image capture and data transfer to the computer at the full frame rate of the V3V camera. *INSIGHT* V3V software package provides control and operation of the V3V system and particle image processing to get flow properties and graphical displays. The V3V system was used to measure flow induced by vortex motion, flow behind a sphere, and flow created by moving or flapping surfaces. The flow properties including the temporal and spatial development of the flow field provide new, unique information to people involved in system optimization, product design, and turbulence research.

14:30 ~ 15:50 (Room 103)

Vortex Flows

Session Chair : Prof. S. Izawa, Tohoku Univ/Japan

T-2C-1. THE VORTEX EVOLUTION AND MIXING CHARACTERISTICS OF A PASSIVE SCALAR IN A COAXIAL JET FLOW

H. S. CHOI, *Korea Institute of Machinery and Materials, Korea*, T. S. PARK, *KyungPook National University, Korea,* In the present study, the flow and mixing fields of a free coaxial jet is investigated by using computational fluid dynamics. For the numerical study, unsteady finite volume method is used with modified PISO algorithm and higher-order spatial discretization schemes, i.e. the forth-order COMPACT and central differencing schemes. In the present study, the coaxial jet flow consists of a central circular jet and an annular jet which surrounds the central jet. Especially, the ambient flow around the coaxial jet flows moves parallel with the coaxial jet flows. In the present study, velocity ratio between the central jet flow and the annular jet flow is changed as well as the velocity ratio between the annular jet flow and the ambient flow. The development of vortices generated from coaxial jet flow and the scalar field affected by the vortices are scrutinized numerically. With increasing the velocity ratio between the central and the annular jet flows, the peculiar vortex evolution pattern develops between them. In some cases of the present study, the vortices show a general vortex evolution pattern such as roll-up, pairing between two vortices and vortex break-down process. Firstly, in smaller velocity ratio, vortices originated from the inner and outer layer of the annular jet flow dominate the whole flow fields. With increasing the velocity ratio the vortices from the central jet flow are able to maintain their identity and can develop further downstream. And these vortices interact vigorously with the vortices developed from the outer layer of the annular jets with increasing the velocity ratio. Finally, the vortices from the central jet dominate the vortex evolution of the entire flow fields in the highest velocity ratio case. These vortex evolution patterns greatly affect the mixing fields and the passive scalar fields follow well with the flow fields in the present study. The global mixing efficiency greatly depends on strong engulfment or entrainment of the fluid parcels caused by vortex evolution process. So, these entrainment or engulfment motions are changed by varying the ratio of three different flows, i.e. the central circular jet, the annular jet and the ambient flows. Especially, with increasing velocity ratio between the annular jet and the ambient flow, the shear layer between them becomes weak with faster ambient flow case. In this case, the vortex evolution is suppressed and also the mixing rate is decreased.

T-2C-2. UNSTEADY FLUID FORCES AND VORTICAL STRUCURE ACTING ON A THREE-DIMENSIONAL AIRFOIL

H. HASEGAWA, *Akita University*, *Japan,* A. NAKAMURA, *Akita University*, *Japan,* K. TANAKA, *Akita University*, *Japan,* Many studies on unsteady fluid forces have been carried out with the numerical and experimental approaches in order to understand the generating mechanism of unsteady fluid forces. In the present study, unsteady fluid forces acting on a discoid airfoil in the sinusoidal pitching motion were measured by using a ring structure 2 elements balance. Furthermore, the vortical fields in the wake of the airfoil were also investigated by using an X-type hot wire probe that was supported by a three-axis computer-controlled unit. The NACA0015 profile airfoil was used as the test model. Experiments were performed in a low speed wind tunnel. Tunnel speed was set to simulate the freestream Reynolds number of 1.0×10^5 ($Re=1.0\times10^5$) based on airfoil chord. Dynamic lift and drag coefficients were compared to the steady ones. For the airfoil in pitching motion on the static stall angle of attack, the delay of stall was observed and the maximum lift coefficient was greater than the maximum lift coefficient under stationary conditions. Degree of hysteresis in dynamic lift curve is found to be a strong function of reduced frequency. The strength of the counter-rotating vortex pair located downstream of the airfoil increased with increasing the lift force. The counter-rotating vortex pair collapsed in shape and the vortices elongated along the trailing edge profile of the airfoil at the instant of stall. For the pitching center over the static stall angle, the stall delay and the increment in maximum lift coefficient were not observed at high pitching frequencies. The unsteady characteristics of a discoid airfoil were affected by an angle of pitching center and the pitching frequency.

T-2C-3. EFFECTS OF WHITCOMB'S WINGLET ON THE WING-TIP VORTICES

M. H. SOHN, *Korea Air Force Academy, Korea,* The present study investigates the wing-tip vortex of a three-dimensional wing for two different wing-tip configurations by using a smoke-wire visualization and PIV measurement of the near flow-field of the wing. The planform, profile, and cross-sectional views of the wing-tip vortices of a half-wing model with an aspect ratio 3.2 and different wing-tip configurations, simple fairing and Whitcomb's full winglet, were visualized at various angles of attack. The distinguishing characteristics of the vortex formation and structure for different wing-tip configurations that were revealed by the visualization results were also backed by a quantitative PIV measurement of the wing-tip trailing region. The wing model used in the present study is made of AA 5052 aluminum and has a taper ratio of 0.5 as well as different section geometry: its root section is a NACA 63_2-215 while its tip-section is a NACA 63_1-212. The wing model was twisted with a twist axis at the 30% chord line and with a washout angle of 2°, and is of basic configuration having no control surface, high-lift devices, and fuselage parts. The tip-region of the wing model was modified by attaching a simple fairing and a full winglet to the basic square-cut wing-tip. The upper part of the winglet has a root chord length of $0.7C_{tip}$ where C_{tip} is the wing-tip chord (128.5mm), and a span of 1.0 C_{tip}, as well as a taper ratio of 0.5, a sweepback angle of 20 deg, and a cant angle of 15 deg. The lower part of the winglet has a root chord length of $0.4C_{tip}$, and a span of $0.23C_{tip}$, as well as a taper ratio of 0.4, a sweepback angle of 52 deg, and a cant angle of 36 deg. The smoke-generating oil for the visualization was a mixture ratio of 93% paraffin oil and 7% lubricating oil, which produced smoke streak-lines of appropriate smoke density and discreteness. Teikoku alloy wire of diameter 0.25mm was used as smoke-generating wires. The free stream velocity of the visualization was set to 3.6m/sec. The Reynolds number based on the chord of the mid-span section was about 5.5×10^4. PIV System used consists of a double-pulse Nd:YAG laser(Vlite-200) with a maximum pulse energy of 2×200 mJ at a repetition rate of 10Hz, a 8-bit digital CCD with a resolution of 2048×2048 pixels, and a PC equipped with DaVis FlowMaster software and a synchronization board developed by LaVision GmbH. An aerosol Generator was used for DEHS($C_{26}H_{50}O_4$) particle seeding. The PIV data in this study was an ensemble average of 20 instantaneous velocity fields. The free-stream velocity of the PIV measurement was 26.0m/sec, which corresponds to the Reynolds number of 4.12×10^5. The visualization pictures clearly captured the characteristics of the wing-tip vortex formation and structure. The comparison of the two different wing-tip configurations showed that the wing-tip vortices of Whitcomb's winglet configuration were reduced in strength, and displaced outboard and upward, at least in the near-wake region, which resulted in an increased lift-to-drag ratio for the Whitcomb's winglet configuration.

T-2C-4. VORTEX RING RELATED TO THE MOTION OF A BODY

S. ICHIKAWA, *Toyo University, Japan*, O. MOCHIZUKI, *Toyo University, Japan,* The purpose of this study is to understand the relation between a vortex ring shed from a jellyfish and thrust force of the motion of a jellyfish. The starting vortex ring was generated by a snappy motion of the tip of the skirt of a jellyfish. It looks like a starting vortex at a trailing edge of an airfoil moving suddenly in two-dimensional flow. The lift force of the airfoil can be calculated by the Kutta-Joukowski theorem. In contrast to a two-dimensional ideal flow, is there a relation between the circulation of the vortex ring and a three-dimensional body moving? This question came from the result of the observation of a jellyfish swimming. The jellyfish did not get thrust from ejection due to contraction of the skirt in our experiment. The thrust appeared when a vortex ring was generated at the tip of the skirt. Therefore, we think that a vortex ring is attributed to the thrust generation of the jellyfish. The translating velocity of the vortex ring itself is related to its circulation, but the relation between the force acting on the body and the circulation of the vortex ring generated by the motion of the body is not clear. To understand the relation, the flow field induced by a circular disk moved by the known force was investigated experimentally in this study. We measured the velocity vector field around the disk by using a PIV method to estimate circulation of the starting vortex ring. It was found that the circulation increased with the squire root of the force which is necessary to move the disk. This showed the same relation of the energy of a vortex ring and its circulation which was presented by Saffman.