OPTIMASI KINERJA TERMOHIDROLIK MODEL KONSEPTUAL *SHELL-AND-TUBE HEAT EXCHANGER* DENGAN *BAFFLE* PERFORASI PADA *MOLTEN SALT FAST REACTOR* BERBASIS *COMPUTATIONAL FLUID DYNAMICS*

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INTISARI

Molten salt menawarkan stabilitas termal tinggi sebagai fluida kerja, seperti pada *Molten Salt Fast Reactor* (MSFR) dengan bahan bakar dan pendingin, LiF–ThF_4–UF_4 dan LiF–NaF–KF. *Shell-and-tube heat exchanger* (STHE) sebagai konfigurasi umum, krusial terhadap desain daya MSFR dan sangat dipengaruhi oleh rancangan *baffle* yang mengatur pola aliran sisi *shell*. Tujuan studi ini adalah mengetahui efek *baffle* berperforasi pada model konseptual dan menentukan kompromi terbaik antara nilai perpindahan kalor dan *pressure drop* (Δp).

Penelitian CFD menggunakan ANSYS Fluent dengan solver κ-ε *realizable* pada geometri STHE 20 tube. Studi independensi mesh dilakukan hingga perubahan $T_{out\ shell}$ sudah tidak signifikan dan kualitas mesh baik. Untuk verifikasi model dilakukan dengan metode Kern dan Bell-Delaware. Variasi utama adalah *baffle* segmental dengan 24 perforasi berdiameter 4, 5, dan 6 mm dengan laju alir massa divariasikan 2, 5, dan 10 kg/s dalam rejim turbulen.

Hasil menunjukkan perforasi secara efektif mengurangi area *dead zone* dan Δp dengan penalti termal kecil. Pada 10 kg/s, Δp turun 49% (4 mm), 62% (5 mm), dan 73% (6 mm), sementara h_{shell} hanya turun ≤ 23%. Indeks kinerja termohidrolik $(Q/PP)_m/(Q/PP)/_b$ tertinggi konsisten pada modifikasi perforasi 6 mm sebesar 3,5 relatif terhadap non-perforasi *baseline* sehingga menjadikannya desain optimum.

Kata kunci: *baffle* perforasi, CFD, kinerja termohidrolik, *molten salt*, penukar kalor

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THERMAL-HYDRAULIC OPTIMIZATION OF A CONCEPTUAL SHELL-AND-TUBE HEAT EXCHANGER WITH PERFORATED BAFFLES FOR MOLTEN-SALT REACTOR APPLICATIONS VIA COMPUTATIONAL FLUID DYNAMICS

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ABSTRACT

Molten salts offer high thermal stability as working fluids, as in the Molten Salt Fast Reactor (MSFR) employing fuel and coolant salts LiF–ThF_4–UF_4 and LiF–NaF–KF, respectively. The shell-and-tube heat exchanger (STHE), as a common configuration, is crucial for MSFR power design and is strongly influenced by the baffle arrangement that controls the shell-side flow pattern. This study aims to investigate the effect of perforated baffles in a conceptual STHE model and to determine the best compromise between heat transfer performance and pressure drop (Δp).

3D CFD simulations were carried out in ANSYS Fluent using the realizable k–ε turbulence model on an STHE geometry with 20 tubes. A mesh-independence study was performed until changes in shell outlet temperature were negligible and the mesh quality was satisfactory. Model verification was conducted using the Kern and Bell–Delaware methods. The main variations are segmental baffles with 24 perforations of 4, 5, and 6 mm in diameter, at mass flow rates of 2, 5, and 10 kg/s in turbulent regime.

The results show that perforations effectively reduce dead-zone regions and Δp with only a minor thermal penalty. At 10 kg/s, Δp decreases by 49% (4 mm), 62% (5 mm), and 73% (6 mm), while h_{shell} decreases by ≤ 23%. The highest thermohydraulic performance index, defined as $(Q/PP)_m/(Q/PP)_b$, is consistently obtained for the 6 mm perforated baffle with a value of 3.5 relative to the non-perforated baseline, making it the optimum design.

Keywords: CFD, heat exchanger, molten salt, perforated baffle, thermal-hydraulic performance

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