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# Book Review

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## *The Scramjet Engine, Processes and Characteristics*

Corin Segal, Cambridge University Press, New York, 2009, 253 pp., $125.00

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Development of the supersonic combustion ramjet (scramjet) engine has gained renewed interest in recent years with a number of significant programs evolving to the stage of flight testing. Despite this progress, there is a scarcity of books focusing on the scramjet with perhaps the most popular being the text by Heiser and Pratt [1] published in 1994. Curran and Murthy [2] edited an excellent compilation of scramjet-related papers in 2000 that included some fundamental process descriptions in addition to updates on relevant projects around the world. While it is acknowledged that much of the detailed developments in this area are held closely by the organizations performing the work, an entry level text providing a broad overview of the essential elements of the scramjet has been lacking. Corin Segal is a leading researcher in the area of scramjet development and has worked on relevant problems in an academic setting since the National AeroSpace Plane (NASP) program in the late 1980s. His book fills the aforementioned gap and provides an excellent initial look at this exciting subject. The book also brings the reader more up to date with brief overviews of domestic and international activities from the last decade.

The first chapter opens with the technical basics comparing key elements of subsonic and supersonic combustion. The benefits of maintaining supersonic flow throughout the engine at high flight Mach numbers are explained and the concept of the thermal throat is introduced. Also included in the chapter is a brief historical overview providing a review of major activities in the area including postNASP programs such as X-43, HyTech, HIFiRE, and X-51.

The theoretical background needed to understand the phenomena associated with scramjets is discussed beginning in the second chapter. Several sections describe the essential relationships of compressible flow with chemical reactions including the basics of shock waves and Rayleigh flow. Fundamental equilibrium and finite rate chemical reactions are discussed in addition to some of the unique characteristics of high temperature air including dissociation and compressibility. Chapter three goes into more technical detail with some specific features of hypersonic and high energy flows presented. The sections on kinetic theory and statistical thermodynamics will likely challenge the attention span of the primary audience for this book but their inclusion is needed for completeness.

An introduction to cycle analysis is presented in chapter four with highlights of trajectory optimization and performance analysis. Given the recognized need to accelerate a ramjet/scramjet powered vehicle to speeds sufficient for the required aerodynamic compression, both turbine and rocket-based combined cycle (TBCC and RBCC) systems are discussed.

A couple of advanced TBCC systems including the deeply cooled turbojet thermally integrated with a liquid rocket engine (known in the field as KLIN$^{TM}$) and the liquid air cycle engine are described with the traditional over/under concept only mentioned briefly. More time is spent on RBCC concepts, most likely because the ability to integrate small rockets into a scramjet flowpath provides interesting issues for discussion and analysis. The chapter that follows provides a relatively thorough discussion of inlet design and analysis issues including several pages dedicated to advanced topics such as magnetohydrodynamic deceleration and flow control via fuel injection. Nozzles are given significantly less attention, though important issues including airframe integration and recombination losses are mentioned.

Chapter six covers supersonic combustion processes, and it is clear from the level of detail presented that this is an area where the author has a great deal of experience. This chapter is one third of the book and is organized as a logical progression of complexity starting with basic time scales and shear layer behavior through fuel injection and mixing and chemical kinetics for systems with relevant fuels. The challenging and highly important topics of flame stability and combustor-inlet interaction (and isolator design) are described in detail and flowpath geometric considerations are included in the context of combustion section design. Fuel management, a critical topic for practical scramjet systems, is also discussed with the issues and challenges relating to the employment of endothermic fuels and their associated decomposition nicely summarized.

The final two chapters cover testing methods and relevant methods of computational fluid dynamics (CFD), respectively. A description of the various types

of hypersonic propulsion test facilities is provided along with an overview of several major long and short duration facilities, primarily in the United States. The CFD chapter provides a good primer for more advanced reading on the subject and focuses intentionally on the modeling aspects of physical processes with particular attention paid to reacting flows. This is consistent with the emphasis placed in this area earlier in the book and the author appropriately describes the complexity of the problem at hand and the state of the art in terms of published results.

In summary, Segal has done a commendable job of providing a needed introductory book on the subject of scramjets. In addition to providing an excellent reference for the engineer beginning his/her work on scramjets, the book provides a good update on the improvements in the state of the art in the last 10 years. As such, it is deserving of a place on every scramjet engineers bookshelf, particularly those interested in details relating to supersonic combustion.

## References

[1] Heiser, William H., and Pratt, David T., *Hypersonic Airbreathing Propulsion*, AIAA Educational Series, edited by J. S. Przemieniecki, AIAA, Reston, VA, 1994.

[2] Curran, E. T., and Murthy, S. N. B. (eds.), *Scramjet Propulsion*, Progress in Astronautics and Aeronautics, Vol. 189, AIAA, Reston, VA, 2000.

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