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CFD analysis of flow pattern in the agitated thin film evaporator

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ABSTRACT

Agitated thin film evaporator (ATFE) is widely used in chemical, pharmaceuticals and food industries to concentrate the feed solutions. The flow pattern in ATFE has been analyzed using ANSYS-CFX 10.0 software. The flow phenomenon is simulated using free surface multiphase model considering two continuous phases, water and water vapour. The geometry is created in ANSYS-ICEM-10 with 110,300 tetrahedral nodes. The k–ε and Reynolds stress homogeneous turbulence models are used with appropriate boundary conditions. The occurrence of bow wave and its variation with respect to flow rate is studied. A thin film of thickness equal to the clearance between blade tip and inner wall is found to adhere to the inner wall. The bow wave is found to travel helically along the inner wall of the evaporator. The shear rate and kinetic energy dissipation is found to be significant at the clearance between blade and inner wall. These values are 10–50 times more than that observed in rest of the volume.

Keywords: CFD modeling; Thin film evaporator; Two phase; Turbulence modeling

1. Introduction

Agitated thin film evaporator (ATFE) is widely used in chemical, pharmaceuticals and food industries to concentrate the feed solution with complete solvent recovery. The combination of short residence time, high turbulence and rapid surface renewal permits the agitated thin-film evaporator successfully operate the heat-sensitive, viscous and fouling feed streams. The agitated thin film evaporator (further referred as ATFE) consists of two major assemblies: a heated body and a close clearance rotor as shown in Fig. 1. The shaft rotates with a fixed angular velocity and the blades lay out a thin film on the wall of the evaporator. If the inlet feed flow rate is high enough, the film formed on the wall of the evaporator would be thicker than the clearance between the wiper blade and outer wall which result in a fillet/bow wave of liquid on its front edge.

The flow patterns and heat transfer mechanism in falling film evaporator (FFE) is different than that in ATFE. ATFE is also referred as wiped film evaporator (WFE). There is continuous falling of film over the heating wall in the FFE whereas in ATFE the film is being scraped off from the heating wall by blades after some periodic time span. McKelvey and Sharps (1979) examined the velocity profile and flow structure of the bow wave in a wiped film evaporator (WFE) and studied the dependence of blade clearance, film thickness and throughput. Komari et al. (1988, 1989) examined the flow structure and mixing mechanism in the bow wave both theoretically and experimentally in WFE. It was found that about 70–90% of fluid flow in the device could be in the bow wave when the evaporator was equipped with vertically aligned blades. McKenna (1995) presented the model for the design of a wiped flow evaporator (WFE). They considered the fluid transport and mass transfer aspects of devolatilisation of polymer solution. They have reported that there is a limiting rotational speed for mixing in WFE above which significant gain in the mass transfer can be obtained at the expense of very large power consumption. Chawankul et al. (2001) studied the concentration of orange juice in ATFE using AspenPlus™. They considered the thermo-physical properties of orange juice as a function of temperature and solid content along the height of evaporator. Recently, Zeboudj et al. (2006) have reported that the hydrodynamic conditions of the flow have a direct effect on the film thickness and on the residence time of fluid elements.

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