cylinder and the propagation of the wave occurs due to the effect of surface tension force on the motion of the fluid. The investigation reveals that before disintegration of the liquid the capillary waves become unstable and the source of making the wave unstable is inherently developed by the system.

T-1F-2. SIMULATION OF DROP MOVEMENT ON AN INCLINED SURFACE

F. TAVAKOLI, *Isfahan University of Technology, Iran,* E. SHIRANI, *Isfahan University of Technology, Iran,* Many engineering and industry applications involve moving of droplets over solid surfaces. Numerical simulations of the dynamics of droplet impact and spreading on inclined surfaces are presented here. The simulation utilizes PLIC-VOF to model the interface. An improved surface tension method is used and contact angles around the droplet are applied as a boundary condition. The effects of the droplet velocity and surface inclined angle on the deformation and movement of the droplet are studied. The main problem in the numerical modeling of surface tension forces is the production of so-called "spurious" or "parasitic" currents. They are small but growing flows, which are generated due to the different density of two phases in the interfacial region. Spurious currents affect the interface shape and produce unphysical results. The more commonly used surface tension treatment methods are the CSF and the CSS. SGIP method was developed by Seifollahi, et al., EJM, 2008 which uses PLIC-VOF methods. In SGIP method the normal and the interface surface area needed for the calculation of the surface tension force are calculated more accurately. This method is applied to a staggered grid and it is referred to as Staggered Grid Interfere Pressure. First we consider a 1 cm stationary water drop in air at standard conditions and examine four different surface tension models which are CSS, CSF, SGIP and CSF-BKZ (the latter is proposed by Brackbill, Kothe and Zemach). With respect to the production of spurious currents and calculation of pressure jump it is found out that the SGIP model has the best performance and thus we used it for our other cases. Bussmann et al., Phys. of Fluids, 1999 successfully simulated the drop spreading on an inclined surface using dynamic contact angle. Afkhami and Bussmann, ILASS, 2006 extended the work of Bussmann et al. by discussing the effect of different implementations of the contact angle and the contact line velocity on the predictions of drop spreading. Based on experimental observations, finally they introduced a model for contact angle as a function of velocity contact line. However, such relationship is difficult to obtain for a general case. Using SGIP model and applying dynamic contact angle, the deformation and movement of a droplet on inclined surfaces is simulated. Simulations comprise impact of a 3mm droplet on an inclined surface, with inclination of 30, 45 and 60 degrees and two impact velocities of 0.5 and 1 m/sec. It shows that a droplet on a surface with small inclination spreads more rapidly and moves down more slowly. Additionally by increasing of droplet impact velocity, the spreading of the droplet will be increased.

T-1F-3. VELOCITY AND ACCELERATION MEASUREMENT OF SPHERICAL CAP BUBBLE USING PIV/LIF AND SHADOWGRAPHY

M. J. SATHE, *Department of Chemical Engineering, UICT, Mumbai, India,* I. H. THAKER, *TSI Inc, Bangalore, India*, T. E. STRAND, *TSI Inc, Shoreview, USA* and J. B. JOSHI, *Department of Chemical Engineering, UICT, Mumbai, India,* Simultaneous measurements of Bubble Size, Shape, Velocity and acceleration along with surrounding liquid velocity are presented for the case of a single spherical cap bubble rising in water. Although the current technique is restricted for the case of low gas hold-up, the information collected is valuable for obtaining the CFD modeling parameters like Drag force, Virtual mass force, Lift force etc. Particle Image Velocimetry (PIV) is carried out with fluorescent tracer particles, along with Shadowgraphy to deduce the bubble shape and size. Bubble velocity and acceleration are obtained by Particle Tracking Velocimetry (PTV) applied to processed bubble images. Details concerning the synchronization between the PIV cameras, Nd: YAG laser, bubble generator and high speed camera are presented. Because of the versatility of the technique the same hardware can be used for different resolutions of the flow field, from few hundred microns to few centimeters. The PIV/PTV results for the spherical cap bubble are presented. Although scarce experimental data regarding flow field around cap bubbles in turbulent regime exist, the results are encouraging.

T-1F-4. AN APPLICATION ANALYSIS OF BUBBLE PUMP SOLAR WATER HEATER

LI Xuesong, *Gyeongsang National University, Korea*, GiTae PARK, *Gyeongsang National University,* Hanshik CHUNG, *Gyeongsang National University, Korea*, Hyomin JEONG, *Gyeongsang National University, Korea,* The experiment in this paper is based on bubble pump applied on solar water heating system. The equipment consists of the bubble pump, heater and heat exchanger. The complete system was instrumented to measure pressures, temperatures and flow-rates at various locations. For solar heating of domestic hot water, two common system types are thermosyphon and pumped. In the thermosyphon system, a storage tank is placed above the collector. As the water in the collector is heated, it will rise and naturally start to circulate around the tank. This draws in colder water from the bottom of the tank. This system is self-regulating and requires no moving parts or external energy, so is very attractive. Its main drawback is the need for the tank to be placed at a level higher than the collector, which may prove to be physically difficult. A pumped system uses a pump to circulate the water, so the tank can be positioned independently of the collector location. This system requires external energy to run the pump. It also requires control electronics to measure the temperature gradient across the collector and modulate the pump accordinglyAs a bubble pump air-pumped pump, we can use the mobile water bubbles up from the lower elevated to a height, so as to achieve the purpose of upgrading cycle pressure. Therefore, the bubble pump can be applied to split-type solar water heating system to replace the electric circulating pump, in the application of solar energy only at the same time to achieve the purpose of automatic cycle.

10:30 ~ 11:50 (Room 107-108)

Computational Fluid Dynamics (IV)

Session Chair : Dr. R. Kidambi, NAL Bangalore/India

T-1G-1. NUMERICAL SIMULATION OF CAVITY OVER HYDROFOIL BY USING BOUNDARY ELEMENT METHOD BASED ON POTENTIAL FLOW

A. R. MOSTOFIZADEH, *Malek Ashtar University of Technology, Iran*, M. PASANDIDEHFARD, *Ferdosi University, Iran,* S. GHOLIZADEH, *Malek Ashtar University of Technology, Iran,* In this paper numerical study of cavity over hydrofoils is considered by using boundary element method based on potential flow. For this purpose hydrofoil and cavity surface are approximated by panels. Then sources and doublets are distributed over these surfaces. In this method the length of cavity is assumed constant. A set of equations are obtained by applying boundary conditions over the hydrofoil and cavity surface with closing cavity condition, which they are solved together. An important advantage of this method is getting the answer in a short period of time along with low cost computations. Also, there is a good agreement between numerical and experimental results that shows the accuracy of this method.

T-1G-2. COMPARISON OF PERFORMANCE OF PPM WITH ROTATION AND KENICS STATIC MIXER

J. Y. C. LEONG, *Monash University, Malaysia*, C. F. THAN, *Monash University, Malaysia*, Y. W. OOI, *Monash University, Malaysia,* A comparison of the performance of a Kenics static mixer and a Partitioned-pipe Mixer (PPM) has been investigated. The Kenics static mixer is a commercially available mixer that incorporates the use of stationary helical mixing elements to direct the flow to promote mixing. The PPM, conversely, partitions the pipe into two semicircular ducts and introduces a rotation at the wall to mimic the effect of the helical shaped mixing elements available in the Kenics static mixer. The study of the PPM is of interest because it is able to capture the main features of the Kenics static mixer to a certain degree while maintaining a fairly simple geometry. However, most analytical work done in defining the flow fields within the PPM has been restricted to highly viscous creeping flows or Stokes flow. This study was conducted with the help of the commercially available Computational Fluid Dynamics software package, Fluent, to simulate the flow fields in both mixers. The use of numerical methods is attractive because it does not suffer from the restrictions of the analytical models and can therefore offer greater insight into the subtleties in both flow fields. The performance of both mixers will be evaluated primarily by its ability to mix two immiscible liquids, namely, palm oil triglyceride and methanol where the mixing of these two fluids is of interest in the palm oil transesterification process. The PPM and Kenics static mixer were compared in terms of pressure drop across the mixer as well as efficiency in performing the mixing. The simulated data showed that the simple PPM model was able to give insight into the performance of the Kenics static mixer within the range of Reynolds number studied. For further study, detail comparison of PPM and Kenics static mixer should include varying pitch and size of the mixer elements and wall rotation speed.