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Master's Thesis Suggestion

Computational fluid dynamic analysis of steam-water separation in a novel flash Chamber

Background and Motivation:

Effective steam-water separation is essential in the chamber of flash evaporator-based water purification and power generation systems. Residual water droplets in the steam reduce turbine power output due to the significantly lower volumetric expansion of the liquid phase compared to vapor. Moreover, these droplets often carry impurities that can erode and foul turbine blades upon impact and deposition.

Objective:

The flow within a steam-water separator is highly complex, characterized by intense turbulence induced by the centrifugal motion of the steam–water mixture, pressure gradients from circulatory flow, and the formation of liquid droplets of varying sizes and shapes. Achieving high-purity steam output requires a detailed understanding flow structure, mass transfer between phases and precise control of both the continuous phases and dispersed droplets. Therefore, the objective of this thesis is to adopt/develop a mathematical model for two-phase droplet-laden flow and to implement a computational solution aimed at enhancing separation efficiency and enabling innovative chamber design.

Tasks:

1. Develop and adapt a two-phase flow model based on the Eulerian–Lagrangian approach to accurately represent motion and the interaction between the continuous (steam/water) and dispersed (droplet) phases.
2. Identify and model interphase exchange mechanisms — including momentum, mass, and energy transfer — such as drag, lift, buoyancy, and phase change effects, and incorporate appropriate mathematical formulations.
3. Select and implement appropriate turbulence models suited for the highly complex and swirling flow fields encountered in steam–water separators.
4. Solve the model for simplified geometries and flow conditions, and validate the numerical results against existing experimental data and published numerical studies.

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5. Formulate and implement a separation efficiency metric within the CFD framework to quantitatively assess performance.
6. Investigate the influence of key operating parameters (e.g., flow rate, pressure, geometry) on separation efficiency and pressure drop.
7. Perform simulations to uncover flow dynamics and design principles that enable the development of a compact, high-performance separator chamber with enhanced separation efficiency and minimal pressure loss.

Methodology:

1. Review of existing numerical and experimental studies on steam water separation in the literature.
2. Drawing chamber geometry using CAD software or CAD interface of a computational fluid dynamics (CFD) package (Star-CCM+, Fluent etc).
3. Familiarization to the CFD package and repeating similar cases available in the library of the soft- ware.
4. Implementation physical conditions, model parameters to repeat existing numerical studies and experimental works in the literature for validation model and turbulence models employed
5. Implementation mass, momentum energy source terms either by employing the existing one in the library of the software or implementation by coding through user interface
6. Run the program and calculate velocities of each phase, pressure distribution in the chamber, mass flow rate of each phase, mass fluxes of the phases and position of representative droplets in the chamber.

Expected results:

A comprehensive understanding of the complex flow dynamics within the flash separation cham- ber, including the behavior of dispersed droplets and their interaction with the continuous phase. The study is expected to identify optimal operating parameters that maximize steam purity and separation efficiency, while minimizing pressure losses—thereby enabling performance improve- ments in flash-based water purification and power generation systems.

The start date for the work is scheduled for September 1, 2025.

The scope of the work is designed for 6 months including documentation.

Supervision by:

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