

PHIL LIGRANI

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PROFESSIONAL PREPARATION

University of Texas at Austin	Mechanical Engineering	Bachelor of Science, 1974
Stanford University	Mechanical Engineering	Master of Science, 1975
Stanford University	Mechanical Engineering	Doctor of Philosophy, 1980

APPOINTMENTS

2014 – present	Eminent Scholar in Propulsion, Professor of Mechanical and Aerospace Engineering, Propulsion Research Center, Department of Mechanical and Aerospace Engineering, University of Alabama at Huntsville
2010 – 2014	Oliver L. Parks Endowed Chair, Professor of Aerospace and Mechanical Engineering, Parks College, Saint Louis University
2010 – 2013	Director of Graduate Programs, Parks College, Saint Louis University
2006 – 2009	Statutory Professor, Department of Engineering Science, University of Oxford, Donald Schultz Professor of Turbomachinery
2006 – 2009	Director, Rolls-Royce UTC (University Technology Centre) in Heat Transfer and Aerodynamics, University of Oxford
1997 – 2006	Professor, Department of Mechanical Engineering, University of Utah
2002 – 2006	Adjunct Professor, Department of Bioengineering, University of Utah
1992 – 1997	Associate Professor, Department of Mechanical Engineering, University of Utah

ARCHIVAL JOURNAL PUBLICATIONS AND RELATED ITEMS.

As of April 2020, Dr. Ligrani is author or co-author of more than 193 publications in archival journals, including the International Journal of Heat and Mass Transfer, the ASME Transactions-Journal of Turbomachinery, the ASME Transactions-Journal of Engineering for Gas Turbines and Power, the ASME Transactions-Journal of Heat Transfer, the ASME Transactions-Journal of Fluids Engineering, Nature - Scientific Reports, the Journal of Fluid Mechanics, the AIAA Journal, Experiments in Fluids, Physics of Fluids, the AIAA Journal of Heat Transfer and Thermophysics, the International Journal of Rotating Machinery, Separation Science and Technology, Sensors and Actuators A: Physical, and the Journal of Microcolumn Separations. He is also author of 10 book chapters, and about 150 conference presentations and publications. A number of these are invited conference presentations at international meetings, at locations which include Korea, France, the Ukraine, Croatia, Germany, England-United Kingdom, and Belgium. From 1994 to 2020, he has also presented approximately 183 lectures at different institutions and establishments, including many invited lectures. From 2006 to 2020, he presented or is scheduled to present 7 Invited Keynote Papers, 12 Invited Papers, and 9 Invited Plenary Keynote Papers at different international conferences.

UNIVERSITY OF ALABAMA IN HUNTSVILLE - ARCHIVAL JOURNAL PUBLICATIONS AND RELATED ITEMS.

From August of 2014 to April of 2020, Dr. Ligrani is author or co-author of approximately 43 publications in archival journals, 3 book chapters, and about 44 conference presentations and publications. During this time period, he presented or is scheduled to present 2 Invited Keynote Papers, 6 Invited Papers, and 7 Invited Plenary Keynote Papers at different international conferences. Current SCOPUS Reference Citation H-INDEX is 44. Current GOOGLE SCHOLAR Reference Citation H-INDEX is 47.

RESEARCH FUNDING AWARDS

Dr. Ligrani has a strong past and present record of performing sponsored, fundamental and applied research for a variety of funding agencies, including ones in the USA and Europe. As such, he has successfully managed a wide variety of research programs, for different industrial, foundation, and government sponsors. **As of April 2020, research funding awards have been received from the following organizations:** U.S. Air Force Research Laboratory - Aerospace Systems Directorate, CFDRS – Computational Fluid Dynamics Research Corporation, Alabama State Innovation Program Fund, University of Alabama in Huntsville Start-Up Funds, AEDC – Arnold Engineering Development Center of Arnold Air Force Base, National Science Foundation, Honeywell Aerospace Corp., The Boeing Company, IHI Corporation, the Henry Luce Foundation, South Carolina Institute for Energy Studies (SCIES-AGTSR) of the Department of Energy, U. S. Army Aviation Research and Technology Activity-AVSCOM, NASA-Ames Research Center, NASA-Lewis Research Center, Hispanic Research Center-Arizona State University, Turbo and Power Machinery Research Center-Seoul National University, Solar Turbines Incorporated, UCON U.S.-Japan Center-Weber State University, General Electric Corporate Research and Development Center, Pratt & Whitney Corporation-Florida, the North Atlantic Treaty Organization (NATO), Pratt & Whitney Corporation-Canada Corp., the Gas Technology Institute, Intel Corporation, HEET-High Efficiency Engines and Turbines Program - South Carolina Energy Research and Development Center, Invesys Corp. - Foxboro Company, Ceramtec Advanced Materials and Electrochemical Technologies Corp., CISCO Systems Inc., SEEDA-South East England Development Agency, EPSRC – Engineering and Physical Sciences Research Council of Great Britain, ISIS Innovation, John Fell Fund,

European Community Sixth Framework Programme, Korea Institute of Geoscience and Mineral Resources - KIGAM, Lockheed Martin UK, The Royal Academy of Engineering, Rolls Royce PLC, Science and Engineering Research Council (SERC) Engineering Board of Great Britain, Office of Naval Research, Naval Postgraduate School Research Foundation, Aero-Propulsion Laboratory-Wright-Patterson Air Force Base, and Naval Postgraduate School Direct Funding.

UNIVERSITY OF ALABAMA IN HUNTSVILLE - CURRENT AND RECENT RESEARCH FUNDING AWARDS

The total amount of funding, including grants contracts, and donations, since arriving at the University of Alabama in Huntsville as of April 2020, is approximately \$3.56 million. Current and recent research sponsors include: (1) Solar Turbines, Inc. of San Diego, California, USA (multiple research contracts), (2) IHI Corp. (Ishikawajima Harima Heavy Industries), of Tokyo, Japan (multiple research contracts), (3) National Science Foundation, CBET Thermal Transport Processes, Division of Chemical, Bioengineering, Environmental, and Transport (CBET) Systems, Arlington, Virginia, USA (multiple funding awards), (4) the Alabama Innovation Fund, Research Program, Montgomery, Alabama, USA, (5) Office of the Vice President for Research and Economic Development, University of Alabama in Huntsville, Huntsville, Alabama, USA, (6) AEDC – Arnold Engineering Development Center, Arnold Air Force Base, Tullahoma, Tennessee, USA (high pressure tank donation), (7) State Administration of Foreign Expert Affairs, Federal Government of the P. R. China, Beijing, P. R. China (through the School of Aerospace Engineering, Beihang University, BUAA - Beijing University of Aeronautics and Astronautics, Beijing, P. R. China), (8) U.S. Air Force Research Laboratory, SBIR/STTR Program, Aerospace Systems Directorate, Wright-Patterson Air Force Base, Ohio, USA.

SELECTED RECENT HONORS, AWARDS, ACADEMIC RECOGNITIONS

● ASME IGTI Outstanding Service Award 2019. ● 2019 University Distinguished Research Award for Excellence. University of Alabama in Huntsville, Huntsville, Alabama, USA. ● Outstanding Senior Faculty Member Award for 2019. College of Engineering, University of Alabama in Huntsville, Huntsville, Alabama, USA. ● Member. European Union Academy of Sciences (EUAS). 2019 to present. ● Guest Professor. School of Mechanical Engineering, Shanghai Jiao Tong University, Shanghai, P. R. China. 2019 to 2022. ● Outstanding Mechanical Engineer of the Year Award 2016, ASME – American Society of Mechanical Engineers, NAS - North Alabama Section, USA. ● Marquis Lifetime Achievement Award, Marquis Who's Who, New Providence, New Jersey, USA, 2016. ● Distinguished Advisory Professor, Inje University, South Korea, 2010 to 2020. ● Distinguished Lecture Award, 2011, CEAS Distinguished Lecture Series, College of Engineering, University of Wisconsin, Milwaukee, Wisconsin, USA. ● Distinguished Editorial Review Board membership for Springer Publishing Corporation. ● Carl E. and Jessie W. Menneken Faculty Award for Excellence in Scientific Research. ● NASA Space Act Tech Brief Award for "Development of Subminiature Multi-Sensor Hot-Wire Probes." ● Silver Winner for the Annual 26th Educational Advertising Awards for the Higher Education Marketing Report.

RESEARCH AREAS AND EXPERTISE.

Dr. Ligrani has a strong past and present record of working with many different collaborators and co-workers, from many locations throughout the world. Additional information on selected, currently active research projects is provided within sections which follow.

(i) **Traditional Heat Transfer and Fluid Mechanics Investigations** involving electronics cooling, heat transfer augmentation, drag reduction, turbulent boundary layers, flows in channels with dimpled surfaces, flows in curved channels, elastic turbulence, slot impingement cooling, and macro-scale pumps and pump flows. Also included are **aerodynamics investigations with high-speed, compressible flows at transonic and supersonic Mach numbers**, including SWBLI – Shock Wave Boundary Layer Interactions. Related projects involve **transonic and supersonic experimental testing**. Research interests also include experimental diagnostics in high speed flows, and air breathing propulsion.

(ii) **Air Breathing Engines - Gas Turbine Heat Transfer, Cooling, and Aerodynamics Losses**, including internal cooling, film cooling, impingement cooling, cooling of extremities, aerodynamic performance including aerodynamic losses, and transonic turbine flows and heat transfer. This subject area includes the effects of uses of bio-fuels, synthetic fuels, and renewable energy sources in relation to gas turbines and gas turbine heat transfer and cooling technologies. Note that an important area of turbomachinery research interest involves heat transfer and aerodynamics investigations with *high-speed, compressible flows at transonic and supersonic Mach numbers*, including linear cascade studies.

(iii) **Micro-Fluidics and Millimeter-Scale-Fluidics**, including micro-pump flows, and the effects of slip phenomena on gas and liquid flows in micro-scale passage flows with and without surface roughness, including the effects of hydrophobic surfaces and elastic turbulence.

(iv) **Experimental Techniques**, including development of millimeter-scale multiple-hole pressure probes, subminiature hot-wire anemometry, and infrared thermography.

EDITORSHIPS

1. Guest Editor, Special Topical Issue on "Measuring Techniques for Turbomachinery," Measurement Science and Technology, 1998-2000.

2. Associate Technical Editor, ASME Transactions-Journal of Heat Transfer, July 1, 2003 – June 30, 2007.

3. "Special Issues on Gas Turbine Heat Transfer: Parts 1 and 2," ASME Transactions-Journal of Heat Transfer, Co-Editor with S. Acharya, Part 1 - April 2005, Part 2 – May 2005.

4. Associate Technical Editor, ASME Transactions-Journal of Fluids Engineering, July 1, 2005 – December 31, 2008.
5. Member, Distinguished Editorial Review Board, Advances in Transport Phenomena, Book Series, Springer Publishing Corporation, 2006 – Present.
6. Associate Technical Editor, ASME Transactions-Journal of Heat Transfer, July 1, 2010 – June 30, 2014.
7. Editorial Board Member, Power and Thermal Engineering Processes and Equipment Journal, Published by the National Technical University “Kharkov Polytechnic Institute”, Russia and Ukraine, 2015 – Present.
8. Editorial Board Member, International Journal of Innovative Works in Engineering and Technology (IJIWET), 2015 – Present.
9. Associate Editor, Journal of Propulsion Technology (JPT) Journal, Published by CNPIEC, P. R. China, 2015 – Present.
10. International Editorial Board Member, Industrial Thermal Engineering Journal, Published by Thermogasdynamics Department, National Academy of Sciences of Ukraine, Kiev, Ukraine, 2018 – Present.
11. Editorial Board Member, Advances in Aerodynamics (AIA) Journal. Published by the Chinese Society of Aerodynamics (CSA), and the China Aerodynamics Research and Development Center (CARDC), P. R. China, 2018 – Present.
12. Associate Editor, Energies Journal, MDPI Publishing Corp., Basel, Switzerland, 2018 – Present.
13. Associate Editor, ASME Transactions-Journal of Journal of Engineering for Gas Turbines and Power, July 1, 2018 - June 30, 2021.

MEMBERSHIP IN PROFESSIONAL ORGANIZATIONS AND ACTIVITIES

- ASME, Member, American Society of Mechanical Engineering, July 1985-Present.
- ASME, Fellow, American Society of Mechanical Engineering, December 2000-Present.
- ASME, American Society of Mechanical Engineering, K-14 Gas Turbine Heat Transfer Committee. December 1986-Present.
Executive Committee and Membership Committee, July 2018-June 2020. Chairman (Entire Committee), July 2016-June 2018. Vice Chairman (Entire Committee), July 2014-June 2016. Chairman, Honors and Awards Sub-Committee, July 2012-June 2014.
- IGTI, International Gas Turbine Institute Heat Transfer Committee. December 1986-Present
- ASEE, Member, American Society for Engineering Education, September 2010-Present.
- AIAA, Member, American Institute of Aeronautics and Astronautics, January 2013 – Present.
- AIAA, Associate Fellow, American Institute of Aeronautics and Astronautics, January 2016 – Present.
- ICHMT – International Center for Heat and Mass Transfer. Member of the Scientific Council, January 2014 – Present.

INTERNATIONAL SCIENTIFIC COMMITTEE MEMBERSHIPS.

1. Member of the Scientific Committee, HMTHSF-2019, Seventh International Conference “Heat and Mass Transfer and Hydrodynamics in Swirling Flows,” National Committee on Heat and Mass Transfer of the Russian Academy of Sciences, Rybinsk, Russian Federation, October 16-18, 2019.
2. Invited Member. European Union Academy of Sciences (EUAS). An international scientific organization and among the most prestigious in Europe. The academy is composed of distinguished members worldwide, including the world’s leading scientists, scholars and business people, aiming to promote excellence in science and technology. Membership was the result of an election done through President’s Council consisting of the distinguished members of the Board of Governors. January 2019 to Present.
3. Invited Expert of the Aerospace Center of Multiscale Mechanics and Thermodynamics (The Overseas Expertise Introduction Center for Discipline Innovation), School of Aeronautic Science and Engineering (ASE), Beihang University, Beijing, P. R. China. A 111 Project, which is sponsored by the State Administration of Foreign Experts Affairs, Beijing, P. R. China. September 2018 to September 2022.
4. Academic Committee Member, 2018 ICAYS Organizing Committee, ICAYS – 2018 International Conference in Aerospace for Young Scientists, September 15-16, 2018. School of Aeronautic Science and Engineering (ASE), Beihang University, Beijing, P. R. China. July to October 2018.
5. Member of the Scientific Committee, ICHHFF6, Sixth International Conference “Heat and Mass Transfer and Hydrodynamics in Swirled Flows,” Siberian Branch of Russian Academy of Sciences, Novosibirsk, Russian Federation, November 21-23, 2017.
6. Member of the Scientific Committee, ICHHFF5, Fifth International Conference “Heat and Mass Transfer and Hydrodynamics in Swirled Flows,” National Committee of the Russian Academy of Sciences, Kazan, Russian Federation, October 19-21, 2015.
7. Vice-Chairman and Member, Academic Committee, Institute of Gas Turbines, Beijing Tsinghua University, Beijing, P. R. China. February 2014-February 2017.
8. ICHMT, Scientific Council Member, International Center for Heat and Mass Transfer. Nominated for membership by Professor Richard Goldstein of the University of Minnesota. January 2014 to Present.
9. International Scientific Committee, International Symposium on “Heat Transfer in Gas Turbine Systems,” Antalya, Turkey, August 9-14, 2009.
10. International Conference on Mechanical Engineering-Algeria, Ministere de l’Enseignement Superieur et de la Recherche Scientifique, Oran, Algeria, April 28-29, 2002.

RECENT U.S. NATIONAL SERVICE ACTIVITIES

1. Participation as Panelist and Panel Moderator, “Fostering Hypersonic Innovation Through Decisive Science and Technology Research and Collaboration,” 2nd Annual Hypersonic Weapons Summit, 2020 Hypersonic Weapons Conference, IDGA - Institute for Defense and Government Advancement, Washington, D.C., USA, October 28-30, 2020.
2. Participation as Panelist, “Gas Turbine Cooling and Aerodynamics” Panel, American Society of Thermal and Fluids Engineers (ASTFE) Conference, Fort Lauderdale, Florida, USA, March 4-7, 2018.
3. Panel Member, Thermal Transport Processes (Unsolicited) Panel, Thermal Transport Processes Program, Chemical, Bioengineering, Environmental and Transport Systems (CBET) Division, National Science Foundation, Arlington, Virginia, USA, 2017.
4. Panel Member, Thermal Transport Processes (Unsolicited) Panel, Thermal Transport Processes Program, Chemical, Bioengineering, Environmental and Transport Systems (CBET) Division, National Science Foundation, Arlington, Virginia, USA, 2016.
5. Sponsored Representative, CVD – Congressional Visits Day, U. S. Senate and House of Representatives, Washington, D. C. Sponsored by Greater Huntsville Section of the AIAA – American Institute of Aeronautics and Astronautics, March 4, 2015.
6. Panel Member, Convection (Unsolicited) Panel, Thermal Transport Processes Program, Chemical, Bioengineering, Environmental and Transport Systems (CBET) Division, National Science Foundation, Arlington, Virginia, USA, 2014.
7. Participation as Panelist, “Educating Today’s and Tomorrow’s Propulsion Engineers” Panel, “Continuing Education and Professional Development” Program of the AIAA Science and Technology Forum and Exposition - SCITECH 2014, Washington, D.C., January, 13-17, 2014.
8. Participant, Second Graduate Deans Workshop on Institutionalizing Interdisciplinary Graduate Education, Virginia Tech, Virginia Polytechnic Institute and State University, and National Science Foundation, Arlington, Virginia, USA, November 1-2, 2012.
9. Participant, Graduate Deans Workshop on Institutionalizing Interdisciplinary Graduate Education, Virginia Tech, Virginia Polytechnic Institute and State University, and National Science Foundation, Arlington, Virginia, USA, April 2-3, 2012.
10. Panel Member, Convection (Unsolicited) Panel, Thermal Transport Processes Program, Chemical, Bioengineering, Environmental and Transport Systems (CBET) Division, National Science Foundation, Arlington, Virginia, USA, 2011.
11. Panel Member, Thermal Transport Processes Program (Unsolicited) Panel, Thermal Transport Processes Program, Chemical, Bioengineering, Environmental and Transport Systems (CBET) Division, National Science Foundation, Arlington, Virginia, USA, 2010.
12. Panel Member, Thermal Transport and Thermo Processing (TTTP) Program, Chemical and Transport Systems (CTS) Division, National Science Foundation, Arlington, Virginia, USA, 2005.
13. Session Chair, External Turbine Cooling, Aero-Heat Transfer Workshop, SCIES-South Carolina Institute for Energy Studies, Baton Rouge, Louisiana, USA, November 11-13, 2002.

UNIVERSITY OF ALABAMA IN HUNTSVILLE – COLLEGE and UNIVERSITY SERVICE ACTIVITIES

1. Member, University Awards for Excellence Committee, University of Alabama in Huntsville, February – April 2020.
2. Member, Ad Hoc Committee for Leadership in Research, UAH Strategic Plan 2028, University of Alabama in Huntsville, January – April 2020.
3. Member, Graduate Mentor Award Committee, UAH Graduate Council, University of Alabama in Huntsville, February 2020.
4. Member, Committee to consider Junior Faculty Member – Reappointment at the Rank of Assistant Professor, College of Engineering, University of Alabama in Huntsville, January 2020.
5. CoE PTAC, College of Engineering - Promotion and Tenure Advisory Committee, College of Engineering, University of Alabama in Huntsville, September 2019 – August 2020.
6. Member, Committee to consider Junior Faculty Member – Reappointment at the Rank of Assistant Professor, College of Engineering, University of Alabama in Huntsville, April 2019.
7. Member, Graduate Mentor Award Committee, UAH Graduate Council, University of Alabama in Huntsville, February 2019.
8. Member, College of Engineering 2019 Research Horizons Poster Session Review Committee, College of Engineering, University of Alabama in Huntsville, February 2019.
9. Member, College of Engineering University Research Proposals Review Committee, College of Engineering, University of Alabama in Huntsville, December 2018.
10. Member, CoE PTAC, College of Engineering - Promotion and Tenure Advisory Committee, College of Engineering, University of Alabama in Huntsville, September 2017 – August 2018.
11. Member and Chairman, Committee to consider Senior Faculty Member Appointment with Tenure to the Rank of Full Professor, College of Engineering, University of Alabama in Huntsville, June 2018.
12. Member, College of Engineering Mid-Career Proposals Review Committee, College of Engineering, University of Alabama in Huntsville, April 2018.
13. Member, Graduate Advisor Award Committee, UAH Graduate Council, University of Alabama in Huntsville, February 2018.

14. Member, Committee to consider Junior Faculty Member – Reappointment at the Rank of Assistant Professor, College of Engineering, University of Alabama in Huntsville, February 2018.
15. Member and Chairman, Committee to consider Junior Faculty Member – Reappointment at the Rank of Assistant Professor, College of Engineering, University of Alabama in Huntsville, January 2018.
16. Member and Chairman, Committee to consider Senior Faculty Member – Promotion to the Rank of Full Professor, College of Engineering, University of Alabama in Huntsville, November 2017.
17. Faculty Mentor to Junior Faculty Member, Assistant Professor, Department of Mechanical and Aerospace Engineering, College of Engineering, University of Alabama in Huntsville, October 2017 – Present.
18. President's Council Member, University of Alabama in Huntsville, August 2017 – Present.
19. Member, College of Engineering Mid-Career Proposals Review Committee, College of Engineering, University of Alabama in Huntsville, April 2017.
20. Member, College of Engineering Best Teaching Award Review Committee, College of Engineering, University of Alabama in Huntsville, April 2017.
21. Member, Committee to consider Junior Faculty Member – Reappointment at the Rank of Assistant Professor, College of Engineering, University of Alabama in Huntsville, January 2017.
22. Member, Committee to consider Senior Faculty Member – Promotion to the Rank of Full Professor with Tenure, College of Engineering, University of Alabama in Huntsville, June – July 2016.
23. Member, College of Engineering Mid-Career Proposals Review Committee, College of Engineering, University of Alabama in Huntsville, March 2016.
24. COE (College of Engineering) Representative and Member, UAH Graduate Council, University of Alabama in Huntsville, August 2015 - Present.
25. Member, MAE Graduate Programs Committee, Department of Mechanical and Aerospace Engineering, College of Engineering, University of Alabama in Huntsville, August 2015 – Present.
26. Member, Task Force on Discussion of Immigration Matters Related to Hiring of Foreign Faculty, University of Alabama in Huntsville, July 2015 - Present.
27. Member, MAE PTAC, Mechanical and Aerospace Engineering Department - Promotion and Tenure Advisory Committee, Department of Mechanical and Aerospace Engineering, College of Engineering, University of Alabama in Huntsville, August 2014 – Present.
28. Representative Member and Alternate, CoE PTAC, College of Engineering - Promotion and Tenure Advisory Committee, College of Engineering, University of Alabama in Huntsville, September 2014 – August 2016.
29. Member, Search Committee, Eminent Scholar in Systems Engineering, College of Engineering, University of Alabama in Huntsville, September 2014 – May 2015.
30. Member and Chairman, Committee to consider Senior Faculty Member – Promotion to the Rank of Full Professor, College of Engineering, University of Alabama in Huntsville, November 2014 – January 2015.

PHIL LIGRANI – ADDITIONAL RESEARCH AND CREATIVE ACHIEVEMENTS

ITEM 1. Invitation to join the **European Union Academy of Sciences, or EUAS**, starting January 2019. The EU Academy of Sciences is an international scientific organization and among the most prestigious in Europe. The academy is composed of distinguished members worldwide, including the world's leading scientists, scholars and business people, aiming to promote excellence in science and technology. The invitation was the result of an election done through President's Council consisting of the distinguished members of the Board of Governors.

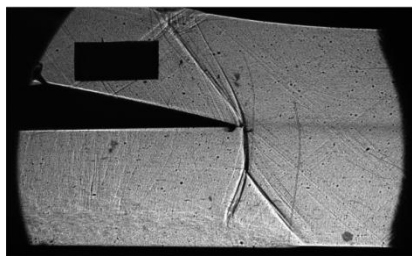
ITEM 2. Current SCOPUS Reference Citation **H-INDEX is 44**. Current GOOGLE SCHOLAR Reference Citation **H-INDEX is 47**.

ITEM 3. Re-appointment as a **Distinguished Advisory Professor** at **Inje University** in South Korea for the period from October 1, 2018 to September 30, 2020. Previously appointed 4 times, each for a 2-year term, from 2000 to 2018. Appointed as a **Guest Professor** at **Shanghai Jiaotong University** from 2019 to 2022.

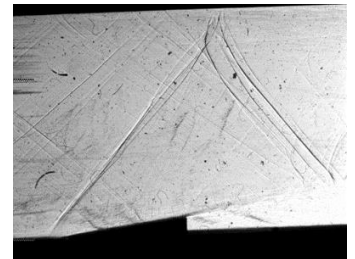
ITEM 4. As of May 2020, successfully supervised 99 graduate students, who have received Diploma Degrees, Master of Science (M.S.) Degrees, Mechanical Engineering (M.E.) Degrees, and Doctor of Philosophy (Ph.D.) Degrees, including 12 successfully supervised Doctor of Philosophy (Ph.D.) Dissertations, and 7 successfully supervised women graduate students. **Successfully Supervised UAH Graduate Students:** (1) Zhong Ren, M.S., December 2015. (2) Warren Buzzard, M.S., December 2015. (3) Nathaniel D. Rogers, M.S., May 2016. (4) Benjamin Lund, M.S., December 2016. (5) Sneha Reddy Vanga, M.S., December 2016. (6) Christopher Allgaier, M.S., Institute of Aerospace Thermodynamics, University of Stuttgart, Stuttgart, Germany, May 2017. (7) Masaaki Suzuki, M.S., December 2017. (8) Patrick McInturff, M.S., December 2017. (9) Zhong Ren, Ph.D., December 2018. (10) Shannon Renee Marko, M.S., December 2018. (11) David Ritchie, M.S., May 2019. (12) Mengying Su, Ph.D., June 2019. (13) Austin Click, M.S., May 2020. (11) Michael Sampson, M.S., May 2020. **Successfully Supervised UAH Undergraduate Theses:** (1) Maggie Hockensmith, B.S. Honors, May 2020. (2) Jacob Moseley, B.S. Honors, May 2020. (3) Avery Stone Fairbanks, B.S. Honors, December 2019. (4) Erin Shae McNabb, B.S. Honors, December 2019. (5) Adrian Pippert, B.S., Institute of Aerospace Thermodynamics, University of Stuttgart, Stuttgart, Germany, August 2019. (6) Valerie Hietsch, B.S., Institute of Aerospace Thermodynamics, University of Stuttgart, Stuttgart, Germany, September 2018. (7) Austin Click, B.S. Honors, December 2018. **UAH Graduate Students In Progress:** 2 Ph.D. students, 4 M.S. students, 2 B.S. student theses.

ITEM 5. EXPERIMENTAL FACILITIES DEVELOPED AT THE UNIVERSITY OF ALABAMA IN HUNTSVILLE.

(1) **SUPERSONIC WIND TUNNEL SYSTEM.** Within the PRC, successfully developed and demonstrated a SUPERSONIC WIND TUNNEL SYSTEM, named the SS/TS/WT or SuperSonic/TranSonic/WindTunnel. Created an oblique shock wave for class demonstrations in the



teaching segment wind tunnel leg. A shadowgraph image with the oblique shock wave (followed by a reflected shock wave) is shown in the image on the right. Flow direction is from left to right. Another shadowgraph image, obtained using one of the research wind tunnel legs, is shown in the image on the left. This image illustrates the presence of a normal shock wave, lambda foot, and separated turbulent boundary layer within the lower flow passage, and an oblique shock wave system within the upper flow passage. Flow direction is from right to left.



(2) **HIGH PRESSURE TANK AIR SUPPLY SYSTEM.** (3) **ANTON PAAR RHEOMETER,** (4) **MINIATURE VISCOUS DISC PUMP,** (5) **ROTATING COUETTE FLOW facility for HEAT TRANSFER MEASUREMENTS,** (6) **ROTATING COUETTE FLOW facility for FLOW VISUALIZATIONS,** (7) **IMPINGEMENT Jet Array COOLING RESEARCH FACILITY,** (8) **DOUBLE WALL COOLING EXPERIMENTAL FACILITY for HEAT TRANSFER MEASUREMENTS,** (9) **DOUBLE WALL COOLING EXPERIMENTAL FACILITY for FLUID MECHANICS MEASUREMENTS, and FLOW VISUALIZATIONS,** and (10) **TRANSONIC TURBINE BLADE CASCADE FOR TIP HEAT TRANSFER MEASUREMENTS WITH FILM COOLING.**

ITEM 6. CURRENTLY ACTIVE AND RECENTLY ACTIVE – RESEARCH COLLABORATIONS

(1) **Beijing Tsinghua University** - Internal Passage Heat Transfer Augmentation Methods and Associated Unsteady Flow Structural Characteristics. (2) **University of Stuttgart** - Second Law Losses Around a Turbine Guide Vane, and Control of Turbine Cascade Endwall Heat Transfer and Secondary Flows. (3) **Inje University** - Unsteady Milliscale Impingement Jets and Associated Vortices for Surface Heat Transfer Augmentation. (4) **University of Cincinnati** - Dean Flow Dynamics and Cell Separations in Low-Aspect Ratio Spiral Microchannels. (5) **City University London and University of Michigan-Shanghai Jiao Tong University Joint Institute** - Secondary Flows and Extra Heat Transfer Enhancement of Ribbed Surfaces With Jet Impingement. (6) **George Mason University** - Investigations of Elastic Turbulence Phenomena Including Thermal Transport Effects. (7) **Beihang University – Beijing University of Aeronautics and Astronautics** - Investigations of Elastic Turbulence Phenomena Including Thermal Transport Effects. (8) **University of Rostock** - Investigations of Swirling Flows, Flows in Curved Pipe Channels, and Heat Exchangers With Impinging Jets. (9) **Purdue University** - Extreme Thermal Transport Events in Supersonic and Hypersonic Shock-Turbulence Interactions. (10) **Changwon National University** - Film Cooling Using Arrays of Compound Angle Holes.