ASME
SETTING THE STANDARD 1880 2005

Fluids Engineering

The Fluids Engineering Division is involved in all areas of fluid mechanics, encompassing both fundamental as well as applications

Chair's Message

by Ali Ogut

Dear FED Members,

As this year's Chair of our Division, I am pleased to have the opportunity to write to you through this year's Newsletter. In this article, I hope to report to you the developments and changes as well as our plans as they relate to FED and ASME.

In the past year, ASME has gone through significant changes. David Belden retired as ASME Executive Director and Virgil R. Carter was appointed as the new Executive Director. Also Thomas G. Loughlin was appointed as the new Managing Director of Engineering. These changes provided opportunities for Divisions, including ours, to voice our concerns and problems to ASME. In addition ASME is looking at its governing and administrative structure to see if changes can be made to make the Society more agile. The discussions to make these changes are currently ongoing (see:http://www.asme.org/coe/). ASME is considering reorganizing itself into following units:

* Basic Engineering
* Applied Engineering
* Cross-cutting Engineering
* Institutes
* General Engineering and Research
* Special Committees and Business Units

We expect some announcements from ASME after the completion of its Summer Meeting in June.

ASME also asked Technical Divisions to review the above unit **definitions** and identify and select the unit that most closely aligns with the interests of each division. FED is currently part of Basic Engineering Group (BEG). The FED Executive Committee (EC) has brought this issue to its membership in its meetings for discussions to arrive at a consensus as to where FED should be in this reorganization. Our current position is to remain with the BEG whether it remains in its current status as a Group in ASME or, reorganizes itself into an Institute.

At the present time, there are strong sentiments to transform BEG to an "Institute for Engineering Sciences", including Applied Mechanics, Bioengineering, Fluid Mechanics, Heat Transfer, Tribology and Materials Divisions. The feasibility of this transformation is currently under study, including a business plan, by-laws, and financial viability under the leadership of ASME BEG Vice President, Carl T. Herakovich (herak@virginia.edu). Carl, also through his efforts, put forth a motion to the Council of Engineering (COE) at the last Congress, where it states the sharing of journal profits/loss with sponsoring Divisions **2 to 1**. The motion was accepted by COE and was sent to ASME Board of Governors for consideration. Divisions currently do not receive any revenue sharing with ASME from their Journals. It should also be mentioned that one outcome of the BEG transformation to an Institute could be that it would hold its own "Winter" meeting instead of being part of future IMECEs.

I also would like to report that FED had **two successful meetings** last year, developed new partners for future joint meetings, enhanced our interaction with industry, expanded

(continued on page 2)

Spring 2004 Newsletter
James C. Meng, Ph.D., *Editor*

Chair's Message (continued from page 1)

our student programs, and increased the number of pages for the *Journal of Fluids Engineering*. Our goal remains developing joint meetings and activities with other societies with interest in Fluids Engineering.

The 2003 FEDSM was held jointly with the Fluids Engineering Division of the Japanese Society of Mechanical Engineers (JSME) in Honolulu, Hawaii, on July 6-10, 2003. This Conference was one of the largest, in attendance and number of presentations, in recent years (see article in this Newsletter). As a consequence, the revenues obtained from this Conference put the FED balance sheet in good standing. Nominally, our expenses are low so we plan to sponsor more programs for undergraduate and graduate student participation at our Conferences. FED EC plans to increase the number and amount of awards given to students in both undergraduate and graduate competitions at our Conferences. EC also formed an ad-hoc committee under the leadership of Dr. Sam Martin [csammartin@comcast.net] to publish **"FED Magazine"** which will capture the history and accomplishments of FED and its contribution to our profession, and the society at-large. FED is one of the oldest Divisions in ASME, and has a rich past which should be shared with the membership. Please send to Sam Martin your comments, stories, and copies of any relevant FED documents you may have. In addition EC has also established two new administrative committees to enhance FED activities; Industry Relations (chair: David Halt: dhalt@visteon.com); Communication (chair: George Papadopoulos: george.papadopoulos@dantec-dynamics.com).

FED offers many programs at its Summer Conferences and at IMECE, including *Plenary* sessions which provide the attendees an opportunity to hear an overview from experts in fluids engineering. *Symposia*, which provide the researchers an opportunity to present complete work of current and archival value. The symposia papers undergo two independent reviews. The *forums* are a place to present ongoing work. The papers are reviewed for relevance to the topic and completeness. *Open forums* are designed for the presentation of ongoing work. *Panels* provide the opportunity to explore broad technological issues and organize focused discussions. The *Industry Exchange Program* provides opportunities for industry participants to discuss fluids engineering-related activities relevant to their companies. The *poster session* offers the opportunity to present the very latest results, including student thesis and research work. *Tutorials* are presentations by experts to provide basic information on a topic of current interest. *Workshops* are given by industry experts to educate and train engineers who are interested in their products, such as computational tools or instrumentation. Finally, the *ASME Continuing Education Institute* has co-located its regular short courses related to fluids engineering to provide opportunities to short-course participants to attend many of the conference sessions.

Our Summer Meeting is also a place where we recognize our colleagues through various awards. In the 2003 Summer Meeting the award recipients were as follows; Marvin Goldstein – Fluids Engineering Award, Sven O. Kraus, Ronald D. Flack, Arnaud Habsieger, George T. Gillies and Klaus Dullenkopf – Lewis F. Moody Award, and Jeffrey Taylor and Mark N. Glauser – Robert T. Knapp Award. Many of our colleagues in FED have made notable contributions to the profession and should be recognized with suitable awards and membership rank of fellow. We should all make an effort to sponsor deserving members.

FED also participated in IMECE in November 15–21, 2003 in Washington, D.C. The emphasis in this meeting was on joint sessions with other Basic Engineering Divisions. FED sponsored 34 sessions with 170 papers. The big draw for the FED sponsored events was the Symposium (S 371) on Micro Fluids – Application of Fluid Mechanics to Microsystems Technology organized by C. Wong, F. Forster, and K. Breuer. It was also co-organized with the MEMS division. This symposium had 485 scanned attendees at the FED sponsored sessions.

This year FED sponsored two student competitions at IMECE'03; Young Engineer Paper Contest and Senior Design Project Report Contest. The winners for the Young Engineer Paper Contest were; First Place – Yung Shiang Judy Hsu, Christina M. Stratton, Justin M. Schauer, Alexis H. Utvich and Jennifer S. Rossmann, *Texas A&M University*. Second Place – Charles Kopplin, *University of Wisconsin – Madison*. Third Place – Vivek Prabhakar, *Texas A&M University*. Honorable Mention – Amit Kumar and T. DebRoy, *Pennsylvania State Unviersity*. The winners for the Senior Design Project Contest were; First Place – A. Famuagun, H. Adedehinbo, D. Sequera, and J. Woodard from *University of Oklahoma*. Second Place – Josh Hilderbrand, Dennis Adams, Scott Silence, Stormie Chenoweth, Cynthia Dickman, and Chelsea Smith from *Mercer University*. Third Place – Kerri Smith and Silvia Pineda from *University of Delaware*.

The Upcoming FED Conferences include 2004 FEDSM which is also our first joint meeting with the ASME Heat Transfer Division, which will be held in Charlotte, NC, in July 11–15, IMECE 2004 in Anaheim, CA, in November 14–19, FEDSM 2005 in Houston, in June 19–24, with emphasis on process industry, Joint European-American Fluids Engineering meeting in summer of 2006 in Miami and Joint ASME/JSME meeting in summer of 2007 in west coast.

The *Journal of Fluids Engineering (JFE)* continues to grow in number of submissions and general stature. The JFE provides a unique forum for the FED community to communicate new findings, techniques, and applications. Authors of papers presented at FED conferences are encouraged to submit their papers to JFE. The FED web site www.asme.org/divisions/fed is another means of communication among our members. The web site has been revised, and is continually upgraded with new information on recent and upcoming meetings, calls for papers, publications, committee activities, student programs, continuing educations, etc.

I would also like to take this opportunity to mention that FED EC and ASME staff has established an excellent working relationship over the past two years. Harvesting this relationship has lead to better managed conferences and delivering better customer services. This was evident at last year's conference in Hawaii. The event was successful on many fronts including financial, value and customer service. I would like to thank the ASME staff, which includes:

(continued on page 11)

Fluids Engineering Technical Committee's Report:

MNFDTC Committee

by Fred K. Forester

The Micro and Nano Fluid Dynamics Technical Committee (MNFDTC) is the youngest committee in the Fluids Engineering Division, The first meeting was held at the 2002 Summer Meeting in Montreal. Our committee serves the division by promoting activities associated with fluid dynamics where global dimensions are measured in micrometers or less. Examples of activities include fluid transport based on motive phenomena useful in small-scale devices such as electro-kinetics, devices utilized to control fluid transport such as pumps, valves and sensors, and also the basic aspects of fluid dynamics in micro- and nano-scale domains, such as mixing and filtering and manipulation of particles such as those used in bead chemistry or individual cells.

Our most important activity is the organization of forums and symposia at the annual Fluids Engineering Division Summer Meeting (FEDSM) and the International Mechanical Engineering Congress and Exposition (IMECE), the latter meeting seeing significant activity in this area since 1994 due to its interdisciplinary nature. At this year's IMECE meeting in November in Washington, D.C. 59 papers were presented, resulting from 80 submissions, which represented the steady growth we have been experiencing in previous years. A heart-felt thanks to the impressively talented organizing committee for that meeting: Ali Beskok, Texas A&M University, Kenny Breuer, Brown University, Ching-Jen Chen, Florida State University, Jacob N. Chung, University of Florida, Prashanta Dutta, Washington State University, Gregory Fiechtner, Sandia National Laboratories, Livermore, CA, Luc Frechette, Columbia University, Xiaoling He, University of Wisconsin, Masahiro Ota, Tokyo Metropolitan University, Japan, Juan Santiago, Stanford University, Kendra Sharp, Pennsylvania State University, Reza Shekarriz, MicroEnergy Technologies, Inc., Steve Wereley, Purdue University, and Hong Xue, California State Polytechnic University. We expect this year's IMECE in Anaheim to be at least as exciting! The call for papers can be found at http://microfluidics.engin.brown.edu/ASME/ufluid04_call_for_papers.pdf.

Activity at the summer meeting is also growing and the member of our committee who serves as advisor to the chair for coordinating efforts between the FEDSM and IMECE is Surya Raghu (sraghu@advancedfluidics.com). Feel free to contact him.

For more information about our committee visit http://www.asme.org/divisions/fed/committees/mnfdtc.html which also has a link to http://microfluidics.engin.brown.edu/ASME/ where you can find more information and also sign onto an e-mail list to stay on top of all our activities. Over 200 persons are currently signed up, and we encourage you to join us! In addition you can contact Fred K. Forster at the University of Washington, the current committee chair, at forster@u.washington.edu or Kenny S. Breuer at Brown University, the current Vice Chair, at kbreuer@brown.edu. ■

Fluid Measurement and Instrumentation Committee

James A. Liburdy, FMITC Chair

The Fluids Measurement and Instrumentation Technical Committee (FMITC) is the ASME Fluids Engineering Division committee devoted to measurement techniques and their application to fluid flows. The scope of the Committee's goals includes both industrial applications and experimental development. The activities of the Committee include development and organization of technical sessions at ASME conferences, the organization of workshops and tutorials as well as acting as a liaison between ASME and industry for fluid flow measurements. The Committee membership represents a broad spectrum of backgrounds including industry, government laboratories and academia. There are currently over 75 members. Due to the wide array of applications of fluid measurements the Committee must effectively collaborate with other technical committees within ASME in general and the Fluid Mechanics Division in particular. The types of measurements and instrumentation include those applicable to subsonic and supersonic flows, multiphase flows, flows pertaining to environmental concerns, large scale industrial flows, microscale fluidic systems, and many others. The Committee's goal is to be at the for front of new measurement techniques and to act to provide a means to bring new research and development advances to the professional community.

The FMITC meets twice per year, once at the ASME IMECE and once at the FED Summer Meeting. Non- members are encouraged to come to these meetings, which are announced in the program of the specific conference. We are looking for individuals interested in participating in the development of new technical sessions, workshops and tutorials. In particular we encourage those in other divisions of ASME to attend to develop collaborative symposia or for a which extend the applications of fluid flows to other disciplines such as heat transfer, bioengineering, energy systems, etc. Examples of some of the recent symposia and fora sponsored or co-sponsored by this Committee include: noninvasive measurement techniques, measurements in environmental flows, MEMS for Fluid Measurements, chemical and biochemical sensing, global flow measurements, microfluidic flow systems, and others. The Committee encourages new members to join from all backgrounds and also encourages students and new engineers to attend meetings and become involved. If there are any questions please contact the Chair, Jim Liburdy at liburdy@engr.oregonstate.edu, 541-737-7017, or the Vice-Chair, Judith Bamberger at Judith.bamberger@pnl.gov. More general information is available at the web site, asme.org/division/fed. ■

(continued on page 4)

Fluids Engineering Committee's Report: (continued from page 3)

FED Honors and Award Committee

by M. H. Hosni

Fluids Engineering Award

The Fluids Engineering Award is conferred upon an individual for outstanding contributions over a period of years to the engineering profession and in particular to the field of fluids engineering through research, practice or teaching. The recepient of the 2003 Fluids Engineering Award is Dr. Marvin Goldstein of NASA Glenn Research Center. Dr. Goldstein was selected for his theoretical contributions to the field of aeroacoustics, particularly his groundbreaking work in boundary layer receptivity, and the development of the nonlinear integral-differential equations for amplitude and phase evolution of interacting waves. Dr. Goldstein has been the Chief Scientist NASA Glenn Research Center since 1980 and was elected to the National Academy of Engineering in 1990. He has won numerous awards including the NASA Exceptional Scientific Achievement Award, the AIAA Aeroacoustics Award, and the Otto Laporte Award for Fluid Dynamics Research from the American Physical Society. He is a fellow of both APS and AIAA. His book on aeroacoustics is considered as an international standard for theoretical aeroacoustics. Dr. Goldstein has delivered numerous lectures in the US and abroad and has published over 120 journal publications in fluid dynamics including 35 in the Journal of Fluid Mechanics.

The Fluids Engineering award was presented to Dr. Goldstein at the Joint ASME/JSME Fluids Engineering Conference, which was held July 6 – 10, 2003 in Honolulu, Hawaii. For detailed information about the Fluids Engineering Award, please visit http://www.asme.org/conf/fed03/fedaward.html. ■

Robert T. Knapp Award:

This award is given to the authors of the best paper presented to the Fluids Engineering Division dealing with analytical, numerical and laboratory research. The 2003 Knapp Award was awarded to Jeffrey Taylor and Mark N. Glauser for their paper entitled "Towards Practical Flow Sensing and Control via POD and LSE Based Low — Dimensional Tools." This paper (FEDSM 2002-31416) was presented at the ASME Fluids Engineering Division Summer Meeting, July 15, 2002 Montreal, Quebec, Canada.

Jeffrey Taylor is with the Mechanical and Aeronautical Engineering Department at Clarkson University and Mark Glauser is a faculty member in the Mechanical, Aerospace and Manufacturing Engineering at Syracuse University. ■

Lewis F. Moody Award:

The Lewis F. Moody Award is given to the authors of the best paper presented to the Fluids Engineering Division dealing with a topic useful to in mechanical engineering practice. The 2003 Moody Award was presented to Sven O. Kraus, Ronald D. Flack, Arnaud Habsieger, George T. Gillies and Klaus Dullenkopf for their paper entitled "Periodic Velocity Measurements in a Wide and Large Radius Ratio Automotive Torque Converter at the Pump/Turbine Interface." This paper (FEDSM2002-31162) was presented at the ASME Fluids Engineering Division Summer Meeting, Monday, July 15th, 2002, Montreal, Quebec, Canada.

S. O. Kraus, R. Flack, A. Habsieger, G. T. Gillies, are with the Department of Mechanical and Aerospace Engineering (MAE) at the University of Virgina and K. Dullenkopf is with Universität Karlsruhe in Germany. ■

4th ASME & JSME Joint Fluids Engineering Conference

by Ali Ogut

The 4th ASME & JSME Joint Fluids Engineering Conference, sponsored by Fluids Engineering Division (FED) of the American Society of Mechanical Engineers (ASME), and the Japanese Society of Mechanical Engineers (JSME) was held during July 6–10th in Honolulu, Hawaii.

The objective of this conference was to provide a forum for exchange of information related to fluids engineering for mechanical engineers from around the world representing academia, industry and government laboratories.

The Conference was organized by Prof. Ali Ogut, Rochester Institute of Technology, representing ASME, adoeme@rit.edu, and Prof. Yutaka Tsuji, Osaka University, tsuji@mech.eng.osaka-u.ac.jp, and Prof. Masaaki Kawahashi, Saitama University, mkawa@mech.saitama-u.ac.jp, representing JSME.

The Conference was a resounding success as it attracted 766 attendees from 33 Nations, including 134 students.

(continued on page 5)

Dreaming permits each and every one of us to be quietly and safely insane every night of our lives. — *William Dement*

4th ASME & JSME Joint Fluids Engineering Conference (continued from page 4)

The Conference Program included 714 papers in 179 Sessions, 6 Plenary Sessions, 2 Industrial Exchange Program Sessions, 28 Posters, and 4 exhibits. It also included a special symposium in memory of Prof. Charles G. Speziale, past Professor of Aerospace and Mechanical Engineering at Boston University, and a Student Paper Contest competition, sponsored by Fluent, Inc.

During the Conference Luncheon, awards were presented to 3rd (1999) ASME/JSME Joint Conference Chairs, Dr. Philip Pfund, and Dr. Toshiki Iino by JSME. In addition 2003 Fluids Engineering, Lewis F. Moody, Robert T. Knapp awards were given to winning individuals. Awards were also given to Student Paper Contest winners.

If you wish to obtain further information on this Conference, you can contact any of the above organizers. ■

Annual Report on the Status of *JFE*

by J. Katz

Another year has passed, my fourth as the guardian of *JFE*. The purpose of this report is to update the community about the changes that have occurred during the past year. Several Associate Editors have completed their three year terms, and I would like to take this opportunity and express my gratitude for their effort and contribution to the *Journal*. Professor Ismail Celik provided expertise in applied CFD, Dr. Edward Graf was our expert in pump and applied multiphase flows, Prof. Ajay Prasad covered experimental fluid mechanics topics, especially those involving optical measurement techniques, Prof. Jeffery Marshall focused on papers involving theoretical analysis, especially vortex dominated flows, and Dr. Thomas Gatski has been our expert in turbulence modeling. Each of them has had substantial impact on the quality of the journal over the past three years, and their departures leave voids, which are not easy to fill.

One of the retiring Associate Editors, Dr. Tom Gatski, has graciously agreed to remain on the editorial board. Tom is a Senior Research Scientist in NASA Lan-

(continued on page 6)

How Did It Go . . .

by S. Gopalakrishnan
Conference chair for IMECE 2003 and HTFEDSM 2004

IMECE 2003: Washington D.C. November 16 - 21, 2003.

Fluids Engineering Division participated in this congress with 34 sessions and approximately 170 papers. ASME staff scanned all the people who attended the various sessions and a summary report was submitted to the conference chair. 938 people were scanned in the FED sessions. (This number is of course larger than the total number of attendees as several attendees would have participated in multiple sessions.) In comparison, Applied Mechanics Division had 1348 and Heat Transfer Division 1459 scanned attendees at their sessions. The big draw for the FED sponsored events was the Symposium (S 371) on Micro Fluids – Application of Fluid Mechanics to Microsystems Technology organized by C. Wong, F. Forster, and K. Breuer. It was also co-organized with the MEMS division. This symposium had 485 scanned attendees at the FED sponsored sessions.

The scanned data contains the names and affiliations of the attendees and this list would be useful to future session organizers for canvassing potential authors, reviewers etc. I will be happy to supply this data to future organizers. (sgopalakrishnan@flowserve.com) ■

HTFEDSM 04: Charlotte, N.C. July 11 - 15, 2004.

This conference is organized jointly with the Heat Transfer Division and co-sponsored by AIChE. The program chair and Technical Chair from HTD are Dr. Yildiz Bayazitoglu and Dr. Raj Manglik respectively. The program chair from AIChE is Dr. Joel Plawsky. The paper submittal process is completely web based. (www. Asmeconferences.org/htfed04). Approximately 750 abstracts have been received and as of spring 04, the paper review process is in full swing. The program is divided into 12 tracks as follows:

1. Fundamental Research and Measurements
2. Energy Systems
3. Industrial Processes, Equipment and Machinery
4. Computational Fluid Dynamics and Heat Transfer
5. Transport Phenomena in Multi Phase Flows
6. Aerospace and Vehicular Flows and Heat Transfer
7. Transport Phenomena in Manufacturing and Materials Processing
8. Micro/Nano Fluid Dynamics and Heat Transfer
9. Heat and Mass Transfer in Bio Technology
10. Transport Phenomena in Process Industry
11. Free Surface Flows and Environmental Heat Transfer
12. General Papers

Each of these tracks has several individual topical areas, each topical area being a symposium or forum as defined by FED. Depending upon the number of papers received in a topical area, appropriate numbers of sessions are being assigned.

About 30% of the papers are for FED sponsored sessions, 38% for HTD sponsored sessions, and 30% are for jointly sponsored sessions. This is in line with our original expectations regarding the total number of papers and the split according to sponsoring division.

Detailed information on the program can be obtained from sgopalakrishnan@flowserve.com. ■

Annual Report on the Status of JFE (continued from page 5)

gley Research Center. Being a widely known expert in turbulence modeling, computational modeling and simulations as well as aerodynamics, I am relieved that we can continue relying on his vast experience. He will join a group of new Associate Editors that have joined us at the end of last year. Professor Kenneth Breuer from Brown University is a renowned expert in micro and nano-scale flows, especially on the experimental side, and has also been involved in control of turbulent boundary layers. His help is essential for handling the increasing number of papers focusing on micro-scale flows. Dr. Georges Chahine, the president of Dynaflow Inc., brings over thirty years of experience in multiphase flows, acoustics, bubble-dynamics and cavitation. His unique expertise will complement other editorial board members that deal with multiphase flows. Dr. Siviram Gogenini is a Senior Engineer and Program Manager at Innovative Scientific Solutions, Inc. He has substantial experience in development and applications of a wide range of optical measurement techniques such as PIV, PLIF and holography.

Three additional Associate Editors will join us at the midpoint of 2004. Professor Pratap Vanka from the University of Illinois at Urbana is a widely known expert in computational fluid dynamics, multi-grid methods, and large eddy simulations turbulent flows. Professor Ugo Piomelli from the University of Maryland brings expertise in both direct numerical simulations and large eddy simulations of boundary layer flows. Their help is essential due to the considerable increase in the number of submitted papers that deal with development and applications of CFD tools. Dr. Akira Goto from Ebara Research Company in Japan brings over twenty years of industrial research and development experience in turbomachinery design and analysis. He will complement current members of the editorial board who deal with the diverse field of Fluid Applications and Systems.

The journal underwent several changes over the past year. Along with all the other ASME journals, authors can now submit papers and monitor the progress of their papers using the Internet. The address for submission is http://journaltool.asme.org . In an attempt to reduce the delay between submission to publication of papers, JFE has transitioned to a bi-monthly journal. The number of pages allocated to the journal has been increased to 1200 pages. The six volumes published during 2003 contained 109 full papers and 22 technical briefs, a total of 131 papers. This number is slightly larger than that in the previous year (126), continuing the trend of steady growth over the past five years (115, 110 and 91 in the previous three years). The number of submitted papers has also increased substantially, from 247 and 229 in the previous two years, to 326 during the last year. We cannot explain the reasons for this trend, but hope that it will be maintained.

Over a decade ago *JFE* was the first journal to introduce standards for numerical uncertainty in journal publications. In keeping pace with the continued advances in CFD, this issue was revisited by several members of the Computational Fluid Dynamic Technical Committee, including Christopher Freitas, Urmila Ghia, Ismail Celik, Patrick Roache and Peter Raad. They reported on their findings in the 41st Aerospace Sciences Meeting of the AIAA, in Reno. Subsequent discussions have led to a new editorial policy statement on the control of numerical accuracy for *JFE*. This policy enumerates the criteria to be considered for archival publication of computational results. These new recommendations have been added to the *JFE* Web page, and can be downloaded from http://ww2.asme.org/techpubs/template.cfm?title=Journal%20of%20Fluids%20Engineering. I would like to express my gratitude to the committee members that contributed to this effort. Comments and suggestions are also welcomed. ■

X-ray Micro-imaging of Flows in Opaque Conduits

by Sang-Joon Lee

Flow visualization has become an indispensable tool in the investigation of complex flow structures. Recent advances in digital image processing techniques have made it possible to extract quantitative flow information from visualized flow images of tracer particles (Adrian, 1991). As a quantitative flow visualization method, PIV(particle image velocimetry) has been accepted as a reliable and powerful velocity field measurement technique. Because optical visualizations or PIV systems use commonly lasers as the light source, they can be applied only to transparent fluids with a clear window. For measuring flows inside opaque conduits or non-transparent fluids such as blood, a transmission-type light source such as an X-ray or ultrasonic wave is required. We developed an X-ray PIV technique in which X-ray beam from the synchrotron radiation source of Pohang Light Source was used as a light source. Using the X-ray PIV technique, we visualized quantitatively several flows; glycerin flow inside an opaque Teflon tube, sap flow inside xylem vessels of a bamboo leaf, blood and micro-bubbles moving in an opaque tube.

Flow in an opaque Teflon tube

Lee and Kim (2003) applied the X-ray PIV technique to a liquid flow in an opaque Teflon tube of an inner diameter of 750 µm. The X-ray flow images were recorded on a cooled CCD camera of 1280 × 1024 pixels resolution. Because the X-ray is a continuous beam, a mechanical shutter was installed to make a pulse type beam for PIV measurements. A delay generator was used to synchronize the mechanical shutter and the CCD camera. Alumina powder (Al_2O_3) of 3 µm, a strong absorber of x-ray, was used as tracer particles. To match the specific weight of the alumina particles, glycerin was used as the working fluid. From preliminary tests, the optimum object-detector distance at which the refraction-based edge enhance-

Fluids Engineering Technical Articles: (continued)

ment is effective was determined. The field of view was 1.5 × 1.5 mm^2 and the spatial resolution was 12.3 × 12.3 μm^2. A cross-correlation PIV algorithm was applied to each pair of consecutive X-ray particle images to get the instantaneous velocity field. Because the X-ray image captures all particles located inside the X-ray pathway, they contain amassed flow information in the direction of X-ray propagation. For two-dimensional or axisymmetric flows, the velocity field information in any cross-section can be obtained using an appropriate mathematical formula. The streamwise mean velocity profile extracted along a horizontal line show parabolic velocity distribution and its magnitude is about two-thirds of the theoretical value. The X-ray PIV can be used to measure the volumetric flow rate of any liquid enclosed in an opaque conduit, for example the rate of blood flow in a living organism.

Sap flow inside xylem vessels

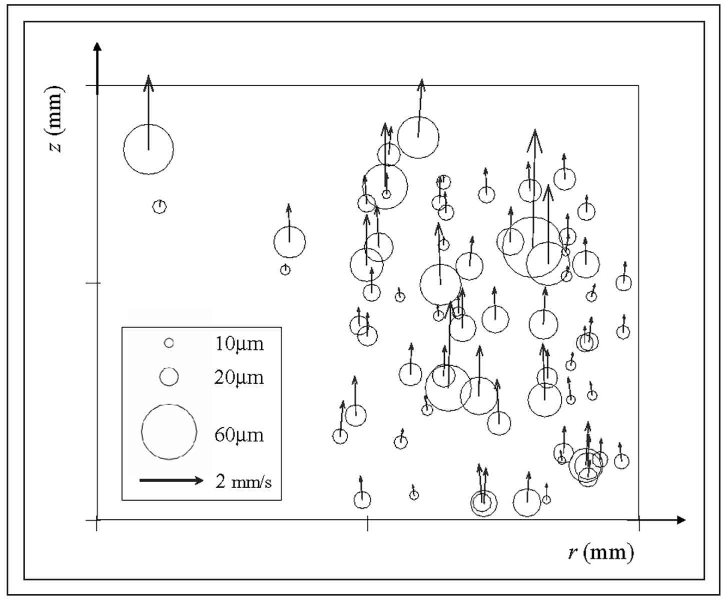
Most conventional measurement methods have limitations in direct visualization of sap flow in xylem vessels of intact plants. Kim and Lee (2003) employed the X-ray micro-imaging technique to monitor the refilling process inside xylem vessels of a bamboo leaf *in situ*. The water-rise kinetics in xylem vessels was investigated by tracking the position of water-front from the X-ray images captured consecutively. The X-ray images show clearly plant anatomy, vapor bubbles, transport of water and variation of contact angle in xylem vessels. During water refilling process, the rising water-front stopped at a vessel end for a while, thereafter it passed the vessel end with a higher velocity than the normal refilling speed. The vessel end acts as a hydraulic valve in the water transport in vascular plants. Repeated cavitation was found to weaken the refilling ability of xylem vessels. In addition, dark environment facilitated the refilling in xylem vessels rather than bright illumination conditions.

Blood flow in a microchannel

Hemodynamic researches have mainly been carried out in vitro using transparent substitute of the blood. It is not easy for MRI and ultrasonography to visualize detailed transport of blood cells due to poor spatial resolution. The micro-PIV technique can be applicable only to transparent fluids inside a clear conduit and seeding particles can affect the biochemical characteristics of blood. Kim and Lee (2004) measured the instantaneous velocity fields of real blood flow in an opaque microchannel by using the X-ray PIV technique to track red blood cells (RBC) as tracer particles without seeding any artificial particles. To acquire clear X-ray images of RBC of real blood, the sample-detector distance and the thickness of sample fluid were optimized.

Measurement of velocity and size of micro-bubbles

The X-ray micro-imaging technique was used to measure simultaneously the size and velocity of micro-bubbles moving in an opaque tube. Clear phase contrast images were obtained at interfaces of micro-bubbles between water and air, due to different refractive index. Micro-bubbles(20–60 μm) rising upward by buoyancy in a straw (ϕ = 2.7 mm) were tested. The opaque tube consists of high molecular substance. To calculate bubble size, digital edge detection method was adopted and the Fresnel diffraction pattern was used as searching function. The



field of view was 858 μm × 686 μm. By processing the X-ray images, the relationship between the bubble size and terminal velocity was derived. The terminal velocity measured was proportional to the square of size of micro-bubble. Instantaneous distribution of the size and velocity of micro-bubbles was obtained accurately without any optical distortion. The overlapped micro-bubbles are also clearly distinguished. Micro-bubbles show spiral motion with a large pitch.

Conclusively, this advanced X-ray PIV technique can be used to get useful information of various micro- and bio-fluid flows and will play an important role in resolving veiled flow phenomena, especially organic flows in living creatures (Westneat et al. 2003).

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Futher information can be obtained from the author, Sang-Joon Lee at the Department of Mechanical Engineering, Pohang University of Science and Technology, Pohang 790-784, Korea E-mail, sjlee@postech.ac.kr www, http,//efcl.postech.ac.kr/about/member1_0.html ■

Fluids Engineering Technical Articles: (continued)

Nascent Noise Reduction Strategies for Underwater Vehicles

Promode R Bandyopadhyay, Fellow ASME
Naval Undersea Warfare Center

Noise radiates from hull due to vibration in propulsion drive and turbulent boundary layer pressure fluctuations. In the propulsor, the sources of noise are cavitation, unsteady loading on propulsor blades due to ingestion of upstream hull turbulence, blade vibration due to periodic vortex shedding and blade tonals due to rotor blades of propulsors being buffeted by wake momentum deficits of upstream rotor blades. Noise from turbulence ingestion, vibration of trailing edge of blades and blade tonals varies as rotational speed to the power of 4, 5 and 6, respectively. Our modeling shows that a 20% reduction in RPM (rotations per minute) would lower radiated noise by 3–5 dB. High lift unsteady mechanisms such as those employed by flying insects are means for reduction of RPM. The progress made with several noise reduction concepts originating from the Biorobotic efforts at NUWC, are presented. The impact on cavitation and full scale noise is unknown.

Supplanting Drive Train: Programmable electro-active polymer foils in future could camber in real-time without conventional drive systems that are prone to vibration (Figure 1). Figure 2 shows a 15% increase in thrust due to active cambering.

Enhancement of Pressure Recovery/Reduction of RPM: Ellington and Dickinson have shown that flying insects like fruit flies employ unsteady aerodynamic mechanisms for lift production that engineers are familiar with but avoid. They are:

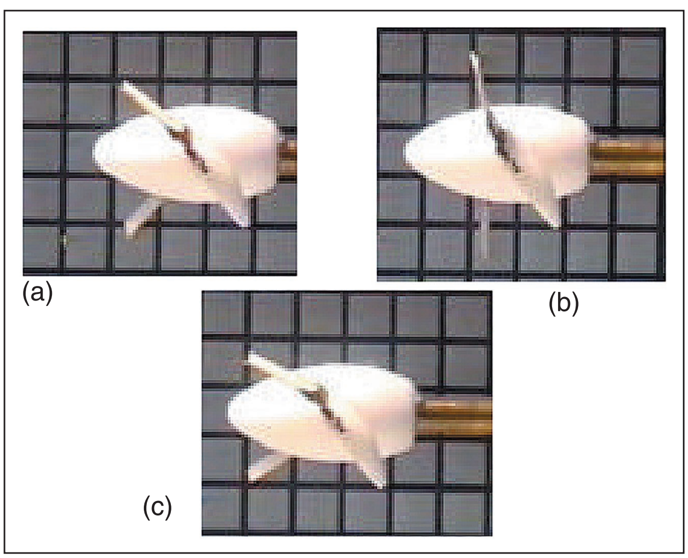

Figure 1 (a–c). Programmable laboratory scale propulsor blades made of artificial polymer muscles. Input pulse forms and cambering: (a) bipolar: flat, (b) positive unipolar: cambered negatively; reverse thrust, and (c) negative unipolar: cambered positively; forward thrust. Power to muscles: 100 Hz and 7 V; high frequency: cambering without oscillation and bubbles (1-cm × 1-cm grid).) *(Bandyopadhyay & Krol).*

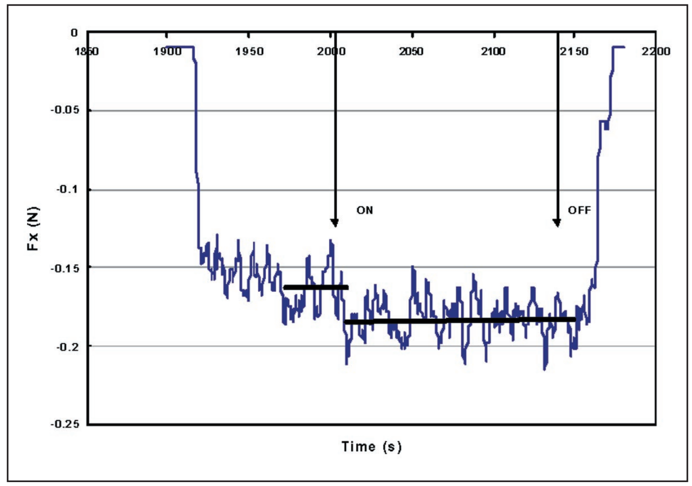

Figure 2. Thrust signature in a two-bladed notional small propulsor. RPM: 520, 3 V, 1 Hz, negative unipolar, positive cambering. *(Bandyopadhyay & Krol)*

delayed stall, rotational effect and wake capture. Figure 3 shows the results of the implementation of delayed stall in a passive manner in a two stage propulsor. The upstream stator blades are set at variable angles of pitch. This is a departure from current practice where all efforts are made to maintain a rotationally uniform flow. A rotor blade while traversing the wake of such a stator row would experience gusts that would lead to delayed stall. Diametrically opposite blades are set at positive and negative pitch angles with respect to a mean value to cancel noise in the far field. Large pressure recovery is possible (Fig. 3b). Cavitation effects in water are not known, which is not an issue in air.

Blade Tonal Reduction: The mechanism of fish propulsion involves the actuation of the caudal fin at its natural frequency whereby a reverse Karman vortex is formed which produces a downstream jet rather than a wake. Figure 4 shows a fish tail like actuation of the trailing edge of an upstream stator blade

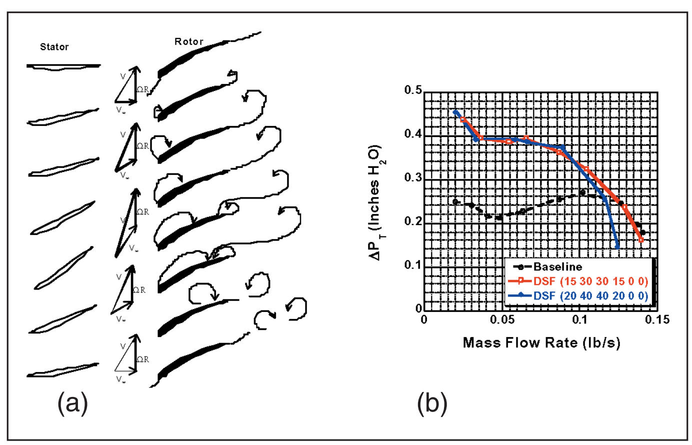

Figure 3. (a) Implementation of the passive delayed stall mechanism of high-lift of insect flight. (a) Mechanism, (b) Wind tunnel pressure recovery data. *(Usab, Bilanin & Hardin).*

Fluids Engineering Technical Articles: (continued)

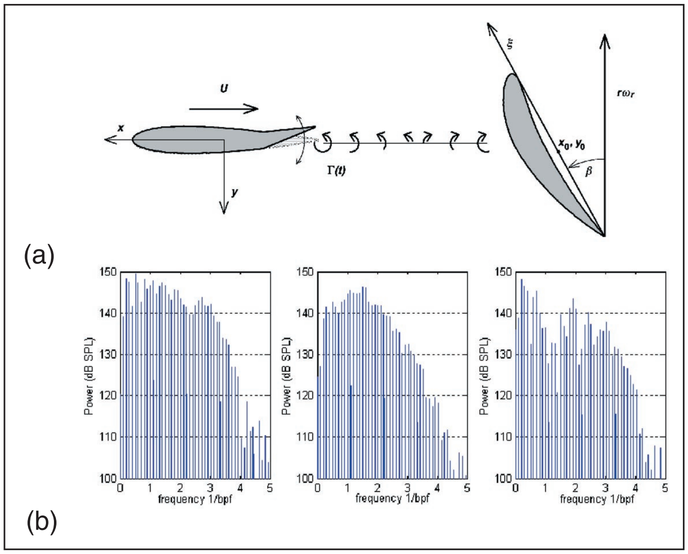

Figure 4. Low Reynolds number notional implementation in water of fish tail propulsion mechanism for blade tonal reduction. (a) Concept. (b) Noise spectrum: uncontrolled (left) and controlled (middle & right). *(Opila, Annaswamy, Krol & Raghu).*

to fill the momentum deficit in its wake. The rotor blade downstream experiences a smaller fluctuation in force. This results in a lower blade tonal noise. Reduction in noise is greater when stator trailing edge actuation is timed to the passage of the downstream rotor blade (Fig. 5b right). Estimated net noise reduction is 20–35% in a two-dimensional foil experiment at a Reynolds number of 4000 and is based on simplified models. ■

NUWC-Russia-UK Research on Compliant Coating

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We report the highlights of a collaborative effort between NUWC, Russia and the UK on the development of passive compliant coatings for undersea application for drag reduction and turbulence control. Five cylindrical coatings were manufactured in Novosibirsk in Russia. The coated cylindrical models were shipped to NUWC and the University of Nottingham in the UK. First round of tests indicated reductions in drag and wall pressure spectra.

Drag, fluctuating wall pressure and boundary layer velocity profile measurements were carried out on a *1 m long 76 mm* diameter sting mounted model in the MIT water tunnel (Fig. 1). The coatings were applied to a *30 cm* long section of the model. Drag was directly measured on this section and wall pressure fluctuation was measured immediately downstream of this floating section. Baseline case measurements were repeated between those with successive coated cylinder models. Five

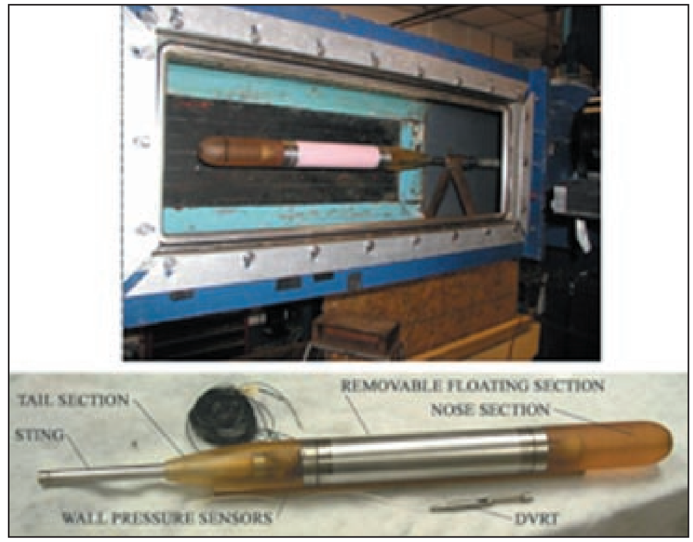

Figure 1. NUWC compliant coating model in water tunnel (top) and model components (bottom).

coatings were fabricated whose thickness, density, elasticity and loss tangent were varied with guidance from Semenovís interference theory. This theory assumes that the no-slip wall boundary condition is altered in the surface normal direction by the coating in response to wall pressure pulses. Such surface-normal oscillations were assumed to remain smaller than the viscous sublayer thickness. A natural frequency of the coating was sought that reacted to the quasi-deterministic nature of the turbulence production process.

The drag balance calibration was linear over the entire range of drag measurement. LDV measurements indicated that a turbulent log law profile was established and momentum thickness Reynolds number was just below 3500. Skin friction computed from measured floating section drag in Fig. 2 showed that the NUWC experiments were carried out in the transitional range. Skin friction values from Clauser plot of LDV measurements

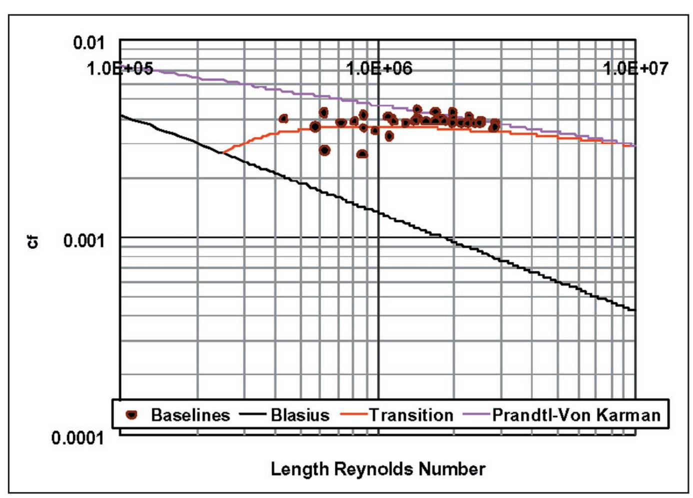

Figure 2. Coefficient of friction versus Reynolds number for baseline NUWC data.

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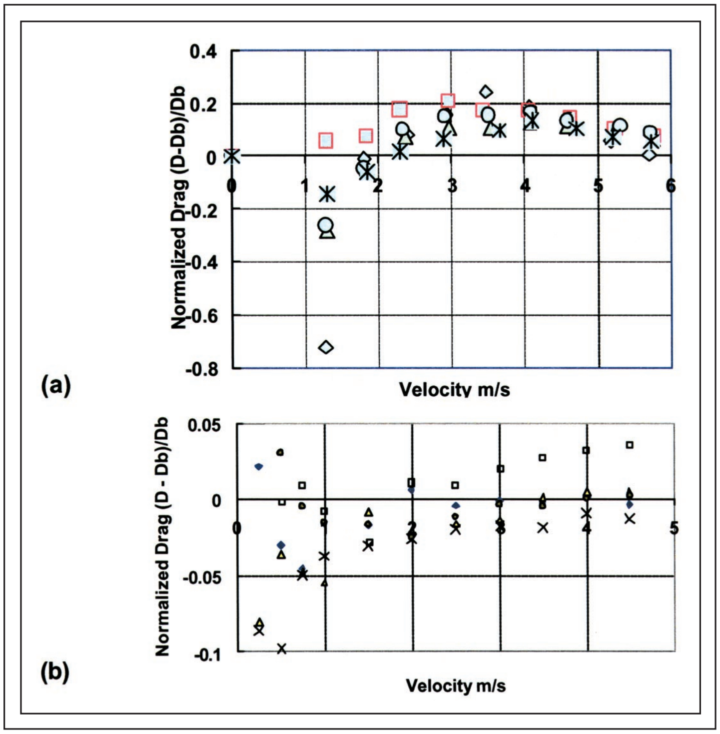

Figure 3. NUWC (a: untripped boundary layer) and UK (b: tripped; due to Choi) drag measurements. The tests are carried out one year and three months after manufacture, respectively.

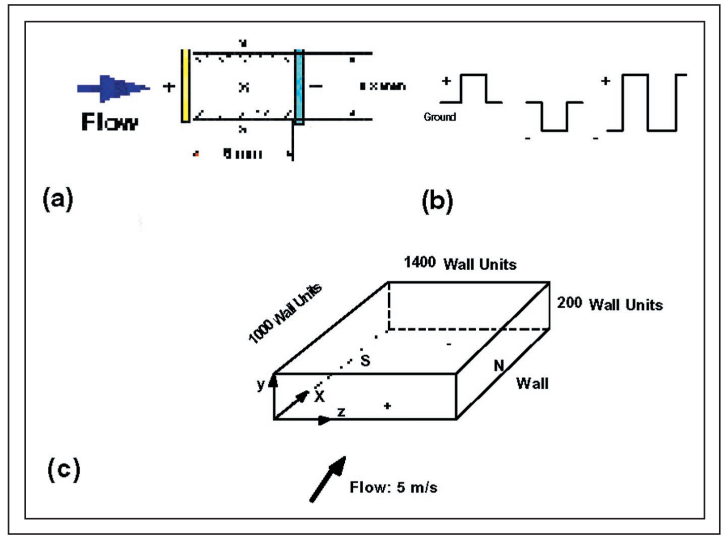

Figure 1. Microtile (a). The electrodes run vertically with the north and south poles of a 0.6T magnet lying in between. (b) Pulse forms. (c) Volume over a maximum of roughly 14 ëunit turbulence production domainsí laid out along span, where Lorenz force field is being applied by one microtile at 5 m/s.

and direct drag values were in close agreement even as drag dropped to *1/4th* as speed was halved from *4.8 m/s* to *2.4 m/s*. Wall-pressure spectra showed a *3–5 dB* reduction over *20–100 Hz* at a freestream velocity of *1.28 m/s*. Figure 3 shows that drag is reduced. The coatings are believed to age with time. Measurements on a larger model are now being planned. ■

Electromagnetic Turbulence Control in an Axisymmetric Body in Saltwater

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The discovery of the quasi-cyclic nature of turbulence production in turbulent boundary layers raises the potential that the process could be interfered with by applying an anti-phase periodic forcing. Such an approach for electromagnetic turbulence control could be efficient if Lorenz force is kept small and confined to the near wall region. Alteration of the surface-normal turbulence in that region is sought here. Figure 1 shows the schematic of the microtile actuator. Simulation shows that Lorenz force due to this microtile remains confined within 1 mm from the wall.

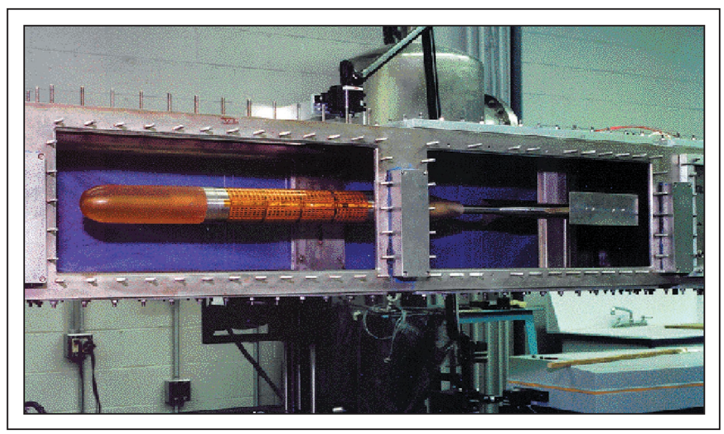

Figure 2. The 76 mm diameter 1m long microtile model in the NUWC salt water tunnel.

In analogy to Stokes' flow, the pulsing Lorenz pressure over microtiles can be modeled as local wall oscillators which produce vorticity waves diffusing outward. Assume that the actuators produce a Stokesí layer whose viscous wave length extends to where turbulence production is maximum. The input waves would cancel the turbulence production process if the two have an opposite phase. Direct numerical simulation confirms that pulsed Lorenz force produces vortex rings whose sense is opposite to that of naturally occurring near wall vortex pairs in turbulent boundary layers. At 5 m/s, the pulsing frequency is estimated to be . The numerous small dark rectangles (1280 in number) visible on the surface of the floating section (7.6 cm diameter x 35.3 cm long) in the middle of the model in Fig. 2 are permanent magnets. Thin layers of electrodes are electroplated over kapton sheets, which cover the floating section, the magnets lying underneath. The electrodes

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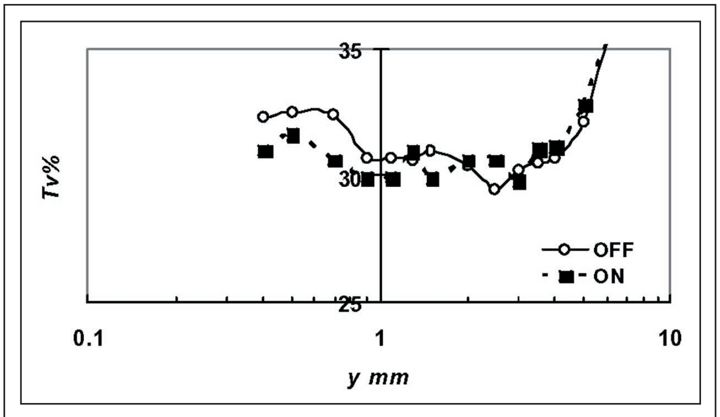

Figure 3. Surface-normal turbulence; bipolar; 250 Hz, 5.6 m/s, 35.4 mS/cm, 5.2 V, 14 A.

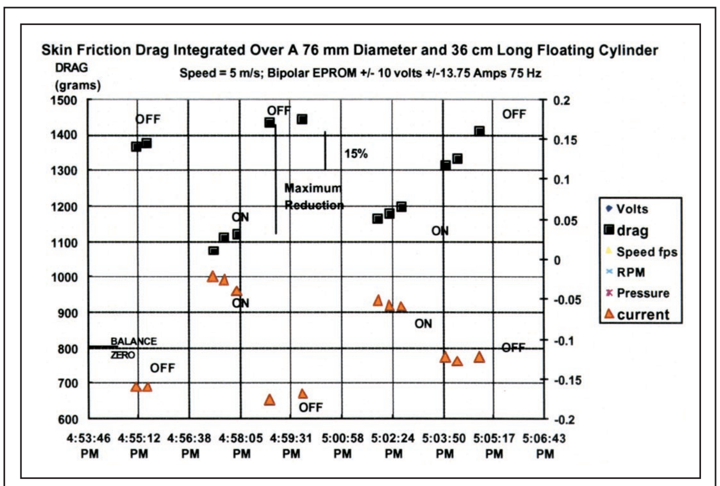

Figure 4. Time trace of drag and current: 5.1 m/s; bi-polar pulsing , 75 Hz and 13.75A.

run circumferentially over the cylinder. At a flow speed of 5.5 m/s, momentum thickness Reynolds number is 2300, coefficient of skin friction is 0.0035, and the amplitude of the interaction parameter, in viscous units, is 0.6. Figure 3 shows that statistical intensity of surface normal turbulence is lowered below a depth of 2mm. Figure 4 shows that, drag is reduced by 15-25% at 5.12 m/s at an efficiency of 2-3.4%. ■

> The future is like heaven everyone exalts it, but no one wants to go there now.
>
> — James Baldwin

Chair's Message (continued from page 2)

Edison Aulestia, Carol Griffin, Bob Niehaus, Serena Zilberstein, Cynthia Clark and all other staff that worked indirectly to help create this success. EC hopes to continue to build on this relationship in the coming years.

You are invited and encouraged to become involved in activities and program planning of the FED. There are a number of opportunities for you. To find out how to get involved, contact one of the TC/CG officers, any member of the Executive Committee, all listed in this Newsletter, or visit the FED website. The TC/CG meetings at our conferences are open to all attendees.

I want to leave you with the thought that FED is your Division. Your participation in its events and conferences only strengthens the Division and gives us the resources to do more for you, ASME, and the society at-large. So, stay in touch, participate and provide us your feedback.

I hope to see many of you in Charlotte in July!

Ali Ogut, Chair *(adoeme@rit.edu)*■

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