Numerical Investigation on a New Type of Two-Stage Steam Separator in Pressurized Water Reactors

Zihao Tian\textsuperscript{a,b}, Lixin Yang\textsuperscript{a,b,*}

\textsuperscript{a}Institute of Thermal Engineering, School of Mechanical, Electronic and Control Engineering, Beijing Jiaotong University, Beijing 100044, China
\textsuperscript{b}Beijing Key Laboratory of Flow and Heat Transfer of Phase Changing in Micro and Small Scale, Beijing 100044, China

Abstract

Stream separator is a fundamental part of pressurized water reactor in order to guarantee the steam humidity produced by steam generator is below 0.25\%. It’s essential for the safe and economical operation of nuclear power plant. Most two-stage steam separator consist of swirl-vane separators and corrugated-plate separators. But the volume and flow resistance of corrugated-plate separators are great and re-entrainment phenomenon happens occurs easily when the velocity of flow is high.

In this paper, a new type of two-stage steam separator was presented that the second stage separator was designed as a swirl-vane type instead of traditional corrugated-plate type in order to improve the separation efficiency of steam and gas in pressurized water reactors. A computational fluid dynamics (CFD) method was used to investigate the effect of this new structure on the separation efficiency and pressure drop. The flow field details of air-gas flow and the variation trend with the Reynold number and air-gas phase flux were obtained. The influencing factors such as the cylinder diameter, the distance between two stage separators and the bending angle of swirling vanes were investigated. The value of separation efficiency was high at the longer diameter, distance and greater bending angle. The separation efficiency of second stage separator experienced an increasing trend when the water flux increase and the first stage separation decrease. A good agreement was obtained between simulation results and engineering test results.

© 2017 The Authors. Published by Elsevier Ltd.
Peer-review under responsibility of the scientific committee of the 9th International Conference on Applied Energy.

Keywords: Two-stage steams separator, Two-phase flow, separation efficiency, CFD

* Lixin Yang. Tel.: +010-5168-4329; fax: +010-5168-4329.
E-mail address: blyang1@bjtu.edu.cn
1. Introduction

The steam separator is an important part of the steam generator of the pressurized water reactor, which acts to keep the steam humidity below 0.25% in the generator to ensure safe and economical operation of the nuclear power plant [1-3]. Modern steam separators are typically set up as vertical two-stage steam separator. The first stage is the swirling vane type steam water separator, that the mixture of steam and water is separated by the centrifugal force generated by the swirling vanes. The second stage is a corrugated plate separator, that its separation is relying on inertial force [4-6]. However, the corrugated plate separator is bulky and has high flow resistance. The secondary entrainment is caused at high flow rate. The separation efficiency is reduced by these reasons [7]. Therefore, some scholars have proposed to use the swirling vane separator instead of the corrugated plate separator in the second stage. Green [8] has been conducting a seven-year experiment since 1977, designed a rotary vial separator with a carrying efficiency less than 0.1%, and investigated the effects of different parameters on the separation characteristics; Kataoka et al. [9-11] tested the performance of the swirling vane separator with different structures and found that the structure of the rotating blades had less loss on the pressure drop of the flow. They also used the visualization method to analyze the influence of the blade on the flow field structure. R. Thundil Karuppa Raj [12] discussed the influence of blade angle, and it is considered that RSM turbulence model is more suitable for large angle than k-ε turbulence model. These studies have shown that swirling blade separators are the most widely used in steam separator compared to corrugated plate separators with higher separation efficiencies and wider load operating ranges.

In this paper, based on the existing two-stage steam-water separator model, a new type of the two-stage steam-water separator was improved. Swirling vane separators are used in both two stages separation and the effect of the second-stage separation on the separation efficiency is analyzed by studying the flow field characteristics. The results are in good agreement with the experimental results of the steam generator separator. Therefore, this numerical calculation will provide a theoretical basis for the optimization of the steam-water separators in the future.

2. Geometry model

The geometric model used in the calculation is shown in Fig. 1. The whole steam-water separator is 850mm high, the first stage separator cylinder diameter is 203mm and its height is 400mm. The second stage separator cylinder diameter is 180mm and it is 189mm high. Two-stage separator are installed with six swirling vanes that the bending angle is 40°. The swirling vanes and the definition of bending angles are shown in Fig. 2 and Fig. 3. The water separated by the centrifugal force flow through the outlet 1 and the separated gas which contains a small amount of water flow into the secondary separator. The water separated by the secondary stage of swirling vanes flow through the outlet 2 and the separated gas is discharged out the steam-water separator through the upper outlet.

3. Numerical model

In this paper, the Euler two-fluid model is used to define the air as a continuous phase and the liquid water is defined as a discrete phase. The unstructured grid divided by ICEM CFD was used. The number of mesh no longer affects the
دریافت فوری متن کامل مقاله
امکان دانلود نسخه تمام متن مقالات انگلیسی
امکان دانلود نسخه ترجمه شده مقالات
پذیرش سفارش ترجمه تخصصی
امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
امکان دانلود رایگان ۲ صفحه اول هر مقاله
امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
دانلود فوری مقاله پس از پرداخت آنلاین
پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات