

MATERIALS AND TECHNOLOGIES FOR A GREEN ENVIRONMENT



Editor:
Santhanam Harikrishnan

Bentham Books

Materials and Technologies for a Green Environment

Edited by

Santhanam Harikrishnan

*Department of Mechanical Engineering, Kings Engineering
College, Chennai, India*

Materials and Technologies for a Green Environment

Editor: Santhanam Harikrishnan

ISBN (Online): 978-981-5051-21-6

ISBN (Print): 978-981-5051-22-3

ISBN (Paperback): 978-981-5051-23-0

© 2023, Bentham Books imprint.

Published by Bentham Science Publishers Pte. Ltd. Singapore. All Rights Reserved.

First published in 2023.

BENTHAM SCIENCE PUBLISHERS LTD.

End User License Agreement (for non-institutional, personal use)

This is an agreement between you and Bentham Science Publishers Ltd. Please read this License Agreement carefully before using the book/echapter/ejournal (“**Work**”). Your use of the Work constitutes your agreement to the terms and conditions set forth in this License Agreement. If you do not agree to these terms and conditions then you should not use the Work.

Bentham Science Publishers agrees to grant you a non-exclusive, non-transferable limited license to use the Work subject to and in accordance with the following terms and conditions. This License Agreement is for non-library, personal use only. For a library / institutional / multi user license in respect of the Work, please contact: permission@benthamscience.net.

Usage Rules:

1. All rights reserved: The Work is the subject of copyright and Bentham Science Publishers either owns the Work (and the copyright in it) or is licensed to distribute the Work. You shall not copy, reproduce, modify, remove, delete, augment, add to, publish, transmit, sell, resell, create derivative works from, or in any way exploit the Work or make the Work available for others to do any of the same, in any form or by any means, in whole or in part, in each case without the prior written permission of Bentham Science Publishers, unless stated otherwise in this License Agreement.
2. You may download a copy of the Work on one occasion to one personal computer (including tablet, laptop, desktop, or other such devices). You may make one back-up copy of the Work to avoid losing it.
3. The unauthorised use or distribution of copyrighted or other proprietary content is illegal and could subject you to liability for substantial money damages. You will be liable for any damage resulting from your misuse of the Work or any violation of this License Agreement, including any infringement by you of copyrights or proprietary rights.

Disclaimer:

Bentham Science Publishers does not guarantee that the information in the Work is error-free, or warrant that it will meet your requirements or that access to the Work will be uninterrupted or error-free. The Work is provided "as is" without warranty of any kind, either express or implied or statutory, including, without limitation, implied warranties of merchantability and fitness for a particular purpose. The entire risk as to the results and performance of the Work is assumed by you. No responsibility is assumed by Bentham Science Publishers, its staff, editors and/or authors for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products instruction, advertisements or ideas contained in the Work.

Limitation of Liability:

In no event will Bentham Science Publishers, its staff, editors and/or authors, be liable for any damages, including, without limitation, special, incidental and/or consequential damages and/or damages for lost data and/or profits arising out of (whether directly or indirectly) the use or inability to use the Work. The entire liability of Bentham Science Publishers shall be limited to the amount actually paid by you for the Work.

General:

1. Any dispute or claim arising out of or in connection with this License Agreement or the Work (including non-contractual disputes or claims) will be governed by and construed in accordance with the laws of Singapore. Each party agrees that the courts of the state of Singapore shall have exclusive jurisdiction to settle any dispute or claim arising out of or in connection with this License Agreement or the Work (including non-contractual disputes or claims).
2. Your rights under this License Agreement will automatically terminate without notice and without the

need for a court order if at any point you breach any terms of this License Agreement. In no event will any delay or failure by Bentham Science Publishers in enforcing your compliance with this License Agreement constitute a waiver of any of its rights.

3. You acknowledge that you have read this License Agreement, and agree to be bound by its terms and conditions. To the extent that any other terms and conditions presented on any website of Bentham Science Publishers conflict with, or are inconsistent with, the terms and conditions set out in this License Agreement, you acknowledge that the terms and conditions set out in this License Agreement shall prevail.

Bentham Science Publishers Pte. Ltd.

80 Robinson Road #02-00

Singapore 068898

Singapore

Email: subscriptions@benthamscience.net



CONTENTS

PREFACE	i
LIST OF CONTRIBUTORS	ii
CHAPTER 1 RENEWABLE ENERGY GENERATION USING A NOVEL GEOTHERMAL-SOLAR HYBRID POWER PLANT USING RORC	1
<i>K. C. Ramya, S. Sheeba Rani, S. Sivaranjani and R. Vinoth Kumar</i>	
1. INTRODUCTION	2
1.1. Renewable Energy	2
2. LITERATURE SURVEY	8
3. METHODOLOGY	13
4. GOVERNING EQUATIONS	15
4.1. Thermal Design of the Hybrid Power Plant	18
4.2. Solar Design of the Hybrid Power Plant	19
5. RESULTS AND DISCUSSION	21
5.1. Geothermal Fluid Mass Flow Rate	21
5.2. RORC Working Fluid Mass Flow	23
5.3. Influence of Parameters on the Condenser	25
CONCLUSION	25
FUTURE SCOPE	27
CONSENT FOR PUBLICATION	27
CONFLICT OF INTEREST	27
ACKNOWLEDGEMENT	27
REFERENCES	27
CHAPTER 2 ENERGY HARVESTING THROUGH THERMOELECTRIC GENERATORS	32
<i>A.D. Dhass, Ganesh Babu L., Raghuram Pradhan, G.V.K Murthy and M. Sreenivasan</i>	
1. INTRODUCTION	32
1.1. Peltier Effect	34
1.2. Thomson Effect	34
1.3. Figure of Merit	34
2. TYPES OF THERMO ELECTRIC GENERATORS	35
2.1. Fossil Fuel Generators	35
2.2. Solar Source Generators	35
2.3. Nuclear-fueled Generators	35
2.4. Semiconductor Materials for Thermoelectric Generators	36
2.5. Environmental Extremes	36
3. WASTE HEAT RECOVERY	38
4. MICROGENERATION	39
5. HARVESTING MICROPOWER	42
6. THERMO ELECTRIC GENERATORS & COOLERS	42
6.1. Thermo Electric Cooler (TEC)	42
6.2. Air Conditioning Systems for Vehicles	45
7. THERMO ELECTRIC MATERIALS	46
7.1. Inorganic TE Materials	46
7.2. Organic TE Materials	46
7.3. Hybrid TE Materials	47
7.4. Polymers acts as TE Materials	48
7.5. Advanced TE Materials	49
7.6. Bulk Binary Semiconductors	49

7.7. Complex Inorganic Structures	49
7.8. Oxide Thermoelectrics	49
7.9. Thin Film Materials	50
8. OPTIMAL DESIGN	50
9. HYBRID THERMO ELECTRIC GENERATORS	52
9.1. Solar Powered Thermoelectric Refrigerator	53
10. ENERGY HARVESTING	54
11. PERFORMANCE AND MEASUREMENT OF THERMO ELECTRIC GENERATORS	56
12. MICRO SCALE APPLICATIONS	59
13. MACRO SCALE APPLICATIONS	59
CONCLUSION	60
NOMENCLATURE	60
CONSENT FOR PUBLICATION	61
CONFLICT OF INTEREST	61
ACKNOWLEDGEMENT	61
REFERENCES	61
CHAPTER 3 SOLAR ELECTRIC VEHICLE CHARGING AND GRID INTERACTION: AN INTEGRATED MODULE	67
<i>D. Muruganandam, J. Jayapriya, P.K. Chidambaram and B. Karthik Anand</i>	
1. INTRODUCTION	68
1.1. Advantages of Electric Vehicles Over ICE Vehicles	69
1.2. Disadvantages of Electric Vehicles over ICE Vehicles	69
2. SOLAR POWER CHARGING	70
2.1. Energy flow & Management	72
2.2. Solar Power Grid	74
2.3. The Power Electronics Components and their Configuration for the Solar	78
2.4. Importance of Photo Voltaic Panel as an Energy Source for EVs	83
2.5. Clean Photovoltaic Energy and Battery Vehicles: Initiatives Taken by Law-making Authorities and Industry/Institutions	84
2.6. Future of Renewable Photo Voltaic Power Generation	85
3. ELECTRIC VEHICLE SMART GRID INTEGRATION	86
3.1. Smart Charging for a Reliable and Resilient Grid	86
3.2. A Typical Sizing Methodology of ESS	87
3.3. Sizing of Battery and the Converter Definition	88
3.4. Number of EVs for Charging	88
3.5. Battery Charging	89
3.6. Commercial and Personal Vehicles	89
3.7. Charging Scenario with Respect to the Location	89
3.8. Charging Scenario with Respect to Timings	90
3.9. Battery Capacity of Vehicles	90
3.9.1. <i>Wireless Battery-operated Electric Vehicle Charging</i>	91
3.10. Smart Charging	93
3.11. Smart Charging Functioning	94
3.12. Load Balancing	94
3.13. V2G Definition	95
4. SECOND LIFE OF BATTERIES	98
4.1. Retired EV Batteries: How They can be Re-used or Recycled?	98
4.2. Opportunities for Second Life Batteries	100
DISCUSSION AND CONCLUSION	101

CONSENT FOR PUBLICATION	101
CONFLICT OF INTEREST	101
ACKNOWLEDGEMENT	101
REFERENCES	101
CHAPTER 4 A REVIEW OF THE CURRENT CHALLENGES ON THE ISSUES OF SCRAMJET COMBUSTION ENGINES	104
<i>Namrata Bordoloi, K. M. Pandey, K. K. Sharma and Dharmendra Sapariya</i>	
1. INTRODUCTION	104
1.1. Principle of Scramjet	105
1.2. The Need for Scramjet	107
1.3. Advantages and Disadvantages	107
2. CHALLENGES IN DESIGNING A SCRAMJET ENGINE	108
3. LITERATURE REVIEW	109
3.1. Studies Conducted Experimentally	110
3.2. Studies Conducted both Experimentally and Numerically	117
3.3. Studies Conducted Numerically	121
4. FUTURE SCOPE	140
CONCLUSION	141
CONSENT FOR PUBLICATION	141
CONFLICT OF INTEREST	141
ACKNOWLEDGEMENT	141
REFERENCES	141
CHAPTER 5 REVIEW OF THE ROLE OF GEOMETRICAL MODIFICATION OF SCRAMJET COMBUSTOR ON PERFORMANCE CHARACTERISTICS	150
<i>Kumari Ambe Verma¹, K. M. Pandey^{1,*}, K.K. Sharma¹ and Dhiren R. Patel²</i>	150
1. INTRODUCTION	150
2. SCRAMJET GEOMETRICAL MODIFICATION	151
2.1. Combustor Geometry	151
2.1.1. Combustor Wall Transverse Fuel Injection	152
2.1.2. Combustor Wall Cavity with Strut Fuel Injection	153
2.2. Fuel Injector Geometrical Modifications	155
2.2.1. Modified Strut or Multi Struts	155
2.2.2. Flame Stabilization Analysis: Ideal Strut or altered Injection Strategy	158
3. SCRAMJET PERFORMANCE CHARACTERISTICS ANALYSIS	161
3.1. Supplementary Fuel (Mixed) Implications	161
3.2. Different Fuels	162
3.3. Variable Inflow Condition	163
3.4. Different Computational Model	165
SUMMARY AND CONCLUDING REMARKS	169
CONSENT FOR PUBLICATION	170
CONFLICT OF INTEREST	170
ACKNOWLEDGEMENT	170
REFERENCES	170
SUBJECT INDEX	179

PREFACE

I am pleased to introduce the book titled "**Materials and Technologies for a Green Environment**". It comprises five chapters, covering different subjects of energy harvesting, biofuel, electric vehicle and Scramjet. All the chapters discuss the fundamentals and the recent developments in their respective subjects. This book could be beneficial to graduates, post-graduates, and researchers as it could cater to their needs. Suggestions and comments from the readers are invited in order to improve the quality of the next edition.

Prof. Santhanam Harikrishnan
Kings Engineering College Chennai
India

List of Contributors

A.D. Dhass	Department of Mechanical Engineering, IITE, Indus University, Gujarat, India
B. Karthik Anand	Department of Mechanical Engineering, Newprince Shri Bhavani College of Engineering and Technology, Chennai, Tamil Nadu, India
D. Muruganandam	Department of Mechanical Engineering, Sri Venkateswaraa College of Technology, Tamil Nadu, India
Dharmendra Sapariya	Department of Mechanical Engineering, IITE, Indus University, Ahmedabad, Gujarat, India
Dhiren R. Patel	Mechanical Engineering Department, IITE, Indus University, Ahmedabad, Gujarat, India
Ganesh Babu L.	Mechatronics Engineering, Tishk International University, Erbil, Iraq
G.V.K. Murthy	Department of Electrical and Electronics Engineering, PACE Institute of Technology and Sciences, Ongole-523272, India
J. Jayapriya	Department of Mechanical Engineering, Sri Venkateswaraa College of Technology, Tamil Nadu, India
K.C. Ramya	Department of Electrical and Electronics Engineering, Sri Krishna College of Engineering and Technology, Coimbatore, India
K. M. Pandey	Department of Mechanical Engineering, National Institute of Technology, Silchar, Assam, India
K. K. Sharma	Department of Mechanical Engineering, National Institute of Technology, Silchar, Assam, India
Kumari Ambe Verma	Department of Mechanical Engineering, National Institute of Technology, Silchar, Assam, India
M. Sreenivasan	Department of Mechanical Engineering, PACE Institute of Technology and Sciences, Ongole-523272, India
Namrata Bordoloi	Department of Mechanical Engineering, National Institute of Technology Silchar, Assam, India
P.K. Chidambaram	Department of Mathematics, Sathyabama Institute of Science and Technology, Chennai, Tamil Nadu, India
Raghuram Pradhan	Department of Mechanical Engineering, PACE Institute of Technology and Sciences, Ongole-523272, India
R. Vinoth Kumar	Department of Electrical and Electronics Engineering, New Horizon College of Engineering, Bengaluru, India
S. Sivaranjani	Department of Electrical and Electronics Engineering, Sri Krishna College of Engineering and Technology, Coimbatore, India
S. Sheeba Rani	Department of Electrical and Electronics Engineering, Sri Krishna College of Engineering and Technology, Coimbatore, India

CHAPTER 1

Renewable Energy Generation Using a Novel Geothermal-Solar Hybrid Power Plant Using RORC**K. C. Ramya^{1*}, S. Sheeba Rani¹, S. Sivaranjani¹ and R. Vinoth Kumar²**¹ Department of Electrical and Electronics Engineering, Sri Krishna College of Engineering and Technology, Coimbatore, India² Department of Electrical and Electronics Engineering, New Horizon College of Engineering, Bengaluru, India

Abstract: A recent survey of energy consumption indicates that there has been exponential growth in the need for renewable energy and also for curbing the growth of fossil fuel reserves. To meet this future need, renewable energy sources are being explored. In this paper, we have proposed a Recuperative Organic Rankine Cycle that operates in conjunction with air-cooled condensers. Solar energy is said to be an energy source that varies periodically, unlike geothermal energy which is available round the clock, to generate electricity continuously. Hence it is a highly recommended source to meet the growing demands for electricity globally. A major contribution to geothermal power development is the progress in Organic Rankine Cycles. These plants are best known for their ability to curb harmful gas emissions, especially that of non-condensable gases. There is a significant growth in geothermal power owing to the ORC (Organic Rankine Cycle) power units that are implemented. In this methodology, the working fluid of ORC is made to go through an evaporator where a hot turbine is used to heat the liquid. In this process, the temperature of the preheated liquid is further increased with the aid of solar energy. This heat generated thus is further converted into electricity when the turbine unit causes the expansion of the fluid. Finally, an air-cooled condenser is used to condense the final exhaust of the turbine. Combining the two powerful forms of renewable energy (solar and geothermal), it is possible to generate power in such a way that the need for power begins to drop from its peak that it has achieved already. The simulated results define the decline in energy consumption of condensers based on the minimum heat transfer area of the condenser as well as the minimum power consumption of the fans.

Keywords: Duct curve, Geothermal-solar power generation, Hybrid power plant, Renewable energy, Recuperative Organic Rankine Cycle.

* **Corresponding author K.C. Ramya:** Department of Electrical and Electronics Engineering, Sri Krishna College of Engineering and Technology, Coimbatore, India; Email: ramyakc@skcet.ac.in

1. INTRODUCTION

1.1. Renewable Energy

As the planet becomes more populated, the demand for energy also increases subsequently at a very fast pace. In recent times, this demand for energy is met with the help of fuels based on fossil. However, the use of these carbon-based fuels resulted in air quality deterioration, increased pollution and global warming. In May 2018, a report by WHO stated that about 90% of people all over the world are breathing polluted air. Because of this, there is a need for renewable energy sources and governments across the globe are investing heavily in this aspect. The Clean Energy future is made possible through the invention of renewable energy. In the beginning, energy was highly dependent on fossil fuels. However, due to the emission of carbon and other impurities that had harmful effects on the environment, there has been much need for cleaner energy usage. The introduction of wind and solar generation was a ground breaking invention that paved the way to a better and healthier atmosphere. This was further improved by the introduction of renewable energy. Renewable energy is commonly referred to as clean energy as it is generated from natural processes or sources. Though the use of natural sources as energy is thought of to be a novel concept, we have been using them for various aspects like transportation, heating, and so on. The sun has been used since ancient times to keep us warm during the day and further to kindle fire and provide warmth during the night. Similarly, windmills have been used to grind grain and wind has been used for a long period of time to sail boats.

However, during the past few centuries, the invention of many energy sources such as fracking gas and coal has led to a more polluted environment. These types of energy sources are known as non-renewable sources. These types of energy take a longer time to replenish and are available for only a limited period of time. Most non-renewable energy sources will have a harmful impact on human health and will also cause harm to the environment. Some known impacts are: drilling of oil performed using fracking might result in water pollution and cause earthquake, while a coal power plant will make the air smell foul.

The following are some of the renewable energy sources that are being used by us:

- **Wind Energy:** One of the most ancient ways of producing electricity is the use of wind as a source of energy. The turbines are built high and as the blades of the turbine turn, electricity is produced using an electric generator. It is also one of the cheapest forms of energy and accounts for about 23% of the total energy produced.

- **Solar Energy:** Solar energy has been used for a long period of time by us for various purposes like drying fruits, staying warm, and growing crops. Energy from the sun is used in many ways to power devices, and to warm water. Solar cells, also known as photovoltaic cells are built of a base metal plate of either steel or aluminum. These cells convert sunlight into electricity directly.
- **Geothermal Energy:** As the radioactive particles begin to decay slowly, in rocks at the earth's centre, they will be as hot as the surface of the sun, resulting in a natural hot spring. An underground well is dug up that acts as a hydrothermal resource, which can be used to create electricity.
- **Biomass Energy:** Trees, waste wood, crops, carcasses of animals, and withered plants are used to make biomass. Chemical energy is liberated in the form of heat from burning biomass. This in turn can be used to generate electricity. Though this form of energy is considered to be a cleaner and greener alternative, it still produces a large amount of carbon emissions.
- **Hydroelectric Power:** The source of hydroelectric power is water which descends rapidly from a higher end to the foot of the river. This force of water can be converted into electricity.
- **Ocean:** Though the production of tidal energy through the waves of the ocean is currently in an experimental phase, it still remains a good option to harness power.

According to energy statistics 2020, a report released by the Ministry of Statistics and Programme Implementation, Government of India, there is an abrupt increase in the use of renewable resources of energy in India. The report states that about 28.18 GW of electricity is generated using solar power, which is a 12.23% increase from the previous year. This is also reflected in decreasing the cost of solar electricity, thereby attracting more people to use the same.

Estimated potential of renewable energy sources is tabulated in Table 1. Here Jammu & Kashmir, Maharashtra and Rajasthan are the states that contribute highly to using renewable energy in India.

Table 1. Usage of Renewable Sources in India.

State	Use of Renewable Energy
Andra Pradesh	8%
Gujarat	11%
Himachal Pradesh	3%

Energy Harvesting Through Thermoelectric Generators

A.D. Dhass^{1,*}, Ganesh Babu L.², Raghuram Pradhan³, G.V.K Murthy⁴ and M. Sreenivasan³

¹ Department of Mechanical Engineering, IITE, Indus University, Gujarat, India

² Mechatronics Engineering, Tishk International University, Erbil, Iraq

³ Department of Mechanical Engineering, PACE Institute of Technology and Sciences, Ongole-523272, India

⁴ Department of Electrical and Electronics Engineering, PACE Institute of Technology and Sciences, Ongole-523272, India

Abstract: Thermoelectric generator (TEG) converts waste heat energy from automobiles into valuable electrical power and has no moving parts compared to conventional thermoelectric motors. The functioning of TEG is dependent on the design and the material used. TEGs are classified as small and medium power outputs. Small power outputs are in the range between 5 μ W to 1W, and high power outputs are higher than 1W in a TEG. Thermoelectric power generators offer fast, economical storage methods for wearable and mobile applications. Macro heat waste application is recovered through in-house, industrial and solid waste. Moreover, an immense amount of waste fuel, such as recycling and power plants, is emitted from the industry; this can be utilized in a useful manner by TEGs. This chapter discusses the TEG study of the fundamental operating principles, TEG products, micro applications and energy generation techniques.

Keywords: Applications, Energy storage, Heat engines, Power generation, Thermoelectric generator, Waste heat recovery.

1. INTRODUCTION

The majority of the operating expense of a gas turbine is due to turbine fuel, and much energy is lost from the flue gas after combustion to the atmosphere. Up to 40% of the fuel is released from exhaust energy. The technology of semicond-

* Corresponding author A.D. Dhass: Department of Mechanical Engineering, IITE, Indus University, Gujarat, India; E-mail: dasaradhan.ad@gmail.com

uctors helps to solve energy problems by procuring waste heat sources [1, 2].

The immensity of the global energy is calculated to be the product of effective thermal energy-saving technologies that can conserve atmospheric energy as heat, generating approximately 40% or less. Thermo-energy waste can improve the power efficiency of the electricity base. The gas turbine, vehicle exhaust, steam and method of production produce waste thermal energy and transform it into energy using a thermoelectrical generator [3].

In recent years, the principal objective has been to increase energy production to improve its economy, methods of transport and quality. Researchers and commercial activities have in particular, tried to enhance resource efficiency through improved energy systems performance since the energy crisis [4].

The energy costs (oil, gas and charcoal) have risen at unpredictable rates over recent years. Consequently, renewable energy is more conventional in producing electricity, since it produces lower emissions. By converting heat energy, the device is converted into electric power. It is suitable for space exploration and satellite exploration and for devices that are unmanned. Modern electrical systems include photovoltaic cells, piezo-electric modules for human motion and thermo-electric heat modules. The aim is to provide electricity efficiency to the human organism with its limited resources [5].

The schematic diagram of the conversion of ambient energy into electrical energy is shown in Fig. (1). The energy supply (solar, mechanical, thermostat, RF) is converted into electrical energy. In order to store extracted power, the energy storage device is almost always required. Since the charge energy and the storage area have different voltage levels, it is necessary to have a voltage controller. Electrical charge typically includes one or more sensors, an RF transceiver, and a microcontroller that wirelessly transmits the sensed information [6].

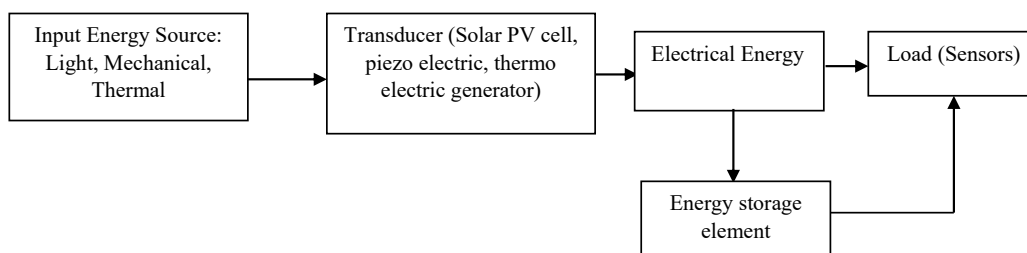


Fig. (1). Schematic Diagram of Ambient Energy is converted to Electrical Energy [6].

1.1. Peltier Effect

The Peltier effect is a phenomenon where heat is absorbed at a link between materials; heat is released at a different intersection, as shown in Fig. (2), when a current (I) flows through the material [7, 8],

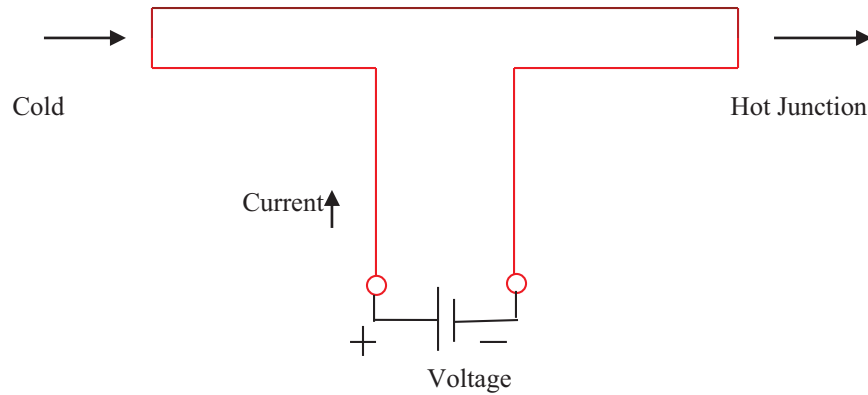


Fig. (2). Schematic diagram of Peltier effect [8].

The Peltier effect is used to describe the sum of Q_p for heat absorption and heat release in the following equation [9]:

$$Q_p = \Pi_{ab} \cdot I \quad (1)$$

1.2. Thomson Effect

The Thomson effect is a phenomenon where heat is absorbed or emitted as the current passes through the material. Thomson effect is expressed in the following equation as quantities of heat (Q_T) absorption or heat discharge per unit volume [9]:

$$Q_T = \tau J \frac{dT}{dl} \quad (2)$$

1.3. Figure of Merit

A Figure of merit (ZT) shall be a number used in comparison with its alternatives to differentiate between systems, devices or processes. Figure of merits are also

CHAPTER 3

Solar Electric Vehicle Charging and Grid Interaction: An Integrated Module**D. Muruganandam^{1,*}, J. Jayapriya², P.K. Chidambaram³ and B. Karthik Anand⁴**¹ *Department of Mechanical Engineering, Adhi College of Engineering and Technology, Tamilnadu, India*² *Department of Mathematics, Sathyabama Institute of Science and Technology, Chennai, Tamilnadu, India*³ *Department of Mechanical Engineering, Newprince Shri Bhavani College of Engineering and Technology, Chennai, Tamil Nadu, India*⁴ *Sathyabama Institute of Science and Technology, Chennai, Tamilnadu, India*

Abstract: Electric mobility is one of the key technologies for the replacement of non-renewable energy sources in the long term; creating new markets, opportunities, and new technologies, as the old energy order comes to an end with the evolution of new ones. With the passing of around two centuries, electric vehicle technology has developed to different levels across the globe. Norway has the highest percentage of electric vehicles, while China has the highest number of electric vehicles sold per year in the world. India is catching up with electric vehicle penetration. As per 2018 data, 49% of the total vehicles sold in Norway were electric. In 2019, China registered the maximum number of electric vehicles sold – 1.15 million vehicles. The key advantages of e-mobility are a reduction in GHG emissions, a reduction in the dependency on fossil fuels, higher efficiency compared to ICE vehicles, fewer noise emissions, and the flexibility of EVs becoming a platform for collaborative development of autonomous cars and shared mobility and MaaS. The key challenges are the total cost of ownership, charging infrastructure, reliance on the imported content and parts, customer acceptance of EVs, vehicle range anxiety and battery manufacturing, and availability of raw materials. This research investigates in detail the opportunities created by technologies such as solar-powered vehicle charging, the second life of traction battery, smart grid integration, connected and autonomous CAVE and vehicle light-weighting to enable e-mobility as a more commercial means of transportation.

Keywords: CAVE, GHG, ICE vehicles, MaaS.

* **Corresponding author D. Muruganandam:** Department of Mechanical Engineering, Sri Venkateswaraa College of Technology, Tamil Nadu, India; E-mail: murudurai@gmail.com

1. INTRODUCTION

A disruptive innovation is an innovation that creates a new market and a value network and eventually disrupts an existing market and value network, displacing established market-leading firms, products, and alliances. There was a disruption in computer technology that started in 1970s and ended with a revolution in speed, structure, communication and size as shown in Fig. (1).



Fig. (1). Tipping point and disruptions.

Similar to the computer technology disruption, the first working electric motor and electric vehicle was built by Thomas Davenport, an American from Vermont, in 1834. It was a small locomotive that used two electromagnets, a pivot and a battery. There were other inventors like Robert Anderson of Scotland (1830s) who had created a fully electric carriage. The evolved architecture EV is shown in Fig. (2).

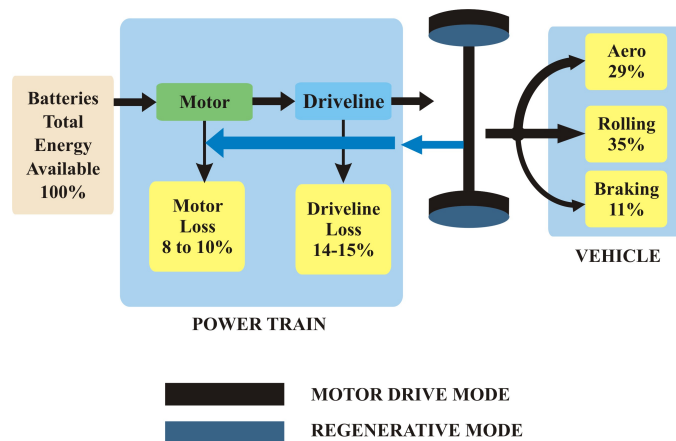


Fig. (2). Electric vehicle architecture.

EV disruptions that are going to be the tipping point are,

- 1) Big data for decisions (expected to be commonplace by 2023 - 2025);
- 2) Autonomous cars (by 2026 - 2027);

- 3) Artificial Intelligence and decision-making (also, by 2030);
- 4) Connected vehicles (by 2030).

Before delving into the challenges and opportunities in EVs, it is worthwhile to look into the advantages and disadvantages of EVs.

1.1. Advantages of Electric Vehicles Over ICE Vehicles

The total cost of ownership of an electric vehicle (EV) is lesser in comparison to a conventional fuel vehicle. Typical life of a battery is around 8 to 10 years, after which it will still find uses in storage and other less complex applications. Electric vehicles (EV) have relatively fewer moving parts, *i.e.*, 75 to 80% less compared to the internal combustion engine vehicles. Due to the above characteristics, electric vehicles are easily adoptable for implementing autonomous technologies which results in autonomous driving. They also reduce emissions to help the environment (less pollution, renewable energy, eco-friendly materials). The battery cost is also expected to be half of the current price in the next 5 years.

1.2. Disadvantages of Electric Vehicles over ICE Vehicles

The affordability of electric vehicles will be of great concern at least for another decade till the prices of batteries become cheaper. In order to decide on the right technology for charging, numerous studies have been undertaken and many are still in progress in understanding the different modes of charging. Customers have options for night charging, home charging, public charging station, charging on the go, wireless charging, swappable solutions, opportunity charging, charging on malls and restaurants and charging at gas stations. The right technology needs are to be made standard. The investment for the charging stations is seen to be higher and subsidies are being provided for using the charging stations. Mergers and acquisitions of market leaders by sustaining business giants are slowly changing the scenario, but are time bound. The majority of the vehicle OEMs in the EV horizon are also in the process of establishing their standard chargers, taking into account customer requirements.

With countries going to end the non-renewable sources in respective years as given in Fig. (3), the e-mobility enablers are to be implemented on a holistic basis to have a seamless integration.

A Review of the Current Challenges on the Issues of Scramjet Combustion Engines

Namrata Bordoloi¹, K. M. Pandey^{1,*}, K. K. Sharma¹ and Dharmendra Sapariya²

¹ Department of Mechanical Engineering, National Institute of Technology Silchar, Assam, India-788010

² Department of Mechanical Engineering, IITE, Indus University, Ahmedabad, India-382115

Abstract: Scramjet technology is one of the revolutionary technologies of the hypersonic industry. The scramjet engine uses air-breathing propulsion technology, which has been proven to be the most promising technology for high Mach number flights. The paper focuses on the status, key challenges and future scope of the scramjet engines. This paper presents an extensive literature review of the experimental and computational studies carried out by various researchers around the globe. In this paper, the current developments in scramjet technology and its future scope are precisely stated. It is concluded from the review that the flow inside the scramjet combustor is very complex and sensitive. The understanding of the turbulence, boundary layer formation and separation, physics of the flow, and the physiochemical processes involved in combustion still require extensive dedication of researchers in the near future to address the stated problems.

Keywords: Boundary layer interaction, Flame structure, Mach number, Supersonic combustion.

1. INTRODUCTION

Aerospace technology is advancing towards the possibility of supersonic or hypersonic technology in propulsion systems for space and military applications. The hypersonic industry is thriving with the success of the X-43A and X-51A, scramjet engines are considered the next generation of space vehicles [1]. Researchers are making a constant effort to find economical solutions to assess space by designing launch vehicles that can fly at hypersonic velocities. One such solution is air-breathing engines that use atmospheric oxygen for the combustion

* Corresponding author K. M. Pandey: Department of Mechanical Engineering, National Institute of Technology Silchar, Assam, India- 788010; E-mail: kmpandey2001@yahoo.com

process. These engines have proved to be superior to any chemical propulsive device in terms of cycle efficiency. These vehicles do not carry any fuel-oxidizer, thus allowing a larger payload than any other conventional system [2]. The concept of Scramjet was first proposed by Antonio Ferri in 1950 [3]. The scramjets start their operation as the flight exceeds Mach number 5, and to escape aerodynamic losses, the combustion is maintained at supersonic speeds [4].

1.1. Principle of Scramjet

The scramjet engine comprises an inlet, an isolator, a fuel injection system, a combustion chamber and an exhaust nozzle [5]. When the vehicle moves forward, air enters the inlet. The air gets rammed, which leads to the formation of shock waves (*i.e.* oblique shock wave). Due to the formation of shock waves, there is an increase in the temperature and pressure. This high pressure and temperature air moves towards the combustion chamber and mixes with the fuel.

The fuel is injected through the fuel injection system and the combustion takes place. The combustion process occurs at supersonic speeds, thus completed within milliseconds. Due to the combustion process, flue gases are evolved which expand through the exhaust nozzle. Due to expansion, the engines get enough amount of thrust to overcome the drag forces of air. The scramjet engines work on the Brayton cycle. Under laboratory conditions, the concept of supersonic combustion was first described in the year 1960 [6]. As shown in Fig. 1, the air flowing into the intake is compressed and decelerated by a series of shock waves known as oblique shock waves. There is an increase in pressure and temperature due to the compression of air. These high-pressure and high-temperature waves reach the combustion chamber at supersonic speeds. In the combustion chamber, fuel injectors inject fuel. Because the flow inside the combustion chamber is supersonic, there is extremely little time for the combustion process to take place. Flue gases are expelled from the exhaust nozzle after the combustion process, producing the push required for the vehicle to move ahead. The Brayton cycle governs the operation of the scramjet engine [8].

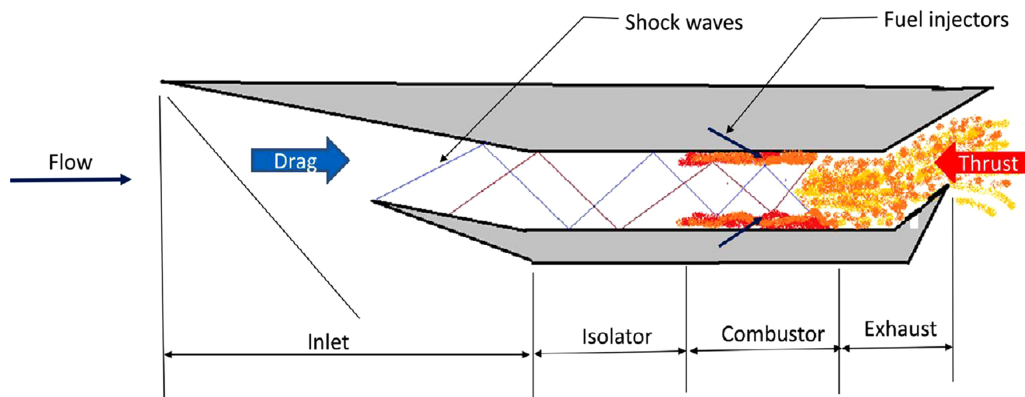


Fig. (1). Scramjet engine working principle (Schmetric Diagram).

Fig. 2 shows the dual Combustor Scramjet of Waltrup in 1997. A model with two combustors is used in this design: an initial subsonic combustor that runs on fuel, and a coaxial supersonic burner that finishes the combustion process. Various piloting approaches are used in other hydrocarbon-fuelled engine types. The wall pilot, split-inlet pilot and catalytic pilot are examples of such approaches [5].

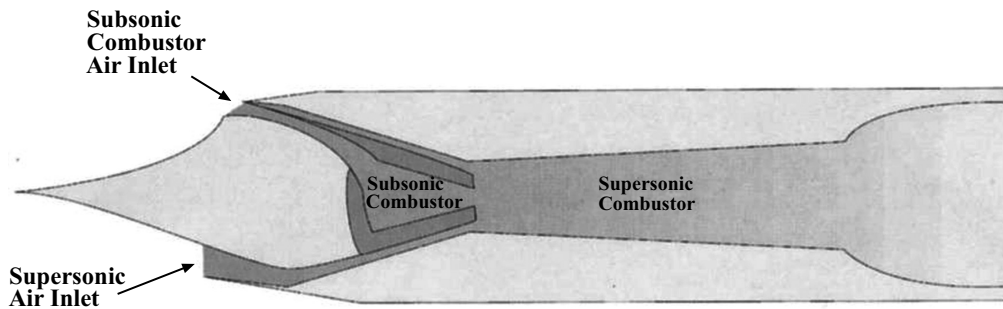


Fig. (2). Dual Combustor Scramjet.

Scramjet research in the United States began in the 1940s. By the end of 1950, the NASA and the US Navy were developing scramjet engines. The first major project on the scramjet engine, named the Hypersonic Research Engine (HRE) was started in the United States [7]. Other nations have also contributed greatly to the evolution of scramjets.

Review of the Role of Geometrical Modification of Scramjet Combustor on Performance Characteristics

Kumari Ambe Verma¹, K. M. Pandey^{1*}, K.K. Sharma¹ and Dhiren R. Patel²

¹ Department of Mechanical Engineering, National Institute of Technology, Silchar, Assam, India

² Mechanical Engineering Department, IITE, Indus University, Ahmedabad, Gujarat, India

Abstract: The current scenario in the field of aviation is focused on hypersonic-speed vehicles. To achieve the required performance, engines have to be designed in such a way that their outcome should be maximum. Nowadays high-speed performance engines have utilized a type of air-breathing engine amongst which, the scramjet is found appropriate. However, the engine can only perform under atmospheric area because the supersonic combustion ramjet engine utilizes the atmospheric air as an oxidizer. Nonetheless, engines do not comprise any rotating or moving parts. So, to complete the mixing and chemical kinetics, engine geometry has special dimensions. The present chapter is focused on a rigorous review of the geometrical modification of the combustor and fuel injector. The impact of mixed fuel, different types of working fuels, and variable inflow conditions have been explored to uncover the beneficial effects on scramjet combustion performance. Since numerous authors have explored different aspects of the ongoing challenges in scramjet hence a summary has been drawn to acquire a suitable model for future work.

Keywords: Combustion Characteristics, Fuel Injection Strategy, Geometrical Modification, Inflow Conditions, Supplementary Fuels.

1. INTRODUCTION

A supersonic combustion ramjet engine is a type of air-breathing engine, which performs all the thermodynamic processes at the supersonic speed level. Any kind of air-breathing engine utilizes the incoming free stream atmospheric air to participate inside the combustor for the completion of chemical kinetics. As shown in Fig. (1), the Scramjet engine comprises three major sections *i.e.*, a converging inlet, a combustor, and a diverging nozzle. The respective four

* Corresponding author K. M. Pandey: Department of Mechanical Engineering, National Institute of Technology, Silchar, Assam, India; E-mail: kmpandey2001@yahoo.com

processes of every engine are compression, combustion, expansion, and exhaust. However, the behavioral impact will change by changing the working conditions of the engine and also its applications [1 - 3]. The specialty of scramjet can be identified by looking at its geometrical configuration *i.e.*, no moving or rotating parts are utilized for completion of the all the processes. So, to create a desirable environment inside the respective section of the scramjet, several approaches are used. Fuel injection strategy and mixing approach in the supersonic combustor can be considered as a leading parameter for achieving higher combustion efficiency and stability [4 - 6]. Through various experimental and numerical investigations of a supersonic combustor, different aspects of ongoing challenges have been performed by many authors, few major considerations have been categorized as follows:

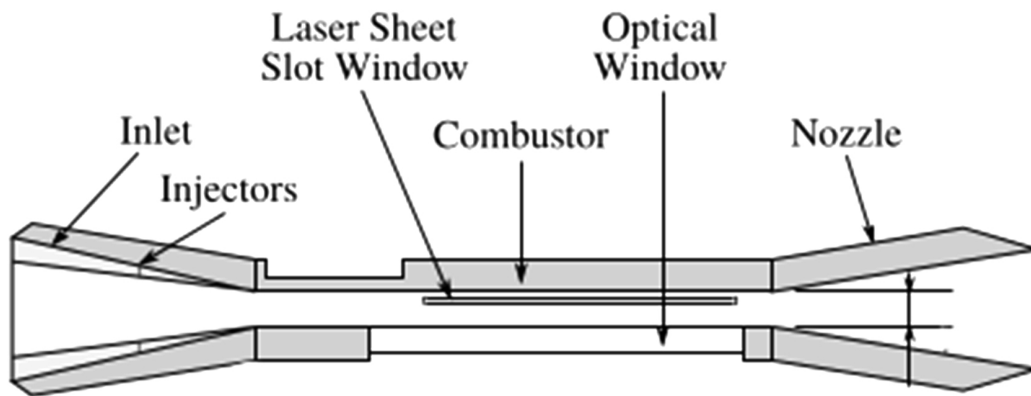


Fig. (1). Scramjet Engine Model.

2. SCRAMJET GEOMETRICAL MODIFICATION

The scramjet engine comprises an isolator, a fuel injection system, a combustion chamber, and an exhaust nozzle. Since all the thermodynamic processes of the scramjet engine are completed in the restricted length of the scramjet. Hence the modifications in the combustor geometry and fuel injection implication have a major influence on the desirable outcome.

2.1. Combustor Geometry

The supersonic combustion ramjet engine does not involve any moving parts. Therefore, Combustor geometry should be designed in such a way that a beneficial environment arises to complete the mixing between incoming fuel and air. During the combustion process, chemical kinetics should evolve rapidly to

create a stable flame entirely. To keep in mind the above phenomena, the below-mentioned subsections are drawn:

2.1.1. Combustor Wall Transverse Fuel Injection

A numerical investigation of a two-strut scramjet combustor was performed by Gautam Choubey and K. M. Pandey [7, 8] to explore the effect of a wall transverse fuel injector. Four different cases were compared and among them, two struts with lower wall transverse fuel injectors at two subsequent locations were found appropriate in regards to mixing performance because fuel penetration was identified deeper in the same case so it leads to better combustion. The same author has also examined the double cavity scramjet combustor [9] by numerical investigation. Eight different sets of the investigation were performed by changing incoming fuel and air boundary conditions. The author concluded that the high-pressure regimes near the cavity could help to create a favorable environment for mixing and stable combustion. An experimental investigation has been performed in the supersonic flow field with a cavity present at the combustor wall. Since the presence of a wall cavity has been identified as a flame holder in the supersonic flow regimes. Yueming Yuan *et al.* [10] approached a similar investigation by changing incoming boundary conditions. To uncover the flame behavior near the cavity, temperature and equivalence ratio were scrutinized. The author identified four different locations at which flame was seen stabilized *i.e.* inside the cavity domain, shear layer around the wall cavity, near jet wake, and also in the oscillation region generated between jet wake and cavity. A strong correlation was recognized that the flame balance in the turbulence regions could be affected by temperature and the global equivalence ratio.

O. R. Kummitha *et al.* [11] optimized the cavity geometry and wall fuel injection position to explore the flow field characteristics. The author concluded that the geometry design is responsible to increase the thickness of the recirculation region and also shear mixing layer growth. Nonetheless, an additional upper wall cavity was found helpful toward combustion stability. The computational investigation was performed by Wei Huang *et al.* [12] to explore mixing augmentation by utilizing a novel step at the lower combustor wall. The combined effect of oblique shock wave and the influence of jet location and jet pressure ratio were examined. A conclusion has been drawn by the author that to lengthen the residence time, oblique shock waves were found suitable nonetheless larger jet pressure ratio was responsible to create a recirculation region near the novel wall step. Hence the above combination can be further promoted for mixing enhancement. K. M. Pandey *et al.* [13, 14] numerically investigated wall cavity scramjet combustors at higher air Mach numbers. A further performance was also done by utilizing

SUBJECT INDEX

A

Adaptive mesh refinement (AMR) 166
 Aerospace technology 104
 Air 2, 6, 7, 25, 26, 105, 108, 113, 117, 118,
 122, 123, 131, 132, 133, 154, 161
 clean 113
 polluted 2
 Antarctic power generation 37
 Artificial intelligence 69, 80
 Automotive engineers 82

B

Battery 81, 91, 97, 100
 monitoring system (BMS) 81, 100
 storage systems 91, 97
 Biomass 3
 burning 3
 energy 3

C

Carbon dioxide 5, 10, 11, 12
 atmospheric 5
 total 11, 12
 Carbon nanotubes 46
 Cars 67, 68, 70, 84, 94
 autonomous 67, 68
 electric 84
 CAVE, autonomous 67
 CFD-based hypersonic research 109
 Charge 33, 56, 76, 77, 78, 86, 92, 96, 97
 electrical 33, 56
 real-time 76
 Charging stations 69, 71, 82, 83, 85, 86, 89,
 90, 94
 public 69
 Chemical energy 3
 Chevrolet suburban suspension 56
 Chip, heat-generating 43

Coal power plant 2
 Combustion 104, 105, 107, 108, 109, 110,
 111, 114, 116, 122, 123, 124, 125, 126,
 127, 128, 129, 130, 131, 134, 135, 137,
 138, 139, 140, 151, 153, 158, 166, 167,
 168
 chamber 105, 107, 122, 123, 124, 125, 126,
 129, 137, 138, 139, 151
 dynamics 116, 130
 efficiency 123, 124, 125, 126, 127, 128,
 129, 130, 131, 134, 135, 137, 140, 153,
 158
 hydrogen-air 167
 oscillation 168
 Combustion process 105, 106, 107, 108, 113,
 121, 124, 127, 136, 137, 139, 140
 supersonic 140
 Combustor 113, 119, 153
 kerosene-fuelled 119
 pressure 113
 wall cavity 153
 Computational fluid dynamics (CFD) 109,
 112, 154
 Condensers 1, 8, 14, 18, 21, 24, 25, 26
 air-cooled 1, 8, 14, 18, 26
 cooled 21, 25, 26
 Condensers consumption power for 22, 23
 geothermal 22
 ORC 23
 Condensing chamber 52
 Conductivity, electrical-thermal 49
 Cooled condenser power consumption 23
 Cooler 43, 53
 electric solar 53
 thermoelectric micro 43
 vapour compression 53

D

Demand side management (DSM) 99
 Devices 33, 34, 35, 42, 59, 71, 78, 79, 93, 105
 auxiliary 93

- blue tooth 71
- chemical propulsive 105
- electrical 59
- electronic 42, 59
- energy storage 33
- Dynamic 165, 166
 - adaptive chemistry (DAC) 165
 - mode decomposition (DMD) 166

E

- Economical storage methods 32
- Eddy dissipation model (EDM) 165
- Electrical and mechanical transducers of energy 56
- Electricity 1, 2, 3, 4, 5, 6, 35, 36, 37, 40, 59, 60, 71, 73, 85, 95
 - energy grid supply 95
 - generator 59
 - grid-connected renewable 85
 - sources 5
- Electric power 5, 6, 33
 - global 5
- Electric vehicle 67, 92
 - charging 92
 - technology 67
- Electrolysis corrosion 35
- Emissions 1, 2, 3, 5, 10, 69, 80, 93
 - carbon 3
 - greenhouse 80
 - harmful gas 1, 5
- Energy 1, 2, 3, 4, 5, 8, 10, 11, 12, 19, 32, 33, 36, 56, 59, 60, 74, 76, 84, 85, 86, 87, 88, 89, 96, 131, 138
 - charge 33
 - consumption 1, 11
 - conserve atmospheric 33
 - converting heat 33
 - electrical 33, 36, 56
 - kinetic 131, 138
 - solar heat 19
 - storage systems (ESS) 86, 87, 88, 89, 96
 - suppliers 85
 - sustainable 84
 - waste heat 32
 - waste thermal 33
- Energy generation 10, 32, 41, 59, 70
 - landscape 70
 - techniques 32
- Energy sources 1, 2, 4, 5, 8, 41, 67, 86, 95

- non-renewable 2, 67
 - nuclear 5
 - weather-dependent renewable 95
- Engine vehicles 69, 89, 101
 - internal combustion 69, 101
- Equipment 35, 48, 81, 83, 96
 - electrical 35
 - electronic 48
 - thermoelectric 35
- Eulerian stochastic fields (ESF) 166

F

- Field 49, 50, 60, 92, 109, 141, 150, 166
 - electrical 50
 - magnetic 92
- Flame 108, 109, 110, 113, 114, 115, 118, 119, 120, 121, 123, 124, 125, 159, 160, 164, 166, 167, 168, 169, 170
 - detached 125
 - heated 115
 - intensity 168, 170
 - oscillation 118, 119, 121
 - propagation process 120
 - quenching 114, 166
 - stability 108, 114, 119, 164, 167
 - steady 110
- Flame stabilization 108, 109, 114, 115, 116, 120, 121, 140, 158, 160, 162, 163, 164, 165, 166, 167
 - analysis 158, 160
 - mechanisms 115, 140
- Flux, thermoelement heat 50
- Fraction 12, 13, 80
 - dryness 12
 - vapour 13
- Fuel 2, 35, 38, 46, 67, 70, 85, 105, 108, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 127, 131, 132, 133, 140, 162
 - carbon-based 2
 - forest 35
 - fossil 2, 38, 46, 67, 85
 - gaseous ethylene 117
 - injecting 116
 - kerosene 110, 111
 - pioneer hydrogen 162
 - renewable 70

Subject Index

Fuel injection 105, 108, 117, 118, 120, 122,
130, 131, 132, 133, 134, 135, 139, 151,
154
transverse 135
mechanics 139
system 105, 120, 151
Fuel injector geometrical modifications 155

G

Gas(es) 8, 10, 11, 32, 33, 35, 69, 110
harmful 10
hot 110
natural 8, 35
production 11
stations 69
turbine 32, 33
Gasoline 70
Geothermal 8, 9, 12, 15, 17
fluid 8, 9, 15, 17
kalina cycle 12
Geothermal power 1, 5, 12
cycle 12
development 1, 5
Geothermal-solar power 1, 14
generation 1
plant 14
Greenhouse gases 40

H

Heat 7, 16, 18, 20, 23, 34, 35, 37, 38, 39, 42,
134
absorption 34
discharge 34
efficiency 16
generation 42
loss 38
pump 35, 42
radiological 37
release combustion 134
resistance 18, 42
source 35, 39
transfer 7, 18, 20, 23
Heating 2, 8, 9, 40, 41, 42, 60
combined 60
geothermal fluids 8
removal system 42
High-speed 114

Materials and Technologies for a Green Environment 181

framing flame luminosity 114
High-speed photography 113, 119, 121
and pressure 119
Human-machine interface (HMI) 82
Hybrid thermo electric generators 52
Hydrocarbon fuels 108, 110, 113, 119, 161
Hydrogen 108, 113, 114, 115, 116, 117, 118,
119, 122, 123, 127, 131, 132, 133, 161,
162, 165
combustion of 108, 116
fueled combustor 165
gaseous 108, 113, 118
Hydroxyl tagging velocimetry (HTV) 119
Hypersonic 106, 163
flow conditions 163
research engine (HRE) 106

I

Ignition ratio 115
Injection techniques 162, 164
Injectors, kerosene-fuelled 116
IOT monitoring system 80

K

Kerosene 116, 162
burning stage 116
equivalence ratio 162
injection 162
Kinetic and potential energy 15

M

Macro 59
scale applications 59
waste heat applications 59
Mass 121, 127, 129, 155, 159, 169
fraction 121, 127, 129, 155
transfer 159, 169
Mechanical 56
tension 56
transducers 56
vibration 56
Micro scale applications 59
Mobility technology 101
Modbus transmission 78

N

Natural hot spring 3

O

Omega ethylene air 132
 Operation 26, 86, 89, 93, 105, 107
 charge-sustaining 93
 Organic 1, 5, 8, 52
 photovoltaic thermoelectric 52
 rankine cycles 1, 5, 8
 Oscillations, low-frequency 114
 Oxide thermoelectrics 49

P

Partially stirred reactor (PaSR) 168
 Photo voltaic (PV) 71, 73, 76, 81, 82, 85
 Planar laser-induced fluorescence (PLIF) 163
 Plants, hybrid geothermal solar 26
 Polluted environment 2
 Power 1, 3, 9, 10, 11, 12, 21, 26, 27, 32, 35,
 36, 56, 57, 59, 60, 71, 74, 76, 77, 83, 84,
 85, 87, 88, 94, 96
 advanced charge controller monitors 77
 consumption 11, 21
 condenser 26
 electrical 32, 56
 generation 9, 10, 11, 27, 32, 56, 74, 84, 85
 hybrid solar-geothermal 12
 hydroelectric 3
 nuclear 59
 photovoltaic 76
 predestined thermoelectric 59
 source 27, 56, 71, 85, 94, 96
 thermal 57
 Power plants 1, 5, 6, 7, 11, 15, 18, 19, 21, 23,
 26, 27, 32, 38, 39
 gas 38, 39
 geothermal solar 26
 hybrid 1, 11, 18, 19, 26, 27
 natural gas 5
 thermal 38
 Pressure oscillation 154
 Probability density function (PDF) 109, 166
 Process 1, 2, 14, 25, 34, 38, 41, 53, 69, 98,
 105, 112, 110, 150, 151, 160
 conversion 38

co-rotating vortices merging 160
 fuel-burning 112
 natural 2
 thermodynamic 150, 151
 Properties 48, 49, 50, 108
 electronic 50

R

Renewable energy 1, 2, 3, 4, 8, 9, 33, 69, 94
 Resources 3, 5, 10, 11, 99
 fossil energy 10
 renewable 3
 temperature geothermal 5

S

Scramjet 115, 126, 136
 combustion 115, 136
 operation 126
 Scramjet combustor 113, 120, 123, 126, 127,
 130, 131, 136, 153
 cavity-based 130, 131, 136, 153
 ethanol-fuelled cavity-induced 113
 ethylene-fuelled 127
 hydrogen-fuelled 123, 126
 kerosene-fuelled 120
 Scramjet engine 104, 105, 106, 107, 108, 109,
 110, 111, 119, 123, 124, 125, 126, 140,
 141, 151
 hydrocarbon-fuelled 119
 Sensors 33, 59
 electronic 59
 Solar 1, 3, 5, 8, 12, 27, 35, 52, 70, 71, 72, 73,
 74, 78, 81, 82, 83, 84, 85, 91, 97
 absorption bladder 52
 cells 3, 72
 charge controller 73
 geothermal power generation plants 12
 mobile 71
 photovoltaic 85
 radiations 52, 73
 reliable hybrid geothermal 27
 source generators 35
 thermal energy generators 35
 Solar energy 3, 4, 5, 6, 8, 9, 12, 13, 19, 70, 71,
 72, 83, 84, 85
 devices 8
 generation 84

Subject Index

source 9
Solar power 5, 6, 12, 70, 74, 75
 generation 70
 grid 74, 75
 plants 5, 6, 12
Sonic condition 117
Stability, thermodynamic 50
Storage systems, stationary energy 86, 87
Stream, supersonic air 139
Strut 117, 120, 121, 122, 123, 124, 131, 132,
 133, 134, 135, 136, 137, 140, 154, 155,
 157, 158, 162, 163, 164, 168
 based combustors 154, 157, 168
 hydrogen-fuelled 135
 injectors 136, 137, 157, 163
 wedged-shaped 137
Supersonic combustion 104, 105, 107, 115,
 157, 159, 163, 164, 165, 166, 170
Supersonic combustor 109, 110, 112, 114,
 119, 123, 151, 157
 ethylenefuelled 114
 fuelled cavity 109
Systems 11, 14, 35, 45, 55, 60, 77, 88
 automobile air conditioning 45
 automotive 45
 automotive air conditioning 45
 intelligent remote sensor 55
 photovoltaic 77
 power conversion 88
 power generation 11, 35
 solar heating 14
 waste heat storage 60

T

TDAC method 165
Techniques 119, 140, 164
 combustion flame stabilization 140
 molecular tagging 119
 transpiration cooling 164
Technology 104
 air-breathing propulsion 104
 hypersonic 104
TEG 40, 42
 electricity generation 42
 power generation system 40
Thermal 48, 50, 51, 60
 conduction 50
 conductivity 48, 50, 51, 60
Thermo electric 35, 42, 43, 45, 56

Materials and Technologies for a Green Environment 183

cooler (TEC) 42, 43, 45
generators 35, 56
Thermoelectric 32, 35, 36, 40, 41, 43
 coolers 43
 forces 41
 heating 35
 power generators 32, 40
 radioisotopes 36
Thermoelectric refrigerator 53, 54
 photovoltaic-powered 53
 powered 53
Turbine, hot 1
Turbulence intensity 155, 169
Turbulent 117, 120, 122, 140, 161, 169
 diffusion flames 122
 flow dynamics 140
 Schmidt number 117
 viscosity 120

V

Vehicle 69, 81, 95, 96
 battery 81, 96
 drivers 95
 grid integration (VGI) 95, 96
 OEMs 69
Voltage controller 33

W

Wall fuel injection 163, 170
Waste 32, 52, 59, 91
 fuel 32
 solid 32, 59
Waste heat 32, 38, 39, 59
 industrial 59
 recovery 32, 38
Waste recycling 41
Well-stirred reactor (WSR) 166
Wind 2, 5
 energy 2
 sources 5
Wireless 39, 92
 sensor network 39
 transfer 92



Santhanam Harikrishnan

Dr. Santhanam Harikrishnan received his B.E. in Electrical & Electronics Engineering from the University of Madras, in 2002; M.E. in 2007 and Ph.D. in 2015 in Mechanical Engineering from Anna University. He is the Professor and Head of the Department of Mechanical Engineering at Kings Engineering College, Chennai, India. He is an active researcher in the fields of phase change materials, nanofluids, and supercapacitors. He has published many papers in refereed journals including Elsevier, Springer, IEEE, IOP, and Taylor & Francis and in conference proceedings. He served as panel session chair, reviewer, and Guest Editor for international conference proceedings.