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Report

The 11th International Symposium on Flow Visualization

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Abstract : The 11th International Symposium on Flow Visualization (ISFV) was held at Notre Dame, IN, USA, August 8-12, 2004. The Symposium attracted 236 participants from around the world. The 52 Technical Sessions and two Poster Sessions covered a wide range of topics as indicated in the Keywords. Of the 182 submitted papers, 162 were presented. The presented papers included 8 invited lectures. Each morning and afternoon began with an invited lecture by an outstanding, recognized leader in the field. Toshio Kobayashi received the Leonardo da Vinci Award, an engraved plate, and presented the Leonardo da Vinci Memorial Lecture on "High-performance Computing and Visualization of Unsteady Turbulent Flows." Toshio Kobayashi is very well known for his outstanding contributions in computational science and flow visualization as well as his leadership in organizing conferences, workshops, and symposia on flow visualization. Ronald J. Adrian discussed "Visualization in Extreme Environments," Rolf H. Engler described "Pressure-sensitive Paints and Temperature-sensitive Paints in Quantitative Wind Tunnel Studies," William K. Blake explained "Cavitation as Flow Visualization Seeding," Giovanni M. Carlomagno discussed "The Use of Colors in Thermo-fluid Dynamic Studies," Ajit Yoganathan presented "A Gallery of Cardiovascular Fluid Flow Fields: From Heart Valves to Congenital Heart Disease," Richard B. Miles described "Flow Visualization by Filtered Molecular and Particular Scattering," and Thomas C. Gruber Jr., displayed a technique for "Visualization of Foreign Gases in Atmospheric Air." At the end of the last day, Jurgen Kompenhaus from DLR discussed the 12th ISFV to be held in Germany in 2006. After this presentation there was a tour of the Hessert Laboratory for Aerospace Research.

Keywords : Direct injection, Electronic sparks and discharge, Holography and holographic interferometry, Interferometry, Laser sheet imaging, Laser induced fluorescence, Particle image velocimetry, Shadowgraphy and Schlieren, Mechanical tufts, liquid indicators, and liquid crystals, Thermal and mass transfer indicators (thermography, sublimation, luminescent paints and pressure- and temperature- sensitive paints, Image processing and image assisted methods, Graphical display of data sets, Numerical flow visualization, CFD, DNS, and LES.

1. Introduction

This Symposium originated in Tokyo in 1977 and continued in Bochum (Germany) in 1980, Ann Arbor, Michigan (USA) in 1983, Paris (France) in 1986, Prague (Czech Republic) in 1989, Yokohama (Japan) in 1992, Seattle (USA) in 1995, Sorrento (Italy) in 1998, Edinburgh (UK) in 2000, and Kyoto (Japan) in 2002. The objective of this Symposium was to provide a forum for the exchange of information in the broad field of flow visualization. A wide variety of both experimental and numerical visualization of basic and applied fluid dynamic problems are of interest. Since 1977, flow visualization has undergone very rapid development as a result of the improvements in lasers for illumination and computers for data processing and computations. For example, there were no papers on the use of particle image velocimetry and only one or two papers with numerical solutions

in the first Symposium and in this Symposium there were more papers using these techniques than all other techniques combined. These improvements have led to the use of flow visualization in research and development, product development, and education.

Flow visualization has had a long history at Notre Dame starting with Professor F. N. M. Brown who began to develop the equipment and techniques for smoke visualization in wind tunnels in the late 1930s. As a result, both subsonic and supersonic research smoke tunnels were in operation in the 1950s and today are an integral part of most research programs conducted in the Hessert Laboratory. In addition to smoke visualization, Schlieren, shadowgraph, particle image velocimetry, graphical display of data sets, and numerical flow visualization are used.

2. ISFV 11

The 11th International Symposium on Flow Visualization was organized at the University of Notre Dame by Professors T. J. Mueller, R. C. Nelson, and T. C. Corke and held from August 8-12, 2004. The University of Notre Dame was founded in November 1842 by Edward F. Sorin, a priest of the Congregation of Holy Cross, a French missionary order. It is one of a handful of truly national universities in the United States with students from all 50 states and 100 countries. It is consistently ranked in the top 20 American universities. Notre Dame ranks first in the percentage of its students studying abroad among the major research universities, offering 26 international study programs in 17 countries. The 1,250-acre Notre Dame campus, which contains two spring fed lakes and an abundance of trees, plants, and flowers, is one of the most beautiful in the United States.

DeBartolo Performing Arts Center

Sailboats on one of the lakes on campus

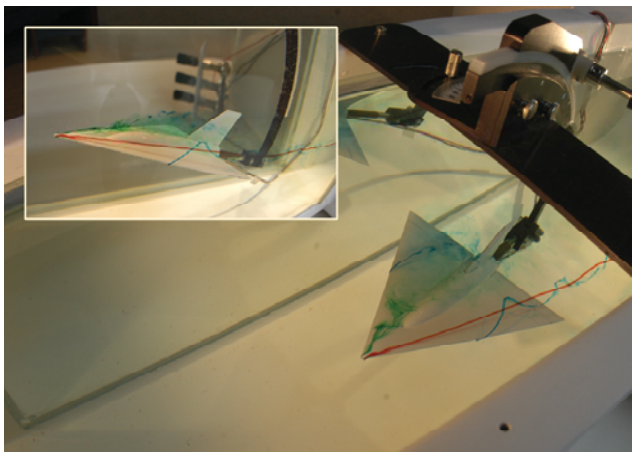
Main Building

More than 230 scientists and engineers came from 20 countries around the world to attend the Symposium. The majority of the participants came from Japan, the United States, France, Germany, Italy, and Korea. The Symposium owes its success to the work of the International Organizing Board who advertised it in their home countries. Advertisements were also published in the *Journal of the Visualization Society of Japan*, *Journal of Flow Visualization* and *Image Processing, Experiments in Fluids*, and *Aerospace America*.

All advertisements referred interested parties to the Symposium website where information was available on the submissions of abstracts and papers, location and travel information, and eventually registration procedures. Professor Ian Grant of Heriot-Watt University set-up and maintained the website. The artwork for the CD-ROM, the book of abstracts, and the final program was created by Joanne Birdsell and her staff in the College of Engineering Graphics Facility at the University of Notre Dame.

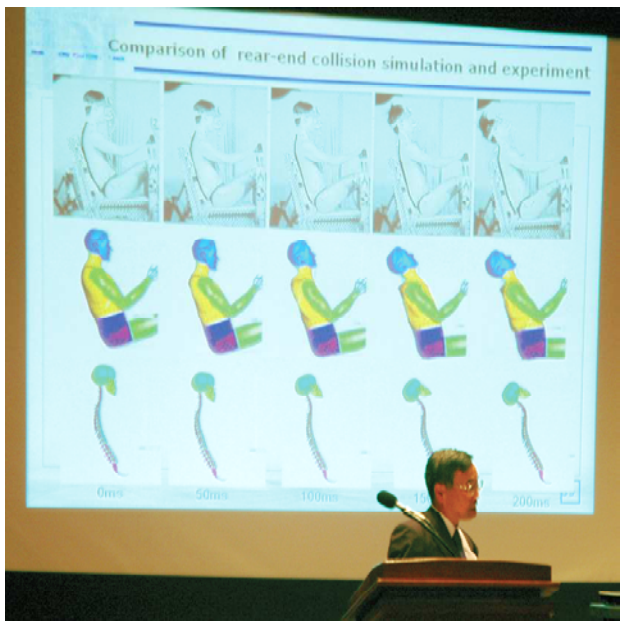
For a nominal fee, copies of the CD-ROM proceedings are available, from the University of Notre Dame CCE, to obtain a copy, e-mail (cce@nd.edu). The 182 papers contained on the CD-ROM are indexed by topic, author, and title. Because of the interest in quantitative results from flow visualization, it is not surprising that the two methods with the largest number of papers were particle image velocimetry and numerical solutions. There were eight company exhibitors with there products on display. These products included particle image velocimetry systems, pulsed lasers, high-speed digital cameras, and an operating free-surface water tunnel.

Particle Image Velocimetry (PIV) demonstration



Dye injection in water table demonstration

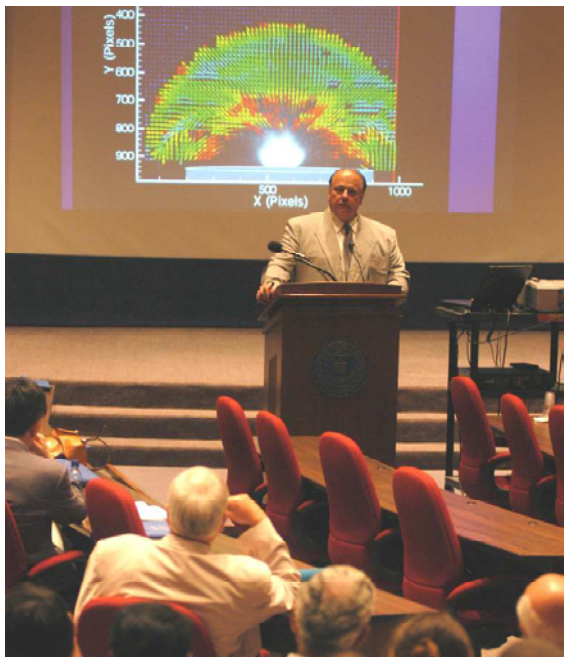
The Symposium actually began on Sunday evening, August 8, with a welcome reception held in the atrium of the Center for Continuing Education (CCE). On Monday morning, the Symposium was opened with a welcome by Nathan O. Hatch, the University Provost and Andrew V. Tackes Professor of History. Although there were papers covering a wide variety of methods and applications, this summary will concentrate on the eight invited lectures.



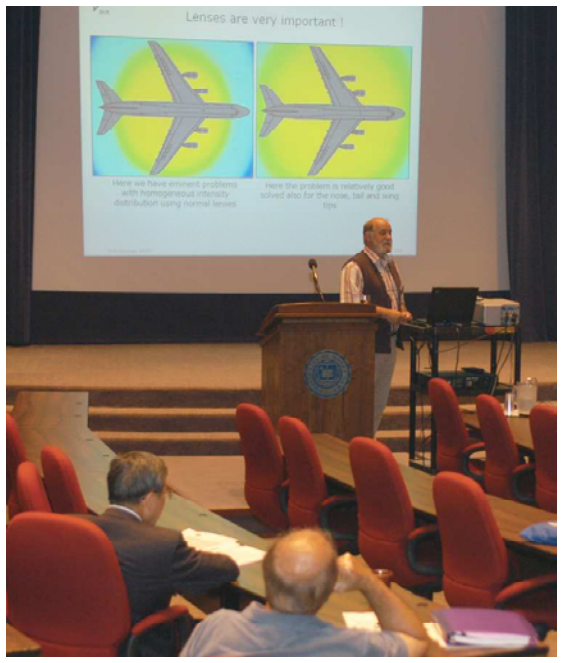
Toshio Kobayashi on high-performance computing

Toshio Kobayashi of the Japan Automobile Research Institute and the University of Tokyo presented the Leonardo da Vinci Memorial Lecture and focused on the validity of flow visualization of unsteady turbulent flows and the 3-D unsteady simulations of these flows. Although fundamental CFD techniques for 3-D turbulence simulation have been well developed they have not yet become popular as an industrial tool. He also described a project to close the gap between fundamental and practical uses of scientific computer simulation.

Recent developments in the use of pulsed solid-state lasers for visualization in extreme environments containing shock and detonation waves were described by Ronald J. Adrian of the University of Illinois at Urbana-Champaign. He focused on specific examples of extreme flow visualization diagnostics using Schlieren photography, classical PIV, and an extension of PIV measurements in particle-seeded, solid materials subject to the limitations of particle response.



Ronald J. Adrian on visualization in extreme environments



Rolf H. Engler on pressure and temperature sensitive paints

Rolf H. Engler of the German Aerospace Center (DLR) addressed the use of pressure- and temperature- sensitive paints to obtain quantitative data in wind tunnel studies. Numerous tests in the low-speed, transonic, and cryogenic regimes have been performed to obtain a high level of accuracy. He showed that the PSP technique not only offers quantitative pressure results but also provides useful initial and boundary conditions for numerical flow simulations. Good quantitative agreement between PSP techniques and conventional pressure measurements was demonstrated over a wide speed range.

William K. Blake of the Carderock Division, U.S. Navy, Naval Surface Warfare Center, reported on recent developments using cavitation as flow visualization seeding. Bubble seeding is useful for tracking vortical structures as long as the bubbles are significantly smaller than the core diameter. Otherwise, gravity and relative motion may cause substantial changes in the flow structure. Dimensionless parameters were used to define the relationship between bubble size and vortex strength that determine the bubble-vortex interaction. For bubbles to be considered passive traces, they must be extremely small. Relationships that permit quantification of sizes of split bubbles in terms of the physical properties of the fluid and turbulence characteristics were also developed. For laboratory shear flows, the limiting bubble size is in the vicinity of 200 μm.

The use of colors in thermo-fluid-dynamics studies was described by Giovanni M. Carlomagno of the University “Frederico II” di Napoli, Italy. Because flow visualization embodies visual observation, the use of color images conveys an immediate global impression of the results of thermo-fluid-dynamic studies. This is an important advantage to researchers in their quest to achieve and understand complex fluid flow problems. Several examples were presented and discussed.

Due to valvular heart diseases, approximately 300,000 prosthetic heart valves are implanted throughout the world each year. The flow fields in the immediate vicinity of prosthetic heart valves produce blood cell damage, thrombo-embolic complications and thrombus formation. Also, approximately two in every 1000 children in the USA are born with a single functional ventricle. Ajit P. Yogorathan of the Wallace H. Coulter School of Biomedical Engineering, Georgia Institute of Technology, addressed the use of flow visualization techniques to investigate the flow in the heart in

both *in-vitro* model systems and *in-vivo* in animals and humans. State-of-the-art studies utilizing laser Doppler velocimetry, DPIV, CFD, and MRI technologies provide a fundamental understanding of the associated complex flow fields. These studies provide valuable information and insight to cardiac surgeons and cardiologists who treat these people.

Richard B. Miles of Princeton University described the use of an optically thick atomic or molecular spectral notch filter together with a narrow line width frequency tunable laser source for spectrally selective flow field imaging and for Rayleigh and Raman spectroscopy. This technique provides a capability of selectively blocking background light and imaging spectral lines and spectral features that give added insight into combusting gases, plasmas, and high-speed flows. Blocking filter technologies have proven their utility through images of shock wave and boundary layer interactions and temperature fields.

Thomas C. Gruber Jr., of MESH, Inc., reported on a Chemical Cloud Tracking System (CCTS) for monitoring foreign gas clouds in atmospheric air. Path integrated concentration measurements from multiple synchronized scanning passive infrared (IR) sensors are processed with a tomography algorithm to produce real-time cloud maps. Both mobile and fixed site sensor systems have been developed that locate foreign gas clouds on a computer map display in real time. These systems can be used to detect nerve and blister agent chemical weapon vapors or for industrial site monitoring and large-scale gas plume visualization research.

The Symposium banquet was held in the Monogram Room of the Joyce Athletic and Convocation Center on Wednesday evening. During the social gathering before dinner, a quintet played a variety of popular music. After the dinner there was an award ceremony. Toshio Kobayashi presented the Asanuma Award on behalf of The Visualization Society of Japan to Gary Settles for his contributions to visualizing phenomena in transparent media. Two James P. Crowder Awards were presented in tribute to Jim Crowder who hosted the 7th ISFV in Seattle in 1995. Jim made numerous contributions to the field of flow visualization in both wind tunnel and flight experiments. Jim died in 2002. These awards were presented to David F. Fisher of NASA Ames Research Center and Leonard M. Weinstein of NASA Langley Research Center for their creative contributions to flow visualization for both wind tunnel and flight vehicle experiments.

3. The 12th International Symposium on Flow Visualization, September 10-14, 2006

The International Organizing Board has decided that the next Symposium will be held in Göttingen, Germany, September 10-14, 2006. This Symposium will be organized by the German Aerospace Center (DLR) in cooperation with the Georg-August-University Göttingen. The Symposium chairman is Jurgen Kompenhaus of DLR. Information about ISFV 12 will be available in early 2005 on the website <http://www.as.go.dlr.de/ISFV12/>.

Author Profile

Thomas J. Mueller: He received a Ph.D. in mechanical engineering in 1961 from the University of Illinois at Urbana-Champaign. His experience includes full-time employment at Bendix Aviation Corp. and United Aircraft Corporation Research Laboratories and a consultant for the U.S. Air Force, ARO Inc., NASA, U.S. Navy ONR, AGARD (NATO), and numerous corporations. He has been on the faculty at the University of Notre Dame for 40 years. His areas of interest include compressible and incompressible fluid mechanics, flow visualization, low Reynolds number aerodynamics, and aeroacoustics. He has more than 200 publications and over 100 invited lectures and seminars. Professor Mueller was appointed the first Roth-Gibson Professor in 1989 and is a Fellow in the Royal Aeronautical Society, the American Society of Mechanical Engineers, and the American Institute of Astronautics and Aeronautics.