W-1B-3. EULERIAN MODELING OF PARTICLE DEPOSITION IN A RESPIRATORY CYCLE USING HORSFIELD AND WEIBEL MODELS FOR WHOLE LUNG AND THE FIVE LOBES

S. S. KHALAFVAND, *Isfahan University of Technology, Iran*, M. S. SAIDI, *Isfahan University of Technology, Iran,* In this work, the dynamic deposition of particles in the lung is modeled based on the Eulerian-Eulerian approach. The whole lung is simulated and the deposition rate in each generation is derived by solving the aerosol General Dynamic Equation (GDE). All deposition mechanisms are considered and the effect of each mechanism for each particle size is studied. The one-dimensional GDE is solved by the fractional step method to obtain the size distribution of the inhaled particles in the lung. Also the alveolar region is considered to have expansion and contraction during a breathing cycle. In this article the growth and coagulation of particles are also modeled. In order to solve the GDE a computational method is implemented based on time-step splitting and subcycling approach, combined with a moving grid method for growth process. Comparison of the results with current experimental and numerical results shows a good agreement. Also it shows that larger particles deposit more on the upper region, while the smaller ones deposit more on the lower region of the lung. Including the effect of particle growth and coagulation increases the rate of deposition of smaller particles. The results show the maximum deposition occurs in right lower lobe and minimum deposition occurs in right middle lobe and that deposition fraction in Horsfield's model is lower than Weibel's model.

W-1B-4. AIR FLOW FIELD AND MICRO-PARTICLE DEPOSITION IN THE THREE GENERATION OF HUMAN LUNG

M. YOUSEFI, *Department of Mechanical Engineering, Isfahan University of Technology, Iran,* M. S. SAIDI, *Department of Mechanical Engineering, Sharif University of Technology, Iran,* The effect of flow structure and particle size on the transport and deposition patterns in a rigid, smooth-walled model of the human lung airways extending from trachea to the segmental bronchi is studied. In this work, based on the Horsfield (1971) morphometrical data of human lung, an out-of-plane model of three generation of human lung is produced. Particle deposition sites and efficiency studied for particles in the Stokes number range of, $0.025 \leq Stk_{Trachea} \leq 0.102$, at inspiratory flow rates of 30 lit/min, measured at trachea. A commercially available CFD code is used for numerical simulation. A lagrangian approach is employed, and one-way coupling is used between the continuum and dispersed phase, which allows particle tracking to be run as a post-processing calculation. The 3-D steady laminar flow is numerically simulated and then the particles trajectories are determined by numerically solving the Newton law. It is shown that the particle size has substantial influence on deposition, regarding both efficiency and location. Also it is noticed that for micron size particles deposition mainly occurs by inertial impaction at upper airways. Deposition efficiency with parabolic velocity at the inlet is about 50% more than realistic inlet condition.

09:00-10:20 (Room103)

Flows Stability (I)

Session Chair : Prof. Y.-W. Lee, Pukyong Univ/Korea

W-1C-1. HYDROMAGNETIC INSTABILITY OF GIESEKUS FLUIDS IN PLANE POISEUILLE FLOW

S. M. TAGHAVI, *University of Tehran, Iran,* K. SADEGHY, *University of Tehran, Iran,* The effect of transverse magnetic field is investigated on the instability of Giesekus fluids in plane Poiseuille flow for small magnetic Prandtl numbers. Our approach is a classical one in which stability of flow to small, two-dimensional disturbances will be studied using linearized theory. The system of equations so obtained will be solved using pseudo-spectral method to determine the effect of parameters such as magnetic number, Weissenberg number, mobility factor, and viscosity ratio on the least stable eigenmode. It is found that magnetic field has always a stabilizing effect on plane Poiseuille flow of Giesekus fluids. In contrast, solvent viscosity, fluid's elasticity, and mobility factor may have a stabilizing or destabilizing effect depending on their magnitude being smaller or larger than a critical value.

W-1C-2. THREE DIMENSIONAL VORTICAL STRUCTURES AROUND A LOW-ASPECT-RATIO WING AT LOW REYNOLDS NUMBER

Jongkook SEONG, *Seoul National University, Korea*, Hyungmin PARK, *Seoul National University, Korea*, Byungdo LEE, *Hynix Semiconductor Inc., Korea,* Haecheon CHOI, *Seoul National University, Korea,* Understanding three-dimensional flow structures around insect wings, operated at low Reynolds numbers (Re < 10^4) both in gliding and flapping flights, is important in developing the micro-air vehicles. Nevertheless, the detailed investigation on the three-dimensional flow phenomena has not been done carried out thoroughly. In nature, the butterfly is one of the representative flying insects having low-aspect ratio wings and performing both gliding and flapping flights effectively. Thus, the investigation of the flow around a butterfly in a gliding flight may provide an insight on the generation of three-dimensional vortical structures and their role in producing the drag and lift forces. In our previous study, we performed an experiment on a swallowtail butterfly in gliding flight at the Reynolds number of 14,400. We observed the variation of leading-edge and wing-tip vortices with the attack angle. Also, we found that the hind-wing tails of the swallowtail butterfly improve the aerodynamic performance of gliding flight such as the increase in the lift-to-drag ratio and longitudinal static stability. In the present study, we perform numerical simulations of flows around a gliding swallowtail butterfly and an inverse delta wing, respectively, having low-aspect-ratio wings at low Reynolds number (Re=1,000), to investigate three-dimensional vortical structures around the wings. The angle of attack considered ranges from 5° to 30°. Four vortical structures are identified: leading-edge, trailing-edge, wing-tip and hairpin vortices. Due to the thin and sharp leading edge of the wing, the flow separates at the leading edge at small attack angle ($\alpha = 10^\circ$) and massive separation occurs at $\alpha > 15^\circ$. Wing-tip vortices are generated at $\alpha > 10^\circ$. The drag and lift forces are significantly affected by those vortical structures. In addition to the well-known leading-edge and wing-tip vortices, the hairpin vortex is for the first time observed. The generation of hairpin vortex induces relatively low pressure region on the upper wing surface, resulting in the increase in the lift force on the wing.

W-1C-3. SPATIAL STABILITY OF COMPRESSIBLE PLANE COUETTE FLOW

M. MALIK, *Department of Aerospace Engineering, Indian Institute of Science, Bangalore, India,* Meheboob ALAM, *Engineering Mechanics Unit, JNCASR, Bangalore, India*, J. DEY, *Department of Aerospace Engineering, Indian Institute of Science, Bangalore, India,* Spatial stability of compressible plane Couette flow is studied. The spatial spectrum of the streamwise wavenumbers in the complex plane resembles that of incompressible case. The instability is caused by a mode which is second least-decaying at very low frequencies, and which becomes most unstable as the frequency is increased. The growth-rate contours in parameter space suggest that the spanwise modulation stabilizes the flow for the parameter ranges studied. An analysis of the energy contained in the least-decaying mode reveals that the instability is due to the work by the pressure fluctuations and an increased transfer of energy from the mean-flow. In the case of oblique modes the stability at higher spanwise wavenumber is due to higher thermal diffusion rate. At high frequencies there are disjoint regions of instability at chosen Reynolds number and Mach number. The stability characteristics in the inviscid limit is also presented. The increase in Mach number and frequency is found to destabilize the inviscid unstable modes. The inviscid mode, having phase-speed within the range of mean-flow velocity, is found to be having non-zero growth/decay-rate in agreement with the nature of absence of generalized inflectional point in the mean-flow. The behaviors of the non-inflectional neutral modes are similar to that of compressible boundary layer. A leading order viscous correction reveals that the neutral and unstable modes are destabilized by the no-slip enforced by viscosity. The viscosity has a dual role on the stable inviscid mode.

W-1C-4. EFFECT OF DIAPHRAGM RUPTURE PROCESS ON S HOCK TUBE FLOWS WITH NON-EQUILIBRIUM CONDENSAT ION IN RAREFACTION WAVE

S. MATSUO, *Saga University, Japan*, H. NISHI, *Saga University, Japan,* T. SETOGUCHI, *Saga University, Japan*, H. D. KIM, *Andong National University, Korea,* For a shock tube with diaphragm, in order to simul ate the flow induced simultaneously with diaphragm rupture accurately, it is important to estimate the process of diaphragm rupture. This bec omes the important point of caution for investigation of formation dis tance of shock wave and non-equilibrium condensation in the unstead y expansion wave. In the flow in shock tube, there are some research es for the effect of rupture time of metal diaphragm and its opening time on shock Mach number. From these researches, it is found that diaphragm rupture process is not instantaneous and the process is thre