INTISARI

Sirkulasi alami merupakan mekanisme perpindahan panas pasif yang banyak diterapkan pada sistem keselamatan reaktor karena kemampuannya beroperasi tanpa komponen mekanis. Namun, aliran pada sistem ini bersifat kompleks dan rentan mengalami ketidakstabilan, seperti osilasi dan transisi rejim aliran dari laminar menuju turbulen. Penelitian ini mengkaji pengaruh variasi daya pemanas terhadap karakteristik termohidrodinamika, pembentukan kondisi tunak, serta perubahan dan batas rejim aliran pada sistem sirkulasi alami satu-fase. Tujuan penelitian ini adalah mengidentifikasi karakteristik aliran secara eksperimental, menganalisis perubahan rejim aliran melalui visualisasi dan parameter tak berdimensi Reynolds serta Grashof, serta mengevaluasi efektivitas CWT sebagai indikator kuantitatif rejim aliran.

Eksperimen dilakukan pada fasilitas sirkulasi alami FASSIP-06 Ver.03 dengan variasi daya pemanas 750–1550 W dan temperatur pendingin konstan sebesar 10°C. Data temperatur pada beberapa titik pengukuran serta laju aliran volumetrik diakuisisi secara kontinu sejak awal pemanasan hingga tercapainya kondisi steady-state. Hasil penelitian menunjukkan bahwa sistem mampu mencapai kondisi tunak secara stabil, dengan temperatur fluida dan laju aliran yang meningkat seiring kenaikan daya pemanas. Analisis visual menunjukkan bahwa peningkatan daya pemanas mempercepat transisi aliran dari rejim laminar menuju transisi dan turbulen, dengan rentang bilangan Reynolds yang bervariasi dan tidak bersifat konstan untuk setiap rejim. Temuan ini menunjukkan bahwa klasifikasi rejim aliran berbasis Reynolds tunggal tidak sepenuhnya merepresentasikan dinamika aliran pada sirkulasi alami yang digerakkan oleh gaya apung. Analisis CWT berhasil mengungkap karakteristik fluktuasi perbedaan temperatur fluida–dinding yang tidak teridentifikasi melalui analisis waktu konvensional. Parameter wavelet seperti power spectrum dan wavelet energy meningkat seiring bertambahnya tingkat ketidakstabilan aliran dan terbukti efektif sebagai indikator kuantitatif untuk memetakan perubahan rejim aliran pada sistem sirkulasi alami.

Kata kunci: sirkulasi alami, ketidakstabilan aliran, rejim aliran, CWT, FASSIP-06 Ver.03

ABSTRACT

Natural circulation is a passive heat transfer mechanism widely applied in reactor safety systems due to its ability to operate without mechanical components. However, the flow behavior in such systems is inherently complex and prone to flow instabilities, including oscillations and regime transitions from laminar to turbulent flow. This study investigates the influence of heating power variations on thermo-hydrodynamic characteristics, the establishment of steady-state conditions, and the evolution of flow regime boundaries in a single-phase natural circulation system. The objectives of this research are to experimentally identify flow characteristics, analyze flow regime transitions through visualization and dimensionless parameters such as Reynolds and Grashof numbers, and evaluate the effectiveness of the CWT as a quantitative indicator for flow regime identification.

Experiments were conducted using the FASSIP-06 Ver.03 natural circulation facility with heating power variations ranging from 750 to 1550 W and a constant cooling temperature of 10°C. Temperature data at multiple measurement points and volumetric flow rate were continuously acquired from the initial heating stage until steady-state conditions were achieved. The results demonstrate that the system reaches stable steady-state operation, with both fluid temperature and flow rate increasing consistently with higher heating power. Flow visualization analysis indicates that increasing heating power significantly accelerates the transition from laminar to transitional and turbulent regimes, with Reynolds number ranges that vary and are not constant across flow regimes. These findings suggest that flow regime classification based solely on a single Reynolds number is insufficient for buoyancy-driven natural circulation systems. Furthermore, CWT analysis successfully reveals characteristics of fluid–wall temperature difference fluctuations that cannot be captured by conventional time-domain analysis. Wavelet-based parameters, such as power spectrum and wavelet energy, increase with the intensity of flow instability and are shown to be effective quantitative indicators for mapping flow regime transitions in natural circulation systems.

Keywords: *natural circulation, flow instability, flow regime, CWT, FASSIP-06 Ver.03.*