T-1G-3. ON THE ROBUSTNESS AND ACCURACY OF LEAST SQUARES KINETIC UPWIND METHOD (LSKUM)

Konark ARORA, *Research Associate, EMU, JNCASR, Jakkur, Bangalore, India,* N. K. S. RAJAN, *CGPL, Dept. of Aerospace Engg., IISc, Bangalore, India,* S. M. DESHPANDE, *EMU, JNCASR, Jakkur, Bangalore, India,* The gridfree methods do not require the grid for flow simulation, which is an essential requirement for all other conventional CFD methods. But they do require a point distribution or a cloud of points. However some problems are encountered while using this method on point distributions around complex configurations. Close analysis of this problem has revealed that bad connectivity of the nodes is the cause leading to code divergence. To overcome this problem of bad connectivity related code divergence, we have followed a novel approach of using weights to alter the nature of the least squares (LS) matrix A. It is observed that along the eigendirections, the corresponding LS formulae reduce to the 1-D type formulae. But a problem arises in combining the eigendirections along with upwinding, which is essential to provide stability of the numerical scheme. This difficulty has been overcome by the use of weights leading to WLSKUM-ED (Weighted Least Squares Kinetic Upwind Method using Eigendirections) wherein the weights are suitably chosen so that a chosen direction becomes an eigendirection of matrix A(w) along which multidimensional LS formulae reduce to the corresponding 1-D type formulae. Higher order accuracy in the LS gridfree methods is obtained by defect correction method. The defect correction based second order accurate LS formula has an implicit dependence on the value of the derivatives at the neighbouring nodes. Hence a few iterations need to be performed to get the second order accurate value of the derivatives. These iterations are called the inner iterations. It has been shown that the formula for the derivative in LS gridfree methods reduces to the standard Finite Difference formula in case of a uniform point distribution. Thus it is quite easy to obtain the formal order of accuracy in case of uniform point distribution. However, in case of an arbitrary point distribution, it is essential to perform some inner iteration to get the desired formal order of accuracy. Combination of WLSKUM-ED with inner iterations has been shown to lead to kinetic meshfree method which is both robust and accurate**.**

T-1G-4. NUMERICAL STUDY OF FLOW-INDUCED OSCILLATIONS OF A CIRCULAR CYLINDER USING OVERSET GRID METHOD

M. SAGHAFIAN, F. BARATCHI, *Isfahan University of Technology, Isfahan,, Iran,* In this paper, a numerical study of a uniform flow over an elastic and responding circular cylinder is presented. The Overset grid approach is applied to prevent remeshing procedure. In this method a major rectangular grid and a minor body fitted O-type co-located grid over circular cylinder (located in the rectangular grid) are used. The flow is solved separately on each mesh or grid and the solutions variables are transmitted from one mesh to the other mesh by interpolating in certain points that are called fringe points. The directional search algorithm is used to localize the fringe points of one grid in the other grid sequentially. Finite volume approach is applied to discritise the differential equations. SIMPLEC algorithm is employed to solve the discritised equations. The QUICK scheme is applied in calculating the convective terms. The Crank-Nicholson time marching method is employed and Rhie-Chow method is used to prevent non-physical oscillations. The Reynolds number is set to 200 and a spring-damper-mass system is used to model the cylinder motions. The cylinder responses and the structure of vortex shedding have been analysed. The effects of dimensionless mass and damping coefficient has been investigated. It is observed that, when structural frequency is near to frequency of vortex shedding of stationary cylinder at the same Reynolds number, lock in will occur. In this case, the drag coefficient, the displacements and the amplitude of oscillations in longitudinal and transverse directions attain their maximum values. In addition, the amplitude of oscillations could be as large as 65 percent of the cylinder diameter for small mass and damping coefficient which a dimensionless structural frequency is near 0.2. In overall, the mean value of the lift coefficient is nearly zero; however, its amplitude size is considerable. In comparison, the mean value of the drag coefficient is significant particularly when lock in occurs. However, its amplitude is small. Thus, the displacement in longitudinal (x) direction is larger than in the transverse (y) direction. But, the amplitude of oscillations in (x) direction is smaller than the amplitude of oscillations in (y) direction.

14:30 ~ 15:50 (Room 101)

Reacting Flows (II)

Session Chair : Prof. P. R. Viswanath, IIS/India

T-2A-1. PIV OF MODE SHIFTS DURING COMBUSTION-ACOUSTIC LOCK-ON IN A NON-PREMIXED BACKWARD-FACING STEP COMBUSTOR

O. J. SHREENIVASAN and S. R. CHAKRAVARTHY, *IIT Madras, India,* This paper reports acoustic mode shifts during combustion-acoustic lock-on in a rectangular non-premixed backward-facing step combustor, in which methane enters the combustor at the corner of the step, and mixes and burns with the air flowing past the step in the unsteady recirculation zone downstream. The investigation is carried out for the Reynolds number range of 6000-60000. The interaction of the flow field and the flame is investigated using phase-locked PIV and high-speed CH* chemiluminescence imaging, along with simultaneous unsteady pressure measurement. As the flow Reynolds number is increased, the dominant frequency in the unsteady pressure spectra converges to a constant value around the no-heat-release natural acoustic frequency of the combustor duct, and then abruptly jumps to a regime of linear increase in frequency with increase in Reynolds number, signifying the onset of a first lock-on. A subsequent jump to another regime of linear increase with a lower slope signifies the second lock-on. The transition from the constant-frequency regime to the linearly increasing one corresponds to a rise in amplitude from low broadband levels to high discrete tones. The subsequent jump from one linear variation to another is also accompanied by a further rise in the amplitude. The phase-locked ensemble-averaged PIV shows flow structures of different length-scales at different phases in the pre-lock-on regime, but a dominant large-scale roll-up during the lock-on regime. The leading edge of the flame, observed in the phase-averaged CH* chemiluminescene images from high-speed imaging, moves in and out of the vortex core over the oscillatory cycle. The chemiluminescent intensity also fluctuates significantly over the oscillatory phase. On the contrary, the flame is located downstream of the recirculation zone and its chemiluminescent intensity fluctuates little in the pre-lock-on regime. These observations explain the mechanism of mode shifts that leads to combustion instability in a backward-facing step combustor.

T-2A-2. CFD SIMULATION OF A GAS TURBINE FOR EXPERIMENTAL PURPOSE

C. F. CHENG and C. L. YOONG, *Department of Mechanical Engineering, Curtin University of Technology Sarawak Campus, Malaysia,* A CFD study has been performed to simulate the gasses combustion within a combustion chamber. A 3D can-type combustion chamber was considered with the simulation performed using FLUENT. Propane (C_3H_8) was used as the combustion fuel agent. Standard k-e turbulent species transport (non-premixed) combustion model with Eddy Dissipation model is used to simulate the combustion process. Four species of simulation were considered, i.e. oxygen (O_2), carbon dioxide (CO_2), C_3H_8 and water (H_2O). The simulation results enable the visualization of flow behaviour of combustion agents within the combustion chambers, i.e. velocity, pressure and temperature. Species concentration and distribution was observed in the combustion process. It is observed that higher temperature profiles occurred at the exit region of combustion chamber. Also found, that the geometrical shape of combustion chamber plays an important role in maximizing the flow parameters by reducing undesirable flow resistance. The simulation result provides a useful guideline in the later stage to design and construct of a simple gas turbine prototype for experimental purpose.

T-2A-3. USE OF SWIRL TO CONTROL OSCILLATIONS IN LEAN COMBUSTION

P. GEIPEL, *Imperial College London, U.K.*, R. P. LINDSTEDT, *Imperial College London, U.K.*, S. SIVASEGARAM, *University of Peradeniya, Sri Lanka*. Extinction in lean premixed flames is preceded by a series of cycles of extinction and relight during which the flame gradually weakens until its final blow-out. Such cycles of extinction and relight can also occur over a range of equivalence ratios close to the lean flammability limit to give rise to large amplitudes of oscillation, thereby narrowing the stable range of operation of the combustor. These low frequency oscillations at around 10 Hz, manifesting themselves as a modulation in amplitude of the wall static pressure signal, are not amenable to active control owing to the broadband nature of the frequency; and the problem is further aggravated by stratification of the fuel-air mixture in ways similar to that in gas turbine combustors. The possibility of ameliorating the oscillations by improving flame stabilization using the addition of swirl and thereby reducing the tendency for local extinction was examined in a round sudden expansion combustor burning a stratified mixture of methane and air. Stratification was achieved using a relatively rich core flow and a leaner annular flow around it in the duct section upstream of the expansion; swirl was added to the upstream core flow or alternatively to the annular flow, using a fixed-