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Combustion of Fire Whirl: How much do we know?

Abstract

In large-scale wildland and urban fires, extreme fire behaviors frequently occur and usually play key roles in accelerating the fires. The term extreme fire behavior was originated in the wildland firefighting community, for which, as described by the National Wildfire Coordinating Group Glossary of Wildland Fire Terminology (NWCG, 2006): “*Extreme implies a level of fire behavior characteristics that ordinarily precludes methods of direct control action*”, for which, “*presence of fire whirls is usually involved*”. Fire whirl is a type of special swirling flame induced by the interaction between general buoyant fire and surrounding rotating flow field. Compared with a general free burning pool fire, fire whirl is characterized by sharp increase in its burning rate, flame temperature, flame height, and radiation output. Therefore, fire whirls are usually a key mechanism for the acceleration of wildland and urban fires.

The fire whirl problem is complicated mainly due to the nonlinear combustion-flow interactions inside the flame. However, there is much lack of experimental data and theoretical models for interpretation of the physical mechanism and dynamics of fire whirls. Since the pioneering experimental work by Emmons and Ying (Emmons, H.W. and S.-J. Ying, The fire whirl. Proceedings of the Combustion Institute 1967, 11(1): 475-488), many laboratory studies on fire whirl have been conducted in the past half century. However, quantitative experimental works and reliable theoretical models are still very limited. Since 2004, a series of new facilities on both medium- and small-scale fire whirls have been established at the State Key Laboratory of Fire Science (SKLFS), and new theoretical models have been developed based on the experimental data and theoretical analyses. This lecture presents a review of the fire whirl study at SKLFS

during the past decade. The formation mechanism and quasi-steady combustion characteristics of fire whirl are summarized, and some challenging problems for future research are outlined.

Short CV

Naian Liu is currently professor at University of Science and Technology of China (USTC). He graduated from USTC getting his PhD degree of Engineering Thermophysics in 2000. Then he was employed in USTC as a lecturer at State Key Laboratory of Fire Science (SKLFS) and in 2004 promoted to be an associate professor of USTC. In 2007 he was promoted to be a professor of USTC. He has been serving as the Vice Director of SKLFS since 2009. He is also the chief of the Division of Wildland and Urban Fires of SKLFS.

The research areas of Prof. Liu include pyrolysis, material flammability, fire spread and extreme fire behaviors. He has authored over 140 peer-reviewed papers and 15 invited speeches. His greatest contributions have been revolutionizing the theoretical and experimental descriptions of extreme fire behaviors. This work has been published in over 40 journals and proceedings papers. Among these, 17 papers have been published in Proc. Combust. Inst. (ProCI) and Combust. Flame (CnF), and also 10 keynote lectures have focused specifically on this topic. In 2018, Prof. Liu was nominated and selected to join the Inaugural Class of Fellows of the Combustion Institute.

Prof. Liu serves many international organizations and conferences. He is Member of Board of Directors of International Association of Wildland Fire, Member of the International Forum of Fire Research Directors, and Member of International Scale Modeling Committee. For international journal editorial work, he has been the Associate Editor of Fire Safety Journal (2013-2015), Associate Editor of International Journal of Wildland Fire (from 2016), and Associate Editor of Fire Technology (from 2016). For conference organization, he served as the Leader Chair for the topic "Wildland fires" of the 11th (2014) and 12th (2017) International Symposium on Fire Safety Science (IAFSS Symposium), and chaired the Poster Session for the 12th IAFSS Symposium. He also served as the Award Committee Chair of the 10th Asia-Oceania Symposium on Fire Science and Technology (AOSFST) (2015) and the Technical Program Chair of the 9th AOSFST (2012). He co-chaired the Colloquium of Fire Research for the 35th (2014) and 36th (2016) International Symposiums on Combustion. He held the Colloquium Coordinator of Fire Research for the 37th (2018) International Symposiums on Combustion. Recently, he chaired the Scientific Advisory Board of the 8th International Seminar on Fire and Explosion Hazards (2019). Also, he has been invited to hold the Program Scientific Co-Chair for the 13th IAFSS Symposium (2020).