Shock Wave Science and Technology Reference Library 10

Collection Editors

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The new Springer collection, Shock Wave Science and Technology Reference Library, conceived in the style of the famous Handbuch der Physik has as its principal motivation to assemble authoritative, state-of-the-art, archival reference articles by leading scientists and engineers in the field of shock wave research and its applications. A numbered and bounded collection, this reference library will consist of specifically commissioned volumes with internationally renowned experts as editors and contributing authors. Each volume consists of a small collection of extensive, topical and independent surveys and reviews. Typical articles start at an elementary level that is accessible to non-specialists and beginners. The main part of the articles deals with the most recent advances in the field with focus on experiment, instrumentation, theory, and modeling. Finally, prospects and opportunities for new developments are examined. Last but not least, the authors offer expert advice and cautions that are valuable for both the novice and the well-seasoned specialist.

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Collection Editors

Hans Grönig

Hans Grönig is Professor emeritus at the Shock Wave Laboratory of RWTH Aachen University, Germany. He obtained his Dr. rer. nat. degree in Mechanical Engineering and then worked as postdoctoral fellow at GALCIT, Pasadena, for one year. For more than 50 years he has been engaged in many aspects of mainly experimental shock wave research including hypersonics, gaseous and dust detonations. For about 10 years he was Editor-in-Chief of the journal Shock Waves.

Yasuyuki Horie

Professor Yasuyuki (Yuki) Horie is internationally recognized for his contributions in high-pressure shock compression of solids and energetic materials modeling. He is a co-chief editor of the Springer series on Shock Wave and High Pressure Phenomena and the Shock Wave Science and Technology Reference Library, and a Liaison editor of the journal Shock Waves. He is a Fellow of the American Physical Society, and Secretary of the International Institute of Shock Wave Research. His current interests include fundamental understanding of (a) the impact sensitivity of energetic solids and its relation to microstructure attributes such as particle size distribution and interface morphology, and (b) heterogeneous and nonequilibrium effects in shock compression of solids at the mesoscale.

Kazuyoshi Takayama

Professor Kazuyoshi Takayama obtained his doctoral degree from Tohoku University in 1970 and was then appointed lecturer at the Institute of High Speed Mechanics, Tohoku University, promoted to associate professor in 1975 and to professor in 1986. He was appointed director of the Shock Wave Research Center at the Institute of High Speed Mechanics in 1988. The Institute of High Speed Mechanics was restructured as the Institute of Fluid Science in 1989. He retired in 2004 and became emeritus professor of Tohoku University. In 1990 he launched Shock Waves, an international journal, taking on the role of managing editor and in 2002 became Editor-in-Chief. He was elected president of the Japan Society for Aeronautical and Space Sciences for one year in 2000 and was chairman of the Japanese Society of Shock Wave Research in 2000. He was appointed president of the International Shock Wave Institute in 2005. His research interests range from fundamental shock wave studies to the interdisciplinary application of shock wave research.

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Friedrich Seiler · Ozer Igra
Editors

Hypervelocity Launchers

Springer

Editors
Friedrich Seiler
Institute of Fluid Mechanics (ISTM)
Karlsruhe Institute of Technology (KIT)
Karlsruhe
Germany

Ozer Igra
Department of Mechanical Engineering
Ben-Gurion University of the Negev
Beer Sheva
Israel

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Preface

Various types of mass accelerators have been developed worldwide in the past, based on different principles. In the early 80s Professor Abe Hertzberg, at that time a professor at the University of Washington (UW) in Seattle, USA, proposed using the Ram accelerator concept for accelerating projectiles to hypersonic velocities. This concept starts with a tube filled with compressed combustible gas mixture equipped with membranes to close both the tube ends. The projectile was injected into the tube at a supersonic speed relative to in-the-tube-gases. The combustible gas was ignited by the high temperature gas generated behind the shock wave located in vicinity of the projectile leading edge. The significant temperature increase is associated with an increase in the gas pressure needed for thrust production. On the other hand, the best known accelerator is the powder gun; the maximum achievable speed while using the powder gun is moderate because of the heavy powder gases in comparison with the light gas used in hypersonic accelerators where hypervelocity speeds in the range of several km/s are reached.

In the present volume numerous descriptions of Ram accelerators are presented as well as descriptions of light gas guns and a ballistic range including explanation of shock waves in solids. These descriptions provide a good overview of the progress made and the present state of the Ram accelerator technology worldwide.

In a light-gas gun (using helium gas), projectile velocities ranging up to 7 km/s are theoretically attainable. Such facilities are mainly used for studying projectile impact on investigated material. Typical examples for impact investigations are comets or asteroids penetrating into the Earth's atmosphere and their final impact on the Earth.

The usage of Ram accelerators is relatively new in comparison with the development of the light-gas gun and the electromagnetic accelerator, i.e., the rail gun, and its operation is still in the development stage. Many Ram accelerator facilities have been built around the globe, some having small tube calibers and some with large caliber, up to the 120 mm pipe diameter at the Army Research Laboratory (ARL) in Maryland, USA. Smaller Ram accelerators were developed at the French–German Research Institute of Saint-Louis (ISL), France: one having a

30 mm caliber and another with a 90 mm caliber acceleration tube. Additional Ram accelerators were built in Japan, at Tohoku University in Sendai with a 25 mm rectangular cross-section. In China, at the China Aerodynamics R&D Center (CARDC) a 37 mm bore accelerator was tested. Different approaches have been used: (a) where the projectile is guided by fins in a smooth pipe and (b) where the projectile is centered by rails fixed within the tube. In both cases a gap exists between the projectile and the tube.

As of today, in spite of all efforts made, the maximum projectile velocity has not exceeded 3 km/s. Therefore, the goal to reach orbital speeds has not been realized. The reason for this failure is the fact that the projectile material quickly burns up while reaching the needed high combustion temperatures required for projectile acceleration inside the Ram tube. As a result, many research institutes and companies decided to freeze their investigations of Ram accelerators at the beginning of 2000. However, some experiments have been carried out at a low level even thereafter. This lull did not involve the theoretical investigations. For example, at the National University of Seoul in Korea, numerical investigations of the combustion dynamics in a Ram accelerator are conducted and their findings are reported in this volume. Hopefully, a rebirth of the Ram accelerator concept will take place in the near future when new materials that can withstand the high gas temperatures without ablating will be found. Should this be the case, the dream of Prof. Hertzberg could be fulfilled: Using the Ram accelerator as a device to launch a capsule into orbit or to other planets. As noted, the biggest problem in reaching the desired projectile speed is the projectile material. The early projectiles were made from magnesium in order to save weight. The high combustion temperatures associated with high heat transfer into the magnesium resulted in melting and ablation. Thus, the projectile guidance became more and more difficult and eventually failed. In the next step, projectiles were made of aluminum. Ablation was lower, but still very problematic. Also, projectiles made of titanium, iron, and composite materials were tested in various Ram devices.

Finally, we would like to thank all authors for their contributions to this volume. Their participation is key to the success of this book.

Karlsruhe, Germany — Friedrich Seiler
Beer Sheva, Israel — Ozer Igra
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About the Editors

Friedrich Seiler is well-known for his studies in shock tube technology at the French-German Research Institute of Saint-Louis in France (ISL). As a scientist at the ISL, from 1980 on, his research mainly deals with high-velocity flight aerodynamics, hypersonics, optical measuring techniques and fundamental research in the field of ram acceleration. Until his retirement in the year 2011, he became in 1997 head of ISL's Aerothermodynamics & Shock Tube Laboratory. He is a member of the editorial board of the "International Journal on Shock Waves" and is also associated to the International Advisory Committee of the "International Symposium on Shock Waves (ISSW)" and the "International Symposium on Flow Visualization (ISFV)". From the University of Karlsruhe in Germany he received his "Dipl.-Phys." degree in physics and his "Dr.-Ing." degree from the same University. Also the University of Karlsruhe, now Karlsruhe Institute of Technology (KIT), has awarded him in 1992 the rank "Professor" and since then he is Lecturing Professor for Fluid Mechanics at KIT. His current interest is focused on the dynamics of Mach waves in supersonic jets. He contributed to a theory which describes the Mach wave behavior using a new approach.

Ozer Igra has devoted most of his research activities to studying various aspects of shock and blast waves phenomena. His studies include both experimental and numerical investigations of strong (ionizing shocks in argon) and moderate to weak shock/blast wave in gases and in suspensions. Results of his investigations can be found in his many publications available in leading professional journals dealing with gas-dynamic flows and shock waves. He received his B.Sc. and M.Sc. degrees from the Department of Aeronautical Engineering of the Technion, Israel Institute of Technology and his Ph.D. from the Institute for Aerospace Engineering, University of Toronto, Canada. He Joined the Ben Gurion University of the Negev in 1971. There he established the Shock Waves Laboratory, supervised many masters, doctorate, and postdoc students and served as the chairmanof the Department of Mechanical Engineering and thereafter as the Dean of the Faculty of Engineering. He is on the International Advisory Committee of the International Symposium on Shock Waves (ISSW) and the International Symposium on Shock Interactions (ISIS), and on the editorial board of the Shock Waves Journal.