International Conference on Numerical Combustion
Rome, Italy, October 14-17, 2025
www.icnc2025.com

DNS study of the impact of thermodiffusive effects on the turbulent flame speed in partially cracked ammonia flames

R. Intranuovo[1]*, F.G. Schiavone[1], S. Zitouni[2], P. Brequigny[2], C. Rousselle [2,3], D. Laera[1,4]
*Lead presenter: r.intranuovo@phd.poliba.it
[1] DMMM, Polytechnic University of Bari, Via Orabona 4, Bari, 70125, Italy
[2] University of Orléans, PRISME, Château de la Source, 45072 Orléans, France
[3] Institut Universitaire de France, Paris, France
[4] Institut de Mécanique des Fluides de Toulouse, Toulouse, France

Ammonia (NH_3) combustion is considered a promising solution to reduce anthropogenic carbon emissions, but it presents several modeling and scientific challenges due to the low reactivity of NH_3 [1]. To solve this issue, a strategy commonly proposed is the partial cracking of NH_3 molecules (PCA). Given the complexity of these flames, numerical simulations are required to complement experimental analyses and gain an understanding. This work aims to improve the knowledge in ammonia combustion for various Karlovitz number (Ka) combustion regimes, focusing on flame-turbulence interaction, thermodiffusive (TD) effects, and their impact on turbulent flame properties. In particular, the peculiar "bending effect" of the turbulent flame speed S_T observed in [2] is investigated. To this scope, Direct Numerical Simulations (DNS) of planar NH_3-air flames stabilized in a three-dimensional (3D) box-shaped domain subjected to a forced Homogeneous Isotropic Turbulence (HIT) are performed. Case studies are selected following the experimental analysis of [2], considering three levels of ammonia cracking γ (5%, 20%, 40%), one level of turbulent intensity u′ (1.13 m/s), and one value for the equivalence ratio, (0.8). The numerical simulations are performed in the explicit compressible solver AVBP and HIT is forced within the domain following the linear forcing model by Bassenne et al. [3].
Preliminary results show that the turbulence-flame interaction varies with mixture composition, impacting S_T. For $\gamma = 5\%$ it is found that S_T increases predominantly because of turbulence, which tends to augment the flame surface area A_T, rather than to TD effects. These are quantified by the stretch factor I_0, which remains close to unity in this case. In contrast, for $\gamma = 20\%$, I_0 is greater than unity. Thus, the combined effect of enhanced H_2 and low Ka is such that TD instabilities are more pronounced than in the high Ka case, resulting in a more wrinkled flame surface. Consequently, both turbulence and TD effects impact S_T. In the $\gamma = 40\%$ case, instead, the enhancement of flame wrinkling is damped by a reduction of I_0 limiting the overall flame velocity.

References

[1] Valera-Medina A et al. Review on Ammonia as a Potential Fuel: From Synthesis to Economics. *Energy & Fuels*. 2021;35(9):6964-7029.

[2] Zitouni S et al. Turbulent partially cracked ammonia/air premixed spherical flames. *Fuel Communications*. 2024; 20:100126.

[3] Bassenne M et al. Constant-energetics physical-space forcing methods for improved convergence to homogeneous-isotropic turbulence with application to particle-laden flows. *Physics of Fluids*. 2016; 28(3).