal hingga mencapai belokan. Pada J_L 0,088 m/s aliran *slug* terjadi dan pecah di pipa horizontal hingga belokan.

Analisis sinyal *parallel wire* dan sensor DPT menunjukkan kondisi yang fluktuatif setiap variasi kecepatan superfisial cairan dan udara tertentu. Seiring peningkatan kecepatan superfisial cairan, lokasi terjadinya *onset of flooding* semakin mendekati RPV. Hubungan kecepatan superfisial cairan (J_L) dan kecepatan superfisial gas (J_G) menunjukkan bahwa semakin meningkatnya J_L maka permulaan *flooding* terjadi semakin pada J_G rendah. Analisis *chaotic* menunjukkan adanya tren penurunan setelah *onset of flooding*. Analisis *wavelet* menunjukkan puncak distribusi frekuensi yang berbeda-beda dan cenderung meningkat seiring dengan peningkatan kecepatan superfial udara.

Kata kunci: *hot leg*, *parallel wire*, *flooding*, analisis statistik, *chaotic*, *wavelet*

ABSTRACT

In a pressurized water reactor (PWR) there is a possibility of a leak in the primary circuit which causes the reactor to suddenly lose pressure and change the liquid phase to saturated vapor which is called loss-of-coolant-accident (LOCA). In the LOCA scenario steam will flow through the hot leg to the steam generator (SG). When the steam discharge increases, the phenomenon of countercurrent flow limitation (CCFL) or onset of flooding will occur. This condition is a phenomenon of condensate turning towards SG again due to the encouragement of saturated steam. Furthermore, with an increasing saturated steam discharge, it results no liquid flowing towards the RPV or it is called zero liquid penetration (ZLP).

This research to study the phenomenon of air-liquid onset of flooding in a hot leg simulator by visual analysis and Interface and pressure signals in liquids with low surface tension. The research was conducted on a PWR reactor primary circuit simulator geometry German Konvoi type scale 1/30 hot leg with a horizontal pipe length of 455 mm, an inner diameter of 25.4 mm, an inclination angle of 50° to the horizontal, I/D ratio equals 1.9 and L/D = 24. Analysis of the onset of flooding phenomenon was carried out by visualizing using a high-speed camera and signal acquisition on parallel wire sensors for Interface fluctuations and a differential pressure transducer (DPT) for pressure fluctuations.

Visual analysis presents a visualization of three liquid superficial velocities (J_L), namely 0,023 m/s (12 gph); 0,056 m/s (24 gph); and 0,088 m/s (36 gph) with an increase in the air superficial velocity (J_G). The visualization shows the phenomena of subcritical flow, supercritical flow, hydraulic jump, stratified flow, wavy flow, slug flow, and churn flow which are a series of flooding phenomena until zero liquid penetration occurs. This is supported by a graph showing the liquid level in the RPV and also the sudden increase in pressure at the onset of flooding. At J_L 0,023 m/s flooding events are initiated by corrugated Interfaces in the horizontal pipe and terminated by slug flow at bends. At J_L 0,056 m/s, wavy flow causes slug flow to occur repeatedly in the horizontal pipe until it reaches a bend. At J_L 0,088 m/s slug flow occurs and breaks in the horizontal pipe and forms a liquid blockage.

Parallel wire signal analysis and DPT sensors show fluctuating conditions for each variation of the superficial velocity of certain liquids and air. As the superficial velocity of the fluid increases, the location of the onset of flooding is closer to the RPV. The relationship between liquid superficial velocity (J_L) and gas superficial velocity (J_G) shows that as J_L increases, the onset of flooding occurs at lower J_G. Chaotic analysis shows a decreasing trend after the onset of flooding. wavelet analysis shows that the frequency distribution peaks are different and tend to increase with the increase in air superficial velocity.

Keywords: hot leg, parallel wire, flooding, statistical analysis, chaotic, wavelet