CSME BULLETIN SCGM

THE CANADIAN SOCIETY FOR MECHANICAL ENGINEERING
LA SOCIÉTÉ CANADIENNE DE GÉNIE MÉCANIQUE

The Wake of a Freely Flying European Starling

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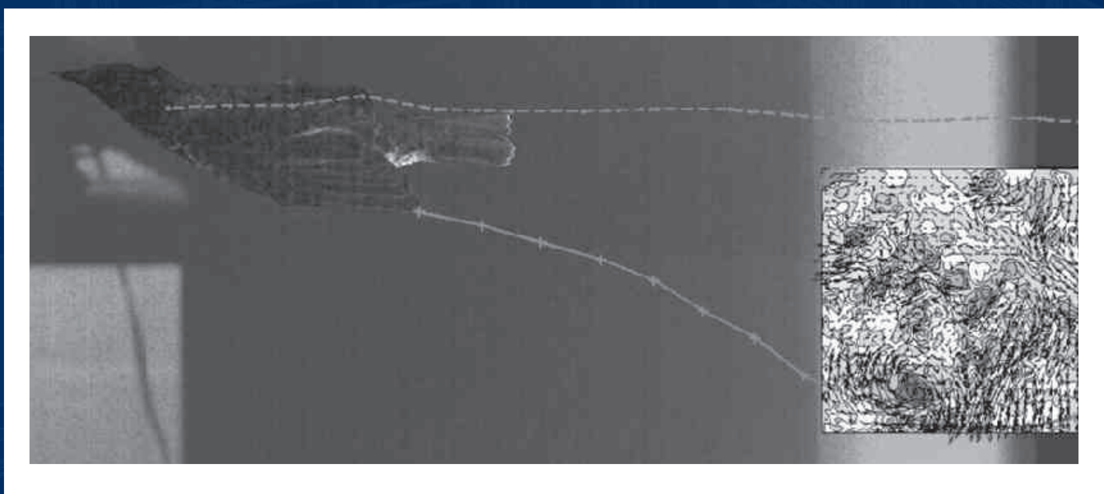

Sustainability and Mechanical Engineering

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Summer 2012 été

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President's Message/Message de la Présidente

Christine Wu, Ph.D., P.Eng., FCSME

President's Message

It is a privilege to serve as the President of the Canadian Society for Mechanical Engineering (CSME), 2012-2014. CSME, as a single organization for Canadian mechanical engineers, serves as a common platform to bring together all mechanical engineers and engineers in other disciplines with interest in mechanical engineering. I have been inspired by the dedication and commitment of our members, who work together to make CSME a remarkable organization. I will continue the efforts to work with you to keep CSME a dynamic voice for Canadian mechanical engineers.

I would like to take this opportunity to thank the past President of CSME, Dr. Kamran Behdinan for his leadership and outstanding contributions to CSME. Under his leadership, CSME has continued to grow and several new initiatives have been implemented, which include providing free memberships for students of sustaining member universities; developing and launching the new CSME website to enhance its service and visibility; establishing partnerships with other engineering associations; supporting and sponsoring several international conferences, and promoting mechanical engineering in these events.

The Department of Mechanical Engineering at the University of Manitoba successfully organized the CSME International Congress 2012, the flagship conference for CSME. In this three-day event, Canadian and international researchers in the area of mechanical engineering presented their research work in several symposia and sessions. I would like to thank Dr. David Kuhn (the Conference Chair), Dr. Tarek Elmekkawy (the Technical Chair) and Dr. Bingchen Wang (the Publication Chair) for their dedication organizing the conference. As the Program Chair, it was my privilege to work with them. I would also like to express my gratitude to the symposium and special session organizers, student volunteers and those who worked behind the scenes that made this Congress successful. The Department of Mechanical and Industrial Engineering, University of Toronto will host the CSME International Congress 2014.

The CSME honours, awards, and fellowships were announced at the CSME International Congress 2012 banquet in Winnipeg, MB on June 5, 2012. The awards for the three winning teams in the CSME Undergraduate Student Design Competition and the three recipients of the CSME Best Student Paper Awards were also announced at the same event. I would like to congratulate all the deserving award winners.

As I begin my term as the President of CSME, I look forward to working with you, our members to strengthen the current connections with academia, and to continue to build collaborative partnerships with other societies and industry. I hope to see you at CSME International Congresses and CSME sponsored Symposia, which bring together all mechanical engineers with the same professional interests and passions.

Sincerely yours,

Christine Wu, Ph.D., P.Eng., FCSME
Professor and NSERC Industrial Research Chair
Department of Mechanical and Manufacturing Engineering, University of Manitoba

Mot du président

C'est avec un grand privilège de servir comme président de la société canadienne de génie mécanique (CSME), 2012-2014. CSME, comme un seul organisme pour les ingénieurs Canadian de Génie mécanique, constitue une plate-forme commune pour réunir tous les ingénieurs de génie mécanique et les ingénieurs dans d'autres disciplines avec un intérêt en génie mécanique. J'ai été inspiré par le dévouement et l'engagement de nos membres, qui travaillent ensemble pour faire CSME une organisation remarquable. Je vais continuer ces efforts en travaillant avec vous pour garder le CSME comme une voix dynamique pour les ingénieurs Canadian en génie mécanique.

Je voudrais saisir cette occasion pour remercier le président partant du CSME, Dr Kamran Behdinan, pour son leadership et sa contribution exceptionnelle au CSME. Sous sa direction, le CSME a continué de croître ainsi que d'autres plusieurs nouvelles initiatives ont été mises en œuvre, qui incluent des adhésions gratuites pour les étudiants ; création et lancement du nouveau site CSME afin d'améliorer son service ainsi que sa visibilité ; établir des partenariats avec d'autres associations de l'ingénierie ; soutenir et parrainer plusieurs conférences internationales et la promotion de Génie mécanique dans ces événements.

Le département de génie mécanique à l'Université du Manitoba a organisé avec succès la conférence internationale de CSME 2012. Dans cet événement de trois jours, des chercheurs canadiens et internationaux dans le domaine du génie mécanique ont présenté leurs travaux de recherche dans plusieurs sessions et symposiums. Je tiens à remercier le Dr David Kuhn (le président de la conférence), Dr Tarek Elmekkawy (le président technique) et Dr Bingchen Wang (le président de la Publication) pour leur efforts et dédicacions à l'organisation de la Conférence. Comme le président du programme, c'était avec un grand privilège de travailler avec eux. Je tiens aussi à exprimer ma reconnaissance pour les organisateurs du symposium et sessions extraordinaire, les étudiants bénévoles et ceux qui ont travaillé dans les coulisses pour la réussite de ce congrès. Le département de génie mécanique et industriel à l'Université de Toronto sera l'hôte du prochain Congrès CSME 2014.

Les prix, bourses et reconnaissances ont été annoncés lors du banquet du Congrès International CSME2012 à Winnipeg, au Manitoba, le 5 juin 2012. Les prix pour les trois équipes gagnantes du concours "Undergraduate Student Design" et les trois lauréats de la "CSME Best Student Paper Awards" ont également été annoncées durant la soirée du banquet. Je tiens à féliciter tous ceux qui les méritent.

Comme je commence mon mandat de président de CSME, j'ai hâte de travailler avec vous et nos membres afin de renforcer les connexions qui existent déjà avec les universitaires et de continuer à construire des partenariats et collaboration avec l'industrie et d'autres associations. J'espère vous voir aux prochains Congrès International de SCME, qui réunissent tous les ingénieurs en mécanique qui ont les mêmes passions et intérêts professionnels.

Sincèrement vôtre,

Christine Wu, Ph.D., P.Eng., FCSME
Professor and NSERC Industrial Research Chair
Department of Mechanical and Manufacturing Engineering, University of Manitoba

CSME Advertising

Contributing to the CSME Bulletin

We welcome submissions of events, announcements, job postings, and feature articles relevant to mechanical engineering from researchers and engineers in Canada. Feature articles in forms of both review and research papers are welcome. The articles should be technical, general, and no more than 6000 words. If you are interested in submitting an article to the Bulletin, please contact the Editor at xiaodong.wang@ualberta.ca.

Contributing to the CSME Bulletin

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CSME / SCGM

Honours, Awards and Fellowships

Presented at **CSME International Congress 2012, Winnipeg, Manitoba, June 5, 2012**

Honours and Awards Committee, 2012

Dr. Kamran Behdinan, FCSME
Dr. Jean Zu, FCSME
Dr. Marius Paraschivoiu, FCSME

Fellow of the CSME

Dr. Murray Thomson

Murray Thomson is a Professor in the Department of Mechanical and Industrial Engineering at the University of Toronto where he has taught courses and conducted research for 15 years. He is an internationally known researcher in the areas of alternative fuels, pollution control and combustion sensors, and he has contributed significantly to the advancement of knowledge in this field.

Among his many accomplishments, he has developed and made patent applications, and he has commercialized and licenced 4 process sensors based on optics and spectroscopy. In addition, Murray has successfully collaborated with industrial partners including Tenova Goodfellow Inc., Resonance Ltd., Unisearch Associates, Ensyn Corp., Pratt and Whitney Canada, Westport Innovations, and Rolls Royce Canada

Murray Thomson has made outstanding contributions to the Combustion Institute, Canadian Section, where he serves on the Board of Directors and he is currently the Treasurer.

Fellow of the CSME

Dr. Pierre Sullivan

Pierre Sullivan is a member of the academic staff in the Department of Mechanical and Industrial Engineering, University of Toronto. Prior to joining the academic staff he received BScME and MScME degrees from Clarkson University in New York, and a PhD from Queen's University in Kingston. He served as the Associate Director of the University of Toronto's Pulp and Paper Institute from 1997 to 2004, and he was the Associate Chair for Graduate Studies in his department from 2003 to 2008.

Dr. Sullivan is active in research in the area of fluid mechanics with emphasis on non-intrusive methods of measurements such as Particle Image Velocimetry and Particle Tracing Velocimetry. The applications of his research include the development of a miniature ion mobility spectrometer and the development of a digital lab-on-a-chip for detecting both pulmonary and extra-pulmonary TB. He has published 150 technical articles and he has supervised to graduation 60 Doctoral and Master's students.

Robert W. Angus Medal

Dr. Jean Zu

Professor Jean Zu received B.Sc. and M.Sc. degrees from Tsinghua University in China and a Ph.D. degree from the University of Manitoba. She joined the academic staff at the University of Toronto in 1994 as an Assistant Professor. In 1999 she was promoted to the rank of Associate Professor, and in 2004 to the rank of Professor. In 2009 she was appointed Chair of the Department of Mechanical and Industrial Engineering – the first female to be appointed to this position. Her research interests are in the area of mechanical vibrations and dynamic analysis with applications to bio-instruments, tissue mechanics, and mechatronics. She has received many honours and awards in recognition of her professional accomplishments and she has been elected Fellow of the CSME, the ASME, the EIC, and the AAAS.

Professor Zu has made many significant contributions to the CSME over an extensive period of time. She has served as the Chair of the Membership Committee, Chair of the Finance Committee, and Chair of the Honours and Awards Committee. She was the Senior Vice President from 2004 to 2006, President during the period 2006 to 2008 and Past President from 2008 to 2010. She is also the President Elect of the Engineering Institute of Canada.Engineering Institute of Canada.Engineering Institute of Canada.

Fellow of the CSME

Dr. Carolyn Ren

Carolyn L. Ren is an Associate Professor in the Department of Mechanical and Mechatronics Engineering at the University of Waterloo where she has been teaching and conducting research since May 2004. She is a Tier II Canada Research Chair in Lab-on-a-Chip Technology and a recipient of Early Research Award from Ontario Ministry of Research and Innovation and Research Excellence Award from the Faculty of Engineering at the University of Waterloo. She is an internationally known researcher in the areas of Microfluidics and Lab-on-a-Chip technology and their applications in the chemical, biomedical and environmental fields. She has contributed significantly to the advancement of knowledge in this field and many of her published papers are cited very well. She has made significant contributions in training highly qualified personnel. One out of her eight postdoctoral fellows founded a company located in Cambridge Ontario focusing on protein analysis using microfluidic platforms and six other PDFs are professors across the world. Among her many accomplishments, she has developed and made patent applications and has successfully collaborated with industrial partners including Convergent Biosciences, Advanced Electrophoresis Solutions Ltd., Xerox Research Center Canada, and Cestoil Chemical Inc. She has actively involved in organizing conferences and has served as Track chairs and co-chairs for various international conferences.

Fellow of the CSME

Hossam Kishawy

Dr. Hossam Kishawy is a Professor of Mechanical Engineering and Assistant Provost, Research, at the University of Ontario Institute of Technology in Oshawa, Ontario. Dr. Kishawy has made significant contributions to manufacturing and welding research, involving characterization of tool wear and machinability of materials, particularly in the automotive and aerospace industries, such as metal matrix composites and titanium alloys. He has also contributed significantly to industrial practice, teaching and research in mechanical engineering, including major developments of new manufacturing courses and education. He received his Ph.D. degree (1998) in Mechanical Engineering from McMaster University in Hamilton, Ontario.

G.H. Duggan Medal

Dr. Louis Gagnon

Louis Gagnon is a mechanical engineering doctoral student at Laval University in Québec City. His main research interest is the dynamic modeling of the energy consumption of vehicles. He received his Bachelor of Engineering degree from McGill University and his Master of Engineering degree from Laval University. He has so far published eight conference articles on the subject of vehicle aero- and multibody dynamics. He has also appeared on various television shows concerning his studies. Finally, he was a member of McGill's Electric Snowmobile and Laval's Alérion Supermileage teams and he his currently organizing a fruit plantation project on Laval's campus.

C.N. Downing Award

Dr. Chul Park

Chul Park is a Professor of Mechanical Engineering at the University of Toronto where he has taught and conducted research since receiving his PhD from the Massachusetts Institute of Technology in 1993. Chul Park is an internationally renowned researcher in the field of plastic foam processing. He is the Tier 1 Canada Research Chair in Advanced Polymer Processing Technologies and is the Editor-in-Chief of the Journal of Cellular Plastics and a member of the Editorial Board of Cellular Polymers and Advanced Polymer Technology. His co-invention and development of the first-generation microcellular extrusion system is a remarkable achievement which has led to successful commercialization of microcellular plastic products. Most of Chul Parkís research visions are successfully implemented in a wide range of industrial applications involving the automotive and construction industries.

Since Prof Chul Park was appointed as the Materials Technology Chair of the CSME in 2001, he has provided a platform with Canadian and International researchers to disseminate knowledge and understanding of the development and use of materials in mechanical engineering design. Furthermore, he facilitated the cross-pollination between the materials science and mechanical engineering communities.

President's Award

Marc Rosen

Dr. Marc A. Rosen, P.Eng. is a professor of Engineering and Applied Science at University of Ontario Institute of Technology in Oshawa, Canada, where he served as founding dean from 2002-08. Dr. Rosen was President of both CSME and the Engineering Institute of Canada. Dr. Rosen has served CSME for 18 years in various other capacities, including Chair of the Thermofluids Engineering Division, Senior VP, Chair of the Finance and Nominations Committees, and Associate Editor of the Transactions of the Canadian Society for Mechanical Engineering. He chaired the CSME Forum in 1998 and is a regular contributor to the CSME Bulletin. Recently, Dr. Rosen played a key role in creating an engineering archive at his university's Library, which houses and is digitizing for broad accessibility the holdings of CSME and the Engineering Institute of Canada. He has carried out extensive research for industry and others on energy technologies, leading to increased efficiency and reduced emissions and costs, and is a leader in sustainable energy and exergy methods. Having received numerous awards, he is a Fellow of many societies (EIC, CSME, ASME, IEF, CAE), and has worked for Argonne National Laboratory near Chicago, Imatra Power Company in Finland, the Institute for Hydrogen Systems, and Ryerson University, where he served as Chair of Mechanical Engineering and Director of Aerospace Engineering.

Fellow of the CSME

Dr. Shushanta Mitra

Dr. Mitra has made significant contributions in understanding of transport processes in micro and nanoscale confinements. He has authored more than 100 papers in peer-reviewed journal and conference proceedings. He is the Editor of the Microfluidics and Nanofluidics Handbook. His group has pioneered the use of FIB-SEM to characterize micro-scale transport in porous media and has invented a microfluidic device ìReservoir-on-a-Chipî for miniaturizing natural oil and gas reservoirs. He has contributed significantly to the CSME community through his involvement as Co-Chair for Symposium at CSME International Congress and as a Faculty Advisor for CSME at the University of Alberta. He has devoted the last ten years of his professional carrier towards teaching and advancement of the mechanical engineer profession. For his achievements, he has been awarded the fellow of the American Society of Mechanical Engineers (ASME).t

G.H. Duggan Medal

Professor Marc Richard

Professor Richard received his Ph.D. from Queenís University, Ontario, Canada in 1985. He is a Professor at Laval University in the department of Mechanical Engineering, QuÈbec, QuÈbec, Canada since 1983 in the area of ìmodelling dynamic systemsî. He has recently been named Fellow of ASME. His research publications cover a very broad range of areas such as Vehicle Dynamics, Random Vibrations and Stability Analysis. He developed the Vector-Network modelling technique which has been the subject of many publications by various authors around the world.

Awards

Fellow of the CSME

Dr. David Kuhn

David Kuhn is a Professor and Head in the Department of Mechanical and Manufacturing Engineering at the University of Manitoba. He obtained his Ph.D. in Mechanical Engineering from Queen's University, Kingston in 1988. David worked as a research engineer for Abitibi-Price Inc. from 1987-1990 until his appointment to the NSERC/Abitibi Junior IRC in Paper Science at the University of Toronto. He was the Associate Chair of the Department of Chemical Engineering and Applied Chemistry from 2001-2005 and Chair of First Year Studies, Faculty of Engineering, from 2006/01-2006/06. David joined the Department of Mechanical and Manufacturing Engineering at the University of Manitoba as Head in 2006. Recent research has focussed on the numerical and experimental study of complex multi-phase flows with recent application to abdominal aortic aneurysms growth, wind turbine icing, lime kiln heat and mass transfer and kraft recovery boiler fouling.

Dr. David Kuhn has contributed significantly to engineering education and taken a leadership role in curriculum change at the departmental level (Head) at the University of Manitoba, and at the departmental (Undergraduate Coordinator and Associate Chair) and faculty (Faculty Curriculum Chair) levels at the University of Toronto. The vision of the curriculum change was increased design content, flexibility, breadth in core curriculum and choice of depth in program area. Dr. David Kuhn has taught a wide range of courses in the areas of thermodynamics, fluid mechanics, heat and mass transfer, process calculations, computational methods and communication. While at the University of Toronto he won teaching awards at the departmental (1991/92, 1994/95 and 1995/96), faculty (2002/03) and University (1999/2000) levels.

I. W. Smith Award

Dr. Martin Jun

Dr. Martin Jun is an Assistant Professor in the Department of Mechanical Engineering at UVic, who is an emerging researcher in the field of multiscale advanced manufacturing and sustainable manufacturing. He has extensive experience in the development of micro-scale manufacturing processes and systems and nanoparticle coating and printing processes and systems. He has been awarded a Canadian Foundation of Innovation New Opportunities Grant to establish the Laboratory for Advanced Multiscale Manufacturing (LAMM) and conduct research in the aforementioned fields. Two provisional patents have been submitted related to highly accurate nanoparticle deposition system and a micro-scale probing system in 2011. He is currently on the Editorial Board of the Journal of Manufacturing Technology Research and the chair of Manufacturing Equipment Technical Committee of the ASME Manufacturing Engineering Division. He is a recipient of the 2011 SME Outstanding Young Manufacturing Engineer Award. He will also be hosting 2013 International Conference on Micro-Manufacturing (ICOMM 2013) in Victoria. He is currently working with more than 7 industry partners on various projects related to nanoparticle printing and sustainable manufacturing processes and technologies.

Fellow of the CSME

Dr. David Sinton

David Sinton is an Associate Professor at the University of Toronto in the Department of Mechanical and Industrial Engineering, and the Associate Director of the Centre for Sustainable. Prior to joining the University of Toronto, Dr. Sinton was an Associate Professor and Canada Research Chair at the University of Victoria, Victoria, British Columbia (2003-2011). He was a Visiting Associate Professor at Cornell University (2009-2010), and continues as an Adjunct Professor. He received a B.A.Sc. from University of Toronto (1998), M.Eng. from McGill University (2000) and Ph.D. from University of Toronto (2003).

Dr. Sinton's research interests are in fluidics and energy. This research involves the study and application of small scale fluid mechanics (microfluidics, nanofluidics, and optofluidics) for use in energy systems and analysis. He has published over 75 journal articles and many conference papers and book contributions. He received the 2006 Canadian Society of Mechanical Engineering I. W. Smith Award, the 2006 Douglas R. Colton Award from CMC Microsystems, the 2007 Award for Teaching Excellence from the University of Victoria Faculty of Engineering, and the 2008 Early Career Achievement Award from the University of Toronto Faculty of Applied Science and Engineering.

CALL FOR CSME AWARDS NOMINATIONS

Nominations are solicited for the 2013 awards and honours of the Canadian Society for Mechanical Engineering (CSME), which aim to recognize and honour deserving members of the Society and the mechanical engineering community.

Honours and Awards

1. The **I. W. Smith Award** was established in 1977 to honour Professor I. W. Smith who devoted a lifetime to teaching mechanical engineering at the University of Toronto. It is awarded annually for outstanding achievement in creative mechanical engineering within 10 years of graduation.
2. The **G.H. Duggan Medal** was established in 1935 to honour Dr. G.H. Duggan who was president of the EIC in 1916. It is awarded annually for the best paper dealing with the use of advanced materials for structural or mechanical purposes. (revised 1983)
3. The **Robert W. Angus Medal** was established in 1957 to honour the late Robert W. Angus who was for many years Professor of Mechanical Engineering at the University of Toronto. It is awarded annually to a Canadian engineer for outstanding contributions to the management and practice of mechanical engineering. (revised 1993)
4. The **Jules Stachiewicz Medal** was established in 1983 to honour the late Jules Stachiewicz who was for many years Professor of Mechanical Engineering at McGill University. It is awarded alternately by the Canadian Society for Chemical Engineering (CSCE) and CSME for outstanding contributions to heat transfer in Canada.
5. The **C.N. Downing Award** may be presented annually to a member of the Society for distinguished service to CSME over many years.
6. The **Andrew H. Wilson History Award** was established in 2008 to recognize the contributions to this field of a past-president of CSME and longtime chair of its History Committee. It may be awarded annually for contributions by a member of the Society to the history of engineering.
7. The title, **Fellow of the CSME,** may be awarded to members, in good standing, with uninterrupted membership in the society for at least 3 years, who have attained excellence in mechanical engineering and who have contributed actively to the progress of their profession and of society.
8. A **Certificate of Service** may be awarded to CSME members in recognition of outstanding service to the Society in a particular capacity.
9. The **President's Award** was created in 2004 to honour individuals for their exceptional service to CSME and to mechanical engineering in Canada. It is awarded at the discretion of the President and Board of Directors.

Nominations

Nominations should be sent to the Chair of the HAF Committee, so as to reach **by January 15, 2013,** at:

Chair, Honours and Awards Committee
Canadian Society for Mechanical Engineering
1295 Hwy 2 East
Kingston ON K7L 4V1, Canada
Email: csme@cogeco.ca
Tel: (613) 547-5989 Fax: (613) 547-0195

The nomination package should consist of:

a. The nominee's name, occupation, position, title, affiliation, CSME membership number, and full address and contact information (including telephone, email, fax).
b. The nominee's CV.
c. A nomination letter from the nominator indicating the nominee's principal contributions and the reasons the nominee merits the award.
d. A draft citation for the nominee (125-150 words), which is intended for use in announcing the award recipient and publicity should the nomination be successful.
e. The nominator's name, position, title, affiliation and full address and contact information (including telephone, email, fax).
f. Two letters of support for the nomination, along with the names and addresses of the two supporters (including telephone, email, fax).

SUSTAINABILITY AND MECHANICAL ENGINEERING: VIEWS, ACTIONS AND BARRIERS

Marc A. Rosen
Past-President, CSME and Engineering Institute of Canada
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Sustainability has received increasing attention in society in recent years. Some have sought to understand sustainability and sustainable development (Waas et al., 2011), while others have examined the changes associated with shifting towards sustainability (Burns, 2012) or questioned its merits (Holden, 2010). Barriers to sustainability have also been the subject of much research (Singer, 2010), as has the incorporation of sustainability ideas in education. Views towards sustainability have been examined in many constituencies, including business (Reid et al., 2009), the public (Mbeng et al., 2009) and students (Reid et al., 2009).

Sustainable engineering has been discussed by many (Jonker and Harmsen, 2012). Trends in design for sustainability have also been identified and assessed (Lindow et al., 2012). Applications of sustainability concepts in engineering have been reported in such areas as energy (Rosen, 2009), infrastructure (Yigitcanlar and Dur, 2010), design (Nagel et al., 2012) and manufacturing (Bi, 2011). The incorporation of sustainable development and sustainability ideas into engineering education has received increasing attention.

Here, the perceptions are investigated that there has been a growing focus on sustainability measures in mechanical engineering and that attitudes of mechanical engineers towards sustainability have become more positive, using data from a 2009 online survey of mechanical engineers (ASME, 2012; Winters, 2010). The aim is to better understand how attitudes and actions towards sustainability have shifted, and barriers to further shifts towards sustainability.

The survey was sent to members of the ASME (www.asme.org) in the U.S. and had 3029 responses from practicing engineers and 1354 from engineering students. The principal job function of the practicing engineer respondents is broad (23% in design/development engineering, 23% in consulting/professional services, 19% in engineering or other management). The industries are represented by the respondents are also broad (24% energy, petroleum and related equipment; 15% consulting, design and professional services; 15% manufacturing, materials and machinery; 13% transportation and defense; 13% others).

Views of Mechanical Engineers

Personal attitudes of practicing engineers are very positive towards sustainability, with well over 80% indicating that they are personally involved in sustainable information and causes outside of work. The professional views and attitudes of practicing engineers are generally, but not exclusively, positive. That is, the majority of practicing engineer respondents feels that the use of sustainable and/or green design principles in the design, production, and operation of manufactured products is of increasing interest to colleagues (60% of respondents) and results in more product innovation (66%).

The personal attitudes of engineering students are even more positive towards sustainability, even more so than those of practicing engineers. Outside of engineering studies, 89% are personally involved in green and sustainable information and causes. The majority of engineering students feels that the use of sustainable and/or green design principles in the design, production, and operation of manufactured products is of increasing interest to fellow students (74% of respondents) and results in more product innovation (86%). 56% of engineering students agree that their school has a sustainable design class, program or assignment.

Although the attitudes towards sustainability of practicing engineers and engineering students are positive, and some believe it is a critical issue (e.g., some state that they feel engineers have a responsibility to bring sustainable processes to society), there are some who have reservations about its merits. These reservations include thinking that sustainability is: a buzzword or a temporary fad, or driven by public relations and politics, or a waste of time and money and harmful to companies, or based on unsound science.

Table 1. Mechanical engineers use and views on sustainability measures

Sustainability measure	Organization currently involved (%)	Used in past year (%)	Viewed as 2 most important	
			Practitioners	Students
Reduce energy use or emissions	71	64	64	66
Comply with environmental standards and regulations	71	54	23	7
Use renewable/recyclable/recycled materials	43	27	24	0
Use non-toxic materials	37	20	10	10
Attain low carbon footprint	36	21	10	11
Reduce manufacturing material waste	40	22	13	21
Reduce manufacturing energy and natural resource use	33	21	27	43
Reduce manufacturing pollution	31	15	11	14

Views and Actions of Mechanical Engineering Companies

The involvement of practicing mechanical engineers with sustainability is notable, with about 67% involved with sustainability or sustainable technologies. The majority (66%) of practicing engineer respondents indicated that at least a small portion of their projects over the past year included sustainable and/or green design principles beyond those mandated by regulations. But only 14% of respondents felt that more than half of their projects included specifications that were based on sustainable and/or green design principles beyond those mandated by regulations. The involvement of engineering students with sustainability or sustainable technologies is less significant, with 48% of student respondents involved with sustainability or sustainable technologies.

The most common sustainable technologies with which organizations are currently involved include designs that use less energy and reduce emissions (71% of respondents' organizations), and designs that comply with environmental standards and regulations (71%) (see Table 1). Similarly, the sustainable technologies that have been worked on by the practicing engineer over the past year include the most are designs that use less energy or reduce emissions (64% or respondents), and designs that comply with environmental standards and regulations (54%). In the past year, more than two-thirds of working respondents have worked on designs that use less energy or reduce emissions. More than half have worked on designs that comply with environmental standards and regulations.

Sustainability and Mechanical Engineering

The most important sustainable technologies are considered by all engineers to be designs that use less energy or reduce emissions (64% of practicing engineer respondents and 66% of engineering student respondents). The second most important sustainable technologies are viewed as manufacturing processes that use less energy and natural resources (27% of practitioners and 43% of students). In the coming year, most practicing mechanical engineers (63%) expect their organization to become more involved in sustainable and/or green design.

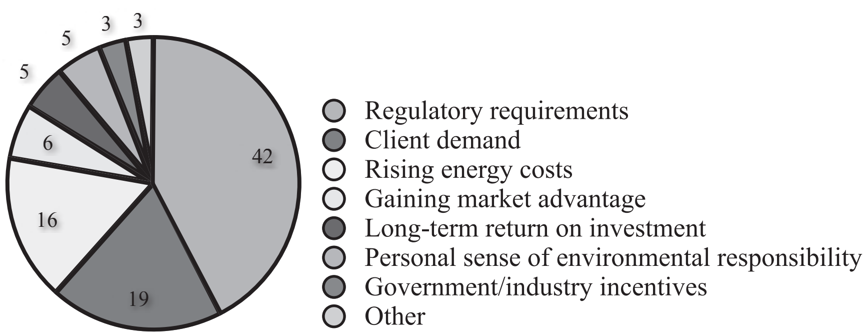

Figure 1. Factors (in %) most likely to affect application of green design practices by mechanical engineering organizations.

Views of Mechanical Engineers on Factors Influencing Sustainable Design

Numerous factors influence the use of sustainable design and practices, according to practicing mechanical engineers (see Figure 1). Regulatory requirements are most likely to influence organizations' use of green design practices and procedures, client demand was cited as the second most likely (and rising energy costs as the third most likely.

Usually, sustainability is better worked into a project when it is first addressed as early as possible within the project and then re-addressed throughout all subsequent stages. The survey shows supports this view, showing that sustainability is most commonly addressed in the conceptual design phase, according to 76% of practicing respondents. Also, 50% address sustainability during materials selection, 44% during process selection and 21% during reporting.

Factors that influence the use of sustainable design and practices must be balanced by organizations against other priorities, especially economics and production: 34% of working respondents' organizations consider sustainable technologies for new products only if they are cost-saving, 27% invest in sustainable technologies only if they increase throughput and cut costs of existing products/processes, 24% invest in sustainable technologies if they do not affect throughput or cost of existing products, 19% will spend extra to incorporate sustainable technologies in most new products, 15% do not invest in sustainable technologies, and 9% invest in sustainable technologies to make a statement with some flagship products.

Barriers Noted by Mechanical Engineers and Closing Remarks

Based on comments made by respondents to the survey, many barriers exist to enhancing the way sustainability is utilized by mechanical engineers and the extent to which it is used mechanical engineering work. These include economics and a short-term focus, competitiveness and the protection of confidential results, market forces, customer demand and inertia to change, as well as a lack of corporate culture and commitment, incentives, best practices, commonly accepted and consistent procedures and measures for assessing sustainable mechanical engineering, and codes, standards, regulations and laws for sustainable engineering. These comments provide some indication of the needs for improved education and debates about sustainability in mechanical engineering, and enhanced methods for applying sustainability concepts. Nonetheless, there appears to be a growing focus on the implementation of sustainability concepts, actions and measures in mechanical engineering

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The Wake of a Freely Flying European Starling

THE WAKE OF A FREELY FLYING EUROPEAN STARLING[1]

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Abstract—The wake of a freely flying European starling (Sturnus Vulgaris) has been measured at The Advanced Facility for Avian Research, Western University, Ontario, Canada. High speed, time resolved, particle image velocimetry, in combination with high speed cameras, have been used to generate vector maps that can be associated with the bird's location and wing configuration in the wind tunnel. Time series of measurements have been expressed as composite wake plots which depict entire wing beat cycles for a select spanwise location in the wake. In this "inner wing region," lack of downwash during the upstroke has been found, suggesting that lift is principally a function of the downstroke. Additional characteristics of the wake may be the result of stream-wise vortices, in addition to tip vortices, interacting in the wake.

Keywords-component; Wake characterization, bird, flapping wings, particle image velocimetry, wind tunnel studies

I. INTRODUCTION

In recent years, an increasing interest in developing unmanned aerodynamic vehicles (UAVs) has prompted research on the aerodynamic phenomena relevant to their travel. This branch of aerodynamics focuses on low Reynolds number flyers, of a variety of shapes, moving through a fluid. A significant portion of the research in this field has been performed on well known geometries, such as NACA profile airfoils, following well defined trajectories. In addition to this research, however, our understanding of UAV flight also benefits from research of the aerodynamics of naturally occurring self propelled bodies at similar scales, such as birds. While the parameters of flight of these natural fliers cannot be systematically varied, the fliers themselves represent a specific combination of parameters (wing stiffness, wing camber, kinematics, etc.) which have been shaped by selective pressures through evolution. The specific combination of flight parameters used by birds has allowed some species/types to accomplish amazing performances. For example, in recent years, a race (baueri) of bar-tailed godwit has been found to make migratory journey's of approximately 11,000 km without rest[1], which far surpasses any similarly scaled design attempted by engineers.

Studies focusing on the aerodynamics of birds are often motivated by the same goals as more traditional flapping wing studies. This goal is to gain an understanding of the relationship between the power required to move the wings through their trajectory, and the propulsive power generated by the movement. In the case of a bird, however, the measurement of these quantities is challenging. The animal can rarely be instrumented as one would instrument a model, and be expected to fly in a typical manner. To overcome this difficulty, the use of kinematics and wake models for force evaluation has gained popularity, especially with improvements in particle image velocimetry (PIV) technology. The evaluation of forces from the wake, however, has depended heavily on the successful modeling of the wake as an assembly of "vortex lines," a conceptual model derived from potential flow theory [2,3].

In the present study, the wake near the body of a European starling is investigated using time resolved PIV measurements at the Advanced Facilities for Avian Research (AFAR) wind tunnel at Western University. From the PIV measurements, visualizations of the wake are presented, with reference to contemporary models of the wake of a bird.

II. EXPERIMENTAL SET-UP

A. *Wind Tunnel*

The experiment was performed in the hypobaric wind tunnel at AFAR. The wind tunnel test section is shown in Fig. 1. The octagonal test section, with a cross-sectional area of 1.2 m2, is preceded by a 2:1 contraction. The width, height and length of the test section are 1 m, 1.5 m, and 2 m, respectively. An open jet exists between the downstream end of the test section and the diffuser. This opening is used for introducing the live bird into the wind tunnel during the experiment. At the testing speed of this experiment, the wind tunnel has a turbulence intensity of 1.4% at the location where measurements were taken. A fine net was placed at the upstream end of the test section to prevent the bird from entering the contraction, which was found to not alter the turbulence significantly.

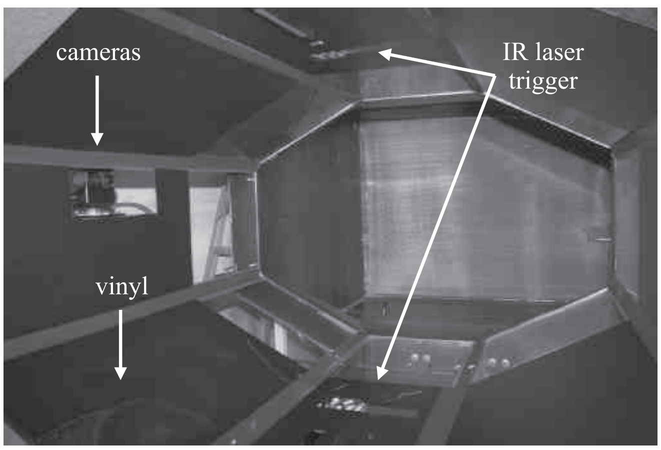

Figure 1 Empty test section of the AFAR wind tunnel, complete with vinyl and infrared laser trigger.

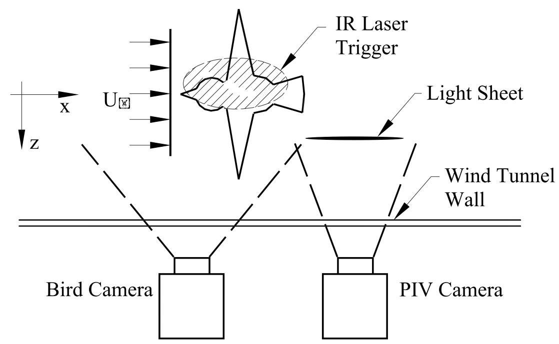

Figure 2. A schematic plan view of the experimental set-up

B. *Long-Duration Time Resolved PIV System*

Wake measurements in this study were taken using the long-duration time-resolved PIV system developed for this project [4]. Olive oil particles of a size of 1μm were introduced into the wind tunnel using a Laskin nozzle at the downstream end of the test section such that it would not cause a disturbance to the flow in the test section or to the bird. Illumination of the flow field was provided by a light sheet formed from an 80W, double-head, diode-pumped, Q-switched, Nd:YLF laser at a wavelength of 527nm. Performing at the highest available spatial resolution (1024 pixels by 1024 pixels), two cameras (Photron FASTCAM-1024PCI CMOS) recorded images at a rate of 1000 Hz. At this spatial resolution, the cameras are capable of acquiring images for 23 minutes continuously. One camera was used to record the position and wing beat cycle phase of the bird and the other was used for PIV. The PIV camera was mounted downstream of the bird camera, as seen in the schematic representation in Fig. 2. The PIV camera's field of view was approximately 12 cm by 12 cm in size (2c by 2c, where c is the mean wing chord). Vector fields were generated using 32 pixel by 32 pixel interrogation windows with 50% overlap, giving a spatial resolution of approximately 32 vectors per chord.

More detailed information regarding the system's components and capabilities are available in Ref. [4].

C. Trained European Starlings

Wake measurements were taken from two European starlings that had learned to fly in the AFAR wind tunnel during their participation in other research projects. The data in this study comes from two separate experiments performed on separate European starlings with similar morphological parameters. The two experiments are referred to as Exp. 1 and Exp. 2. Morphological parameters, as well as parameters of the experiment,are summarized in Table 1.

TABLE I. MORPHOLOGICAL AND EXPERIMENTAL PARAMETERS

Parameter	Unit	Exp. 1	Exp. 2
Average chord, *c*	m	0.06	0.066
Wing semi-span, *b*	m	0.191	0.188
Mass	g	78	76
Flapping frequency, *f*	Hz	13.5	11.4
Wind tunnel speed, U	m/s	12	13.5 m/s
Chord based Rynolds number, *Re*	-	49000	60600

The flight speed of the birds in the wind tunnel was chosen based on the comfort of the individual bird and its ability to fly for prolonged periods of time during the testing.

Due to the powerful laser operating within a few chord lengths of the bird's tail, two precautions were taken to ensure the bird's safety and comfort. To prevent reflections of the laser from reaching the bird's eyes, sheets of black, matte finish, vinyl were applied to the inside walls of the wind tunnel. Only three small sections of the surrounding glass surfaces in the wind tunnel surface were left uncovered to allow the light sheet to enter the wind tunnel, and a clear field of view for the cameras. To prevent direct contact between the bird and the light sheet, a collection of optoisolators, operated by six infrared transceivers (Balluff Inc.), were integrated into the PIV system. The funciton of these optoisolators was to interupt the connection between the laser and its controller unless any of the infrared beams between the transceivers were blocked by the bird, which ensured that the bird was in a position where it was not in danger of being hit by the laser. The beam was oriented vertically in the wind tunnel a few chord lengths upstream of the PIV camera's field of view, slightly offset in the spanwise direction by approximately two chord lengths. The relative position of the beams with respect to the cameras and the light sheet is shown in Fig. 2.

III. MEASUREMENTS

A. Simultaneous Measurements of the Bird and the Wake

Since the experiments were performed on an animal, the bird as a "test model" was no longer a boundary condition that could be set before the experiment, but rather one that needed to be measured during the experiment. To understand the effect of the flapping wings, it is essential to measure both the bird's activities and the resulting wake.

An instantaneous realization from the experiments is shown in Fig. 3. Two red curves are included in the image, which represent streak lines of the bird's wing root and wing tip. These streak lines, henceforth referred to as the wing tip trace and wing root trace, were generated after the experiment. The traces were created by plotting coordinates of the wing tip and root, each with individual streamwise offsets, from earlier instances. To give the streak line effect, the coordinates were plotted with offsets of $U \cdot \Delta t \cdot n$ in the streamwise direction, where Δt is the time between images and n is the number of images which have passed since the wing coordinates were recorded. The result of generating the wing tip traces is that the measurements of the wake, seen in the inset in the lower right hand corner of Fig. 3, can be associated with a phase of the wing beat cycle. In the case of Fig. 3, it is seen that the wake is generated from a downstroke to upstroke transition of the wing, which will be addressed in Section IV.

The inset of Fig. 3 shows a vector map, which has been under sampled by a factor of two for the sake of clarity. The under sampling does not qualitatively alter the appearance of the flow field. The vector map has had the free stream velocity subtracted

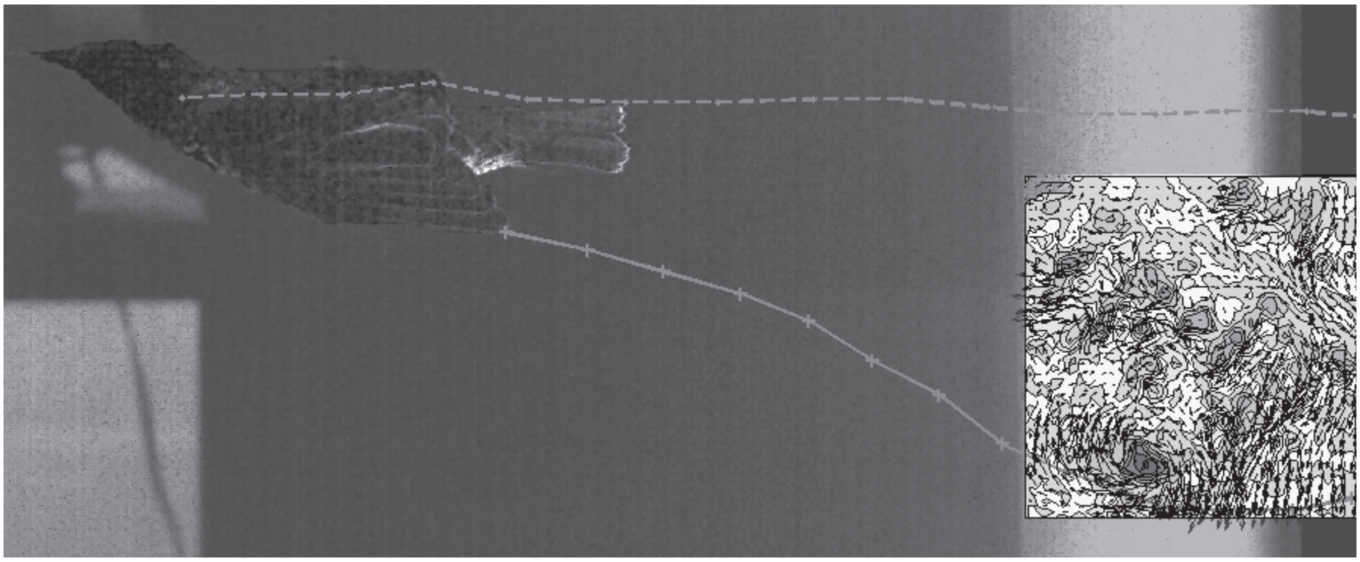

Fig. 3. Simultaneous realizations of the bird and the wake. Streak lines originating from the wing root and wing tip have been added from a kinematic analysis after the experiment.

from the instantaneous measurement, such that the magnitude of the disturbance the bird has generated is not overshadowed by the magnitude of the wind tunnel velocity.

In a sense, the vector map plotted is what an observer would see in otherwise still air if a bird flew by. The vectors are superimposed over a contour map of spanwise vorticity, normalized by the free stream speed and the chord length of the bird.

B. Wake Composites

While the purpose of Fig. 3 is to relate the wake measurement to a phase of the wing beat cycle, a visualization of the entire wing beat cycle is yet to be established. This is accomplished by generating a "wake composite" of multiple PIV realizations. The wake composite is formed by plotting sequential PIV realizations, simultaneously, each offset to one-another in the streamwise direction. Similarly to the depiction of the wing root and wing tip traces above, the offset of the PIV images is calculated as $U_\infty \cdot \Delta t \cdot n$.

The generation of a wake composite provides a useful tool for seeing the time-series of measurements representing the wake of a wing beat cycle, however, it should be kept in mind that the entire spatial extent of the wake composite does not exist in the wind tunnel at a given instant. Rather, what appears as "downstream" in the wake composite happens earlier, while what appears "upstream" in the composite happens later, and all measurements are taken at approximately the same relative position to the bird. In a sense, the generation of the wake composite invokes Taylor's hypothesis in which the changing characteristics of the flow are a frozen spatial pattern advected through the field of view. [5]

In addition, the offset of one image to the next is based on the free stream speed. It should be noted that the typical offset of $U_\infty \cdot \Delta t \cdot n$ between images is approximately 0.4 c and an instantaneous PIV measurement has a spatial dimension of 1.8 c. Therefore, at any location in the wake composites, there are several overlapping images which can be used to ascertain the instantaneous wake characteristics over the streamwise distance of 1.8 c to compare with the wake composite at the same location. For a complete wing beat cycle, a composite wake plot covers a distance of approximately 1.2m (18 c), which was measured over a time interval of 0.09 s.

IV. WAKE CHARACTERIZATION

A. Wake Overview

Two wake composites at a similar spanwise location have been plotted in Fig. 4. The figure depicts the wake generated over an entire wing beat cycle. The composites have been generated from two sequences of PIV measurements in the "inner wing region," as indicated by the planform outline of the bird's wing. The green line indicates the spanwise position at which the measurements have been taken. To provide a spatial scale, the length of a chord is given in the figure. In addition, the planform outline of the bird is appropriately scaled. The apparent vertical offset of the two composites is set according to the elevation of the wing root when each sequence was measured.

At this spanwise location in the flow, the spatial extent of the wake covers a vertical distance of several chords, and a streamwise length of approximately twenty chords. For ease of visualization and discussion, the flow field has been subdivided based on phase of the wing beat cycle. The following sections discuss features found during these phases.

B. Characteristics of the Wake from the Downstroke to Upstroke Transition

The downstroke to upstroke transition in the mid-wing region shows several interesting features. For clarity, this particular region of the flow is shown in detail in Fig. 5, complete with annotation referenced by the following discussion.

At the downstream end of the composite, or "earlier" in the series, one notices that the flow is initially directed along the path of the wing. As one follows the wing tip trace further, the flow vectors start to indicate a strong downwash. The flow field seems to be divided into two portions at this spanwise location; an upper region in which the downwash is coincident with non-zero vorticity, and a lower region, in which the downwash exists with virtually no spanwise vorticity. The downwash in both regions though, is indicative of lift being generated by the wing. Lift generation by the bird during flight is essential, and it is reasonable to find that the downstroke produces lift.

As the wing tip trace approaches the downstroke to upstroke transition, one notices a strong, negative, region of vorticity in close proximity to the transition. This region of vorticity has been seen in previous studies relating to bird flight [2,3] as well as general flapping wing studies [6]. Two explanations for the presence of this vorticity are readily available in the literature. It is possible that, similar to insects [7] and bats [8] and hovering humming birds [9], the bird wing flaps such that performance enhancing vortices develop on the upper surface of the wing during the downstroke. It has been suggested in the literature that these performance enhancing vortices are utilized by many self-propelled animals [10], although this vortex has not been measured on a bird traveling at a typical cruising speed, i.e., a speed typical of migration. The other possible explanation is that the wing is changing lift, which is associated with a change in bound circulation on the wing. This bound circulation is shed into the flow in the form of vorticity, and may be conceptualized as a "vortex sheet." Once in the wake, the vorticity in these sheets may gather into vortices under the influence of induced velocities. Ref. [11] features a chapter in which this theory applied to flapping wings.

Following the downstroke to upstroke transition, the wing tip trace in the field of view begins to move upwards. A general characteristic of the field of view is that, in contrast to what was seen downstream of the vortex, there is a noticeable lack of downwash. This suggests that the upstroke portion of the wing beat cycle does not generate lift.

In addition to the lack of downwash, it is observed that the wake contains two elongated regions of disturbance, as opposed to a single one. The lower of these two appears to extend from the region of strong negative vorticity (noted above), while the upper elongated region seems to originate from the downstream region of downwash.

C. Characteristics of the Wake from the Upstroke to Downstroke Transition

A detailed view of the upstroke to downstroke transition is provided in Fig. 6. At the downstream end of the wake composite, the downwash is negligible. This lack of downwash is consistent with the suggestion in the previous section that the upstroke is negligible in terms of lift generation. Once the wing has passed the upstroke to downstroke transition, however, downwash is once again noted, with a slight tilt in the upstream direction.

As the wing tip trace approaches the peak of its excursion, two elongated regions are noticed. This is similar to the elongated regions from the downstroke to upstroke transition depicted in Fig 5, except that a region of strong vorticity is not present near the change in direction of the wing. However, this is not to say that the upstroke to downstroke transition of the wing does not leave a region of single-signed vorticity at the transition. An example of this is shown in Fig. 7, a small wake composite taken closer to the wing tips. As can be seen in Fig. 7, a region of positive vorticity exists near the upstroke to downstroke transition.

V. DISCUSSION

A. Downwash Limited to the Downstroke

In wake studies conducted on birds in the past, it has been found that the characteristics of the wake vary gradually over the range of flight speeds [2]. One of the characteristics of the wake that varies is the usefulness of the downstroke in terms of generating lift. It has been suggested that at lower speeds, the downstroke is the principal source of lift and thrust, while at higher speeds, the upstroke and the downstroke are both contributing to the generation of lift forces. It has been suggested as early as [12] that lift is produced by the inner wing at all parts of the wing beat cycle. This has been expressed in the vortex wake model by Ref. [2] for high speed flight of a thrush nightingale, although the study indicates that the strongest downwash is present during the downstroke in the inner wing region. It is suggested in Ref. [2] that this is due to the tip vortex moving inboard of the measurement plane. Although the present data is not capable of showing the spanwise position of streamwise vortices, it should be noted that, in the case of Fig. 4 and Fig. 5, there is evidence of a disturbance form the wing continuing upstream of the region in which downwash has been observed. It has also been found that in the wake of a robin [3] the aerodynamic contribution of the upstroke cannot be ignored for modeling purposes, even at low speeds. Contribution to lift in the upstroke has also been implied by the wake of a swift, although the kinematics of the swift are qualitatively different from the above mentioned species [13].

The wake visualizations reported herein indicate that, based on downwash, the upstroke of the wing beat cycle does not contribute lift, and it is principally the role of the downstroke to keep the bird aloft. The inactivity of the upstroke would suggest that the bird is flying with a wake structure that is typical of lower speeds, and in some cases, hovering. This speed is characterized by some wake models [2,3] as a series of elliptical vortex loops in the wake, where each loop being generated by a downstroke of the wing. A feature of this wake is that the vortex loop shed by the downstroke traverses the centreplane of the wake, in which the vorticity would be perpendicular to a spanwise-normal plane of measurement. The consequence of this vortex loop in the wake of the present study would be that it is most easily measured at the centreplane, where the vorticity in the loop is perpendicular to the PIV field of view. If this “vortex” is found in the wake of the present study, it would imply that the Starling has a wake characteristic of slower speeds, even though it is traveling relatively fast (13.5 m/s). Alternatively, if evidence of this vortex is not found, there are several possible implications. One implication, using the theory of [14], is that a vortex sheet exists at the streamwise location measured in this study, rather than a fully formed vortex ring. Another possible implication is that the wake of the body overshadows any evidence of the vortex loop traversing the centreplane of the body. A third possible implication is that the vortex loop does not cross the body, but in fact, continues downstream. This would be similar to the vortex wake model of a bat [15,16], in that each wing is generating its own "vortex ring" rather than one vortex ring being created during each downstroke.

B. Streamwise Vorticies

Multiple elongated regions of activity in the wake have been observed in the mid-wing region during both the upstroke of the wing and the downstroke of the wing. It is believed that the source of these two elongated regions may be the result of multiple streamwise vortices interacting with one another in the wake, similar to what has been seen in the study by [17].

In the study by [17], the wake of a wing with a "flap" (sudden increase in chord length of a wing near the plane of symmetry) was examined. The wing was found to have streamwise vortices originating from the tip (typical of finite wings), as well as from the edges of the flap. The consequence of these two streamwise vortices being introduced into the wake was that they would orbit around one another until an eventual merger. During the orbiting process, the two streamwise vortices would occasionally be above one another, even though the source of the vortices was approximately at the same elevation.

It is possible that the two elongated regions observed in the present work is the result of taking a cross section through these two streamwise vortices, which are generated by the bird. One of these vortices may be the classic "tip" vortex associated with finite wings, while the other may be what has come to be known as a "root vortex" in the literature. The root vortex was first measured by Ref. [18] in a PIV study in the wake of a blackcap with measurements in a streamwise-normal, or "transverse" plane. The authors noted that streamwise vortices, in addition to those formed by the tip, were present in the flow. The two streamwise vortices in the wake of the blackcap under observation do not appear to be directly above one another at any point in the cycle, although their minimum spanwise separation occurs at the beginning of the downstroke and near the end of the downstroke. A similar scenario is seen in the wake of the swift as well. Measurements in the streamwise normal plane in the wake of a swift have shown the presence of tip vortices, root vortices, as well as "tail vortices." [19].

Multiple streamwise vortices have also been observed in the computational simulations performed by [20] the model was tested over a variety of reduced frequencies and flow velocities. It was found that the wake of the bird at lower reduced frequencies was dominated by elliptical vortex loops shed from each wing, connected at the transitions of the wings from stroke to stroke. It was found that at higher reduced frequencies, the wake of the bird was dominated by streamwise tip vortices and root vortices. From the manuscript, it is difficult to find the precise orientation of these streamwise vortices at a location in the flow convenient for comparison with the present study. However, through both simulation and experiments, the presence of multiple streamwise vortices has been indicated, and can therefore be considered a possible cause of the multiple "elongated regions" seen in the wake.

VI. SUMMARY

Long-duration, time-resolved, particle image velocimetry was used to measure the wake of two European starlings. For the sake of visualization, the measurements have been expressed as a composite of wake realizations acquired over time. The resulting wake composites have been used to provide a general depiction of the wake of a European starling flying at a comfortable speed in a wind tunnel. Through the characterization, several features of the wake have been highlighted, including evidence that the bird does not generate lift during the upstroke. In addition, characteristics of the wake in what has been described as the "inner wing region" have lead to suggestions that multiple streamwise vortices may be acting in the wake of a bird.

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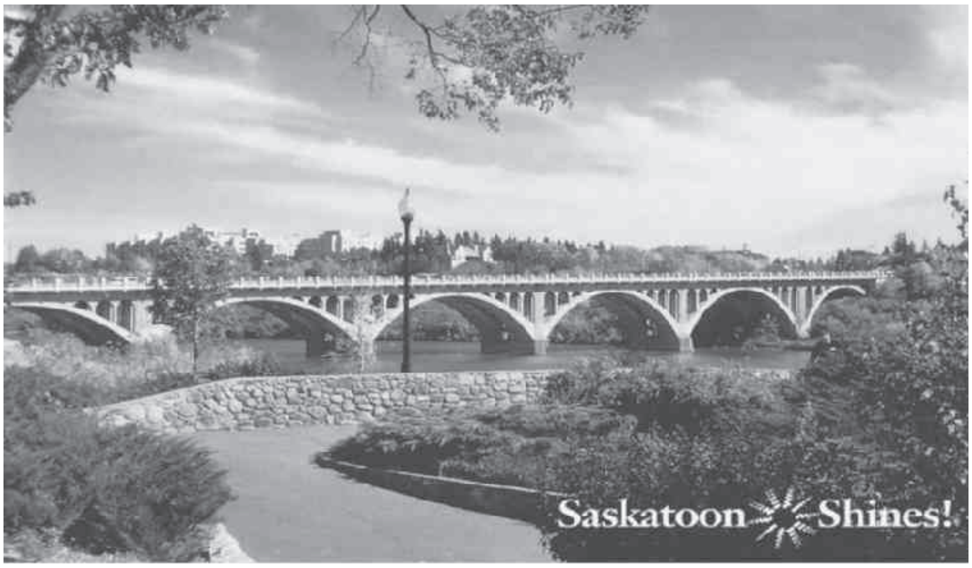

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