■日本燃焼学会創立50周年記念特集■

Fifty Years of Magnificent Combustion Research in Japan

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It is an honor and pleasure for the author to participate in the celebration of the fiftieth anniversary of the founding of the Combustion Researchers' Society of Japan. In these fifty years the contribution of our Japanese colleagues to the science and technology of combustion has been truly remarkable, paralleling the equally impressive growth of combustion at the global level as a practically important and intellectually stimulating branch of science. The latter fact is consistent with, and a tribute to, the swiftness with which new ideas are typically harvested and new frontiers expanded by the Japanese scientific enterprise, from aerodynamics to particle physics. Thus while we celebrate this important anniversary event in combustion, we are also reminded of, and indeed are grateful for, the important role that Japan has played in the advancement of science in the modern era.

The impact of the magnificent combustion research performed by our Japanese colleagues can perhaps be best illustrated through the works of Professors Seiichiro Kumagai and Hiroshi Tsuji, who were by all measures two of the giants in combustion. Specifically, Professor Kumagai was among the first group of eminent scientists, including S. S. Penner and D. B. Spalding, who initiated in the early 1950s the study of droplet combustion for its relevance to spray combustion and the modeling of liquid-fueled rockets. The concerted effort culminated in the theoretical formulation and experimental verification of the classical d^2-law of droplet combustion. The unique role that Kumagai played in this endeavor was his distinctive departure from the avenue pursued by others, who usually just measured the droplet surface regression rate in atmospheric conditions, which is a rather simple task. Kumagai, however, recognized the importance of buoyancy which distorts the flame shape from spherical, based on which the d^2-law was formulated. He subsequently designed a free-fall experiment through which the intruding influence of gravity was eliminated. It was an arduous and brave undertaking, but the effort paid off in his eventual reporting of the burning rate and the flame-front movement of spherically symmetric droplet combustion, accompanied by beautiful images of a spherical flame concentrically enveloping a vaporizing droplet. There are three important implications of this work. First, it yielded the first bench-mark datum on the droplet burning rate constant that conforms closely to the specifications of the d^2-law. This datum is essential because it allows the quantification of various effects influencing the d^2-law, and through it the assessment of their correctness with confidence. Second, the flame images showed a temporally increasing and then decreasing flame diameter, with the increasing trend extending far beyond the influence of droplet heating. This subsequently led to the identification of the importance of fuel vapor accumulation in droplet burning, and by extension the inadequacy of steady-state formulations of flame phenomena affected by initial conditions. Third, and perhaps most significant, is that this work ushered in the era of microgravity combustion research in that, subsequent to Kumagai's experiment, extensive microgravity combustion research at the international level was developed, leading to a sustained period of activity from the 1970s until the present day. One of the most important developments was the construction of the 10-second drop facility in Japan, offering substantially more free-fall time than those at the NASA Glenn Research Center and elsewhere. Consequently, substantial amount of valuable microgravity combustion results were acquired, on single and multiple droplet combustion, flammability of ultra weak flames and how they are affected by radiation loss, particle cloud combustion, fire research, diagnostics, and soot formation. These high-quality results have led to some of the most exciting recent developments in combustion.

The importance of Kumagai's work was recognized by his receiving the Egerton Gold Medal of the Combustion Institute at the 17th Symposium in 1978. Recognizing the pioneering role that Kumagai played in microgravity combustion, it is entirely fitting that he should be referred to as the Father of Microgravity Combustion.

Hiroshi Tsuji is best recognized for his development of the counterflow flame technique and through it the systematic

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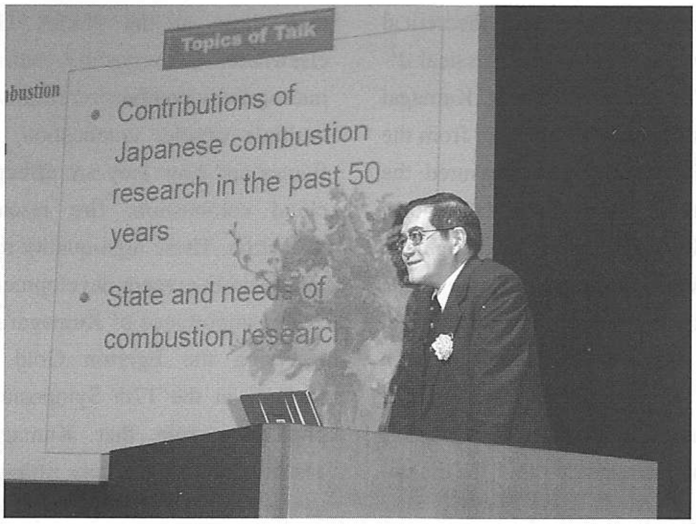
investigation of the structure and response of laminar flames. While the existence of the counterflow flame was recognized earlier, it was Tsuji who perfected the technique and fully exploited the unique properties of such a flame. It is important to recognize that the experimental availability of the counterflow flame in the 1970s coincided with the period when combustion research entered an exciting new era. Particularly, computational simulation of flame structures with realistic chemistry was undertaken seriously and systematically. Since simulation with complex chemistry in diffusive media can only be computationally accommodated for one-dimensional flames at that time, and to a large extent even today, the locally one-dimensional flame situated in the counterflow offers an ideal configuration for the study of the chemical structure of both premixed and diffusion flames. Through comparisons between computation and experiment, the intricate role of chemistry in flame environments can be investigated. Concurrently, the essential influence of aerodynamic stretch on the response of flames was recognized, and elegant theories on stretched flames were developed by eminent theorists such as Clavin, Sivashinsky, and Williams. Subsequently, it was also recognized that stretched flames form the basic unit of turbulent flames in the regime of laminar flamelets, leading to the development of turbulent flame theories based on this concept. Furthermore, since the stretch nature of the counterflow flame is characterized by only one parameter, the stretch rate, which can be readily measured experimentally and accommodated theoretically and computationally, the counterflow flame offers the ideal configuration for the study of stretched flames. Indeed, the utility of counterflow flames is so essential in studies of flames and combustion chemistry that nowadays it is hard to find an issue of a combustion journal without one or more papers reporting work based on this flame configuration.

Tsuji was honored for this contribution by the Institute's Lewis Gold Medal at the 22nd Symposium in 1988. Appropriately, we shall refer to him as the Father of Counterflow Flames.

The accomplishments mentioned above only serve to illustrate the significance of combustion research in Japan. Indeed, the Japanese involvement in combustion research has been all embracing, covering additional topics such as turbulent combustion, fire and hazard research, laser diagnostics, chemical kinetics, supersonic combustion, detonation phenomena, pollutant formation and control, materials synthesis, engine and furnace research, coal combustion, and many more. The impact they have made on combustion in the past half century can be characterized as amazing. Furthermore, this strong tradition of world-class research is now being carried on by a "dream" team of outstanding second- and third-generation of combustion researchers in Japan, with frequent discoveries as well as recognitions through the Institute's gold medals and plenary lectureships. It is therefore with much appreciation that the author, on behalf of the world-wide community of combustion researchers, extends our warmest congratulations to the Japanese Section of the Combustion Institute on the occasion of its fiftieth anniversary. In addition, we also extend the best wishes to our Japanese colleagues in their pursuit of knowledge and excellence in the next fifty years. Through the service of combustion, we shall together make the world a better place.



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