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Announcement

Homage to a Legendary Dynamicist on His Seventy-Fifth Birthday

Mohamed Gad-el-Hak

Professor Mohamed Gad-el-Hak is an engineering scientist, globally well-known in the field of classical physics and the subfields of mechanics, biomechanics, fluid mechanics, turbulence, flow control, microelectromechanical systems (MEMS), microfluidics, and nanotechnology. He was born on Feb. 11, 1945 in Tanta, Egypt, a city in the heart of the Nile Delta, 94 km north of Cairo. Gad-el-Hak's elementary, secondary, and tertiary public education took place in Cairo. He received a B.Sc. in mechanical engineering from Ain Shams University in 1966, where he graduated summa cum laude and ranked first in his class. Gad-el-Hak moved to U.S. in 1968 to start his graduate studies. He received a Ph.D. Degree in fluid mechanics in 1973 from the Johns Hopkins University under the tutelage of Professor Stanley Corrsin. (Corrsin's graduate advisors at Caltech were Hans W. Liepmann and Theodore von Kármán. The latter's doctoral advisor at Göttingen was Ludwig Prandtl.) Gad-el-Hak's doctoral thesis is entitled "Experiments on the Nearly Isotropic Turbulence Behind a Jet-Grid."

After obtaining his Ph.D., Mohamed Gad-el-Hak joined the department of aerospace engineering at the University of Southern California, and afterward the department of engineering science and systems at the University of Virginia. After that, he was a senior research scientist and program manager at Flow Research Company in Seattle, Washington, where he managed different hydrodynamic and aerodynamic research projects. After this 10-year industrial experience, Gad-el-Hak returned to academia, joining the department of aerospace and mechanical engineering at the University of Notre Dame.

In 2002, Gad-el-Hak accepted a position at Virginia Commonwealth University as chair of mechanical engineering and the Inez Caudill Eminent Professor of Biomedical Engineering. During his tenure as department chair, Gad-el-Hak initiated a unique graduate and undergraduate program in nuclear engineering. The unit is now known as the department of mechanical and nuclear engineering.

Other academic appointments include visiting professorship at Institut de Mécanique de Grenoble, Université de-Poitiers, Friedrich-Alexander-Universität Erlangen–Nürnberg, Technische Universität München, Technische Universität Berlin, Brandenburgische Technische Universität Cottbus, Université de Valenciennes, and Peking University. Nonacademic appointments include the Naval Undersea Warfare Center in Newport, RI, and Forschungszentrum Rossendorf in Dresden, Germany.

The present authors and numerous others describe Gad-el-Hak as original, pioneering, visionary, creative, indefatigable, nonconformist, having breadth and depth, and ahead of the curve. (The subject passionately opposed to the label "stable genius".) Dr. Gad-el-Hak's teaching is innovative, rigorous, and does not appeal to the lowest common denominator, and his research is always leading edge. One of Gad-el-Hak's traits is his ability to invent novel measuring techniques where none existed. He has done that with the laser-induced fluorescence, compliant coating deformation, wind-waves characterizations, micropumping, and superhydrophobic surface's longevity, amount of entrapped air, and microscale thickness, among others.

Dr. Gad-el-Hak holds two patents: one for a drag-reducing method for airplanes and underwater vehicles, and the other for a lift control device for delta wings. He has additionally disclosed seven patents. Gad-el-Hak has authored/edited 20 books [1–11], and authored 140 journal articles, 52 essays in magazines and newspapers, 63 book chapters, 223 conference papers, and 28 book reviews. He presented over 310 invited lectures in every continent except Antarctica.

As of April 2020, Gad-el-Hak's papers have been cited more than 14,600 times in the technical literature, and his h-index is 53, i10-index is 142, and i100-index is 28 (source Google Scholar). Two of Gad-el-Hak's books have been translated into Chinese [9,10], and several of his articles/essays have been translated into Arabic, Chinese, the Czech language, French, German, Japanese, Spanish, and Turkish. Gad-el-Hak is the author of the book *Flow Control: Passive, Active, and Reactive Flow Management*, and editor of the books *Frontiers in Experimental Fluid Mechanics*, *Advances in Fluid Mechanics Measurements*, *Flow Control: Fundamentals and Practices*, *The MEMS Handbook* (first and second editions), *Transition and Turbulence Control*, and *Large-Scale Disasters: Prediction, Control and Mitigation*.

Recent work on large-scale disasters by Gad-el-Hak [11] resulted in the establishment of a universal metric by which the severity of all natural and manmade disasters is measured. That book was the first in the U.S. and second in the world to view large-scale disasters from the physical point of view, in contrast to the social, logistical, or medical viewpoint.

Professor Gad-el-Hak's scholarship has been featured in NPR, PBS, Nature magazine, Newsweek, and The New York Times. Additional to working in the broad field of mechanics, he penned essays and op/ed's on global warming [12]; energy crisis [13]; proliferation of scholarly publications [14]; massive open online courses (MOOC) [15]; university governance [16]; STEM and the humanities [17]; engineering education [18]; and societal values of basic research [19].

In 1981, Dr. Gad-el-Hak authored the first archival paper to describe the laser-induced fluorescence flow visualization technique [20]. The novelty lies in the ability to generate a very thin sheet of laser light as to be able to see one plane at a time, and the use of extremely small amounts of fluorescent dye as not to make the fluid's interior opaque. Among the technique's advantages are its high signal-to-noise ratio and its ability to dissect the flow field, as a CAT scan would to solid objects. Laser-induced fluorescence is now routinely used in numerous laboratories around the world, for both gas and liquid flows. He also identified the mechanism by which a turbulent region grows into a laminar, vortical flow [20].

The efficient growth by destabilization mechanism is an order of magnitude more effective than the conventional entrainment process in which a turbulent region incorporates/engulfs the surrounding irrotational flow.

The article "Reynolds Number Effects in Wall-Bounded Turbulent Flows" by Gad-el-Hak, published in *Applied Mechanics Reviews*, marked a paradigm shift in the approach to this subject [21]. Funding programs by the U.S. Defense Advanced Research Projects Agency (DARPA), Office of Naval Research (ONR), and Air Force Office of Scientific Research (AFOSR) were inspired by this seminal paper. He introduced the concept of selective/targeted/opposition/reactive control [22] to achieve drag reduction, lift enhancement, mixing augmentation, and noise suppression in wall-bounded flows. This patented closed-loop control is now researched intensively around the world. Entire scientific conferences and funding programs are dedicated to reactive (in contrast to active) control.

Dr. Gad-el-Hak conducted the groundbreaking experiments that detailed the fluid–compliant surface interactions in turbulent boundary layers [23–27]. He also introduced a noninvasive technique to probe the coating's instability waves. The laser-based probe has a spatial resolution of 1 μm and temporal resolution of several kHz. He was among the first group of aerodynamicists in the U.S. to work on the "supermaneuverability" research program [28], a word coined by the German aerodynamicist Wolfgang Herbst. The DARPA/AFOSR unsteady aerodynamics program formed the foundation of the millions of unmanned aerial vehicles flying today.

Gad-el-Hak's paper in ASME *Journal of Fluids Engineering*, "A Novel Pump for MEMS Applications" [29], presented a new method for pumping fluids in microelectromechanical systems (MEMS) applications at very low Reynolds numbers. Inertial pumps do not work at low Reynolds numbers. The only type that worked for MEMS, prior to introducing Gad-el-Hak's rotary pump, was of the reciprocating variety. His most cited paper was published in the *ASME Journal of Fluids Engineering*, "The Fluid Mechanics of Microdevices—The Freeman Scholar Lecture" [30]. He is the first scientist to place the fledgling field of microfluidics on firm physical ground. Whole books, courses, and funding programs sprang worldwide as a result of this single paper. As of April 2020, that article has been cited over 1480 times (source Google Scholar).

Dr. Gad-el-Hak's analytical, numerical, and experimental research on the characterization of superhydrophobic coatings resulted in better understanding of the fledgling field. Twenty journal publications, including two invited review papers [31,32], resulted from his three-year effort. Two measurement techniques were introduced for the first time: (i) an in situ, noninvasive probe to assess the longevity of such coatings and (ii) a method to measure the coating's thickness down to the micron scale as well as the amount of entrapped air in the coating's micropockets [31–34]. Additionally, using electrospinning, Gad-el-Hak advanced a cost-effective fabrication technique that can produce superhydrophobic surfaces with both random and aligned fibrous micro/nanostructures. He also developed an alternative method for engineering affordable superhydrophobic surfaces by randomly depositing size-controlled hydrophobic aerogel particles on a substrate. Dr. Gad-el-Hak advanced theoretical and experimental strategies to characterize the micro/nanostructure of the surface morphology. His research showed that the laboratory-scale surfaces could be scaled-up for marine applications.

To commemorate the 90th Anniversary of the ASME Fluids Engineering Division, Professor Mohamed Gad-el-Hak delivered the plenary talk "Nine Decades of Fluid Mechanics" at the ASME FEDSM 2016 meeting, July 10–14, 2016, Washington, DC. His talk was published in October 2016 in a special issue of the *ASME Journal of Fluids Engineering*. In this review paper [35], Gad-el-Hak covered the progress in fluid mechanics during the period 1926–2016. He described selected experimental, theoretical, and numerical advances, and elucidated the grand benefits of inventing the computer and the laser to the field of fluid dynamics.

Dr. Gad-el-Hak's research covers a remarkable range of Reynolds, Mach, and Knudsen numbers. His recent work on hypersonic flows identified a new principle for aerodynamic heating [36,37]. The resulting five journal papers were independently highlighted in 2018 by two prestigious publications: American Institute of Physics' *SciLight*, and Oxford's *National Science Review*.

In his role as an engineering professor, Gad-el-Hak developed a unique writing course for advanced undergraduate and beginning graduate students in science and engineering [38]. The class is writing intensive and, through assessments, has proven to be more effective than similar classes taught by English and communications faculty. The semester-long course has also been offered as a short course in other universities. His superbly penned essay for *The Chronicle of Higher Education*, "We Must Stop the Avalanche of Low-Quality Research" [39], was chosen in 2011 by the British Science Council to be part of a standardized English examination.

Professor Gad-el-Hak has served as editor of eight international journals including *Applied Mechanics Reviews*, *AIAA Journal*, and *Bulletin of the Polish Academy of Sciences*. Gad-el-Hak is also a contributing editor for McGraw-Hill's Year Book of Science and Technology, for Springer-Verlag's Lecture Notes in Engineering and Lecture Notes in Physics, and for CRC Press's Mechanical Engineering Series. He serve as a consultant to the United Nations, the governments of 12 countries, and many industrial and academic concerns. Professor Gad-el-Hak has been a member of many advisory panels for the U.S. Department of Defense (DOD), Department of Energy (DOE), National Aeronautics and Space Administration (NASA), and National Science Foundation (NSF).

In testament to Dr. Gad-el-Hak's successes, he has been the elected Fellow of the American Academy of Mechanics (AAM) [40], American Association for the Advancement of Science (AAAS), American Institute of Physics (AIP), American Physical Society (APS), and American Society of Mechanical Engineers (ASME). In addition, Gad-el-Hak is the recipient of numerous international awards, for example, the 14th Freeman Scholar Award by the American Society of Mechanical Engineers [41], the Japanese Government Research Award for Foreign Scholars, and the German Alexander von Humboldt Prize. He was designated an ASME Distinguished Lecturer as well as inducted into the Johns Hopkins Society of Scholars in 2002. In 2016, Dr. Gad-el-Hak was awarded an ASME Medal for seminal contributions to the discipline of fluids engineering. In the same year, he also received an ASME certificate of appreciation in testimony of the high regard of his associates and the deep appreciation of the society for his valued services in advancing the engineering profession.

On the occasion of his 75th birthday, and on behalf of his friends, colleagues, and students all over the globe, the present authors wish Professor Mohamed Gad-el-Hak a continuous active life in happiness and good health, and a very happy birthday!

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