# Subgrid-scale modelling of premixed flames using artificial neural networks in large eddy simulations

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Large eddy simulation (LES) of compressible turbulent combustion has several challenges. Accurate modelling of unresolved subgrid-scale (SGS) terms in LES is the key for high-fidelity simulations.Traditional combustion models for premixed flames such as partially stirred reactor model (PaSR), thickened flame model (TFM), subgrid segregation model (SSM), approximate-deconvolution method (ADM) have been applied to various combustion simulations. However, issues still exist in applying traditional models in simulating highly compressible turbulent flames due to a lack of consideration for turbulence-chemistry interaction in those models.

In the current study, we extend the deconvolutional artificial neural network (DANN) framework[1,2] in modelling the SGS terms in a compressible planar premixed flame. In the DANN framework, the normalized density-weighted filtered variables in the neighboring stencils are taken as the inputs, while the outputs are unfiltered density-weighted variables. The SGS flow terms (SGS stress, SGS heat flux, and SGS scalar flux) as well as the SGS reaction source terms (SGS reaction rates) are modelled using a unified neural network. *A priori* and *a posteriori* studies are conducted to test the accuracy of the DANN model.

Figure 1 shows the average of $H_2O$ reaction rates conditioned on reaction progress variable $\mathcal{C}$ for traditional combustion models in *a priori* tests. It is shown that the reaction rates predicted by traditional models (PaSR, TFM, SSM) deviate from the filtered direct numerical simulation results (fDNS) at $\mathcal{C} = 0.2 \sim 0.6$. The accuracy of traditional combustion models decreases with the increase of filter width.

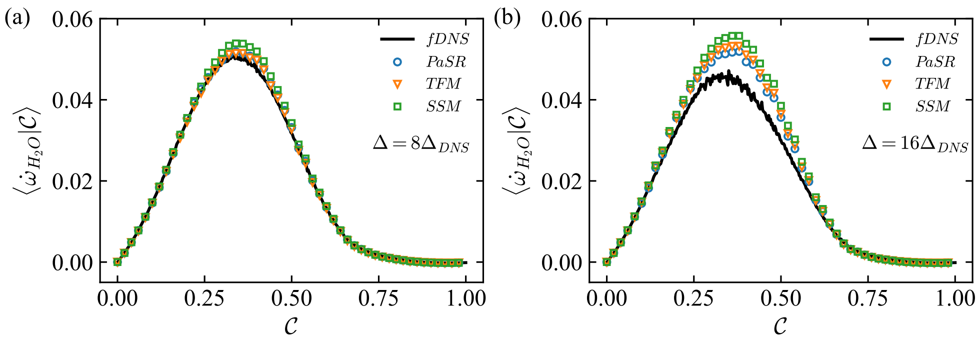


Figure 1: Average of $H_2O$ reaction rates conditioned on reaction progress variable $\mathcal{C}$ for traditional combustion models: (a) filter width $\Delta = 8\Delta_{DNS}$. (b) filter width $\Delta = 16\Delta_{DNS}$.

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[1] Yuan *et al.*, *Phys. Fluids* **32**, 115106 (2020).
[2] Teng *et al.*, *Int. J Heat Fluid Flow* **96**, 109000 (2022).