IMPACT OF HEAT LOSSES ON FREELY PROPAGATING PREMIXED FLAMES IN NARROW CHANNELS: FROM NON-SYMMETRIC TO SYMMETRIC FLAME SHAPES

Carmen Jiménez*[1], Anne Dejoan[1], Daniel Martínez-Ruiz[2], Victor Muntean[2],
Mario Sánchez-Sanz[3], and Vadim N. Kurdyumov[1]
[1]Center for Research in Energy, Environment and Technology (CIEMAT), Madrid, Spain
[2] E.T.S.I.A.E., Universidad Politécnica de Madrid, Madrid, Spain
[3]Fluid Mechanics Group, Universidad Carlos III de Madrid, Leganés, Spain

Summary. The influence of heat losses on the structure of premixed flames freely propagating in narrow channels is investigated. It is shown that the flame shape depends on the channel width, the reactants mean flow rate and the heat losses. For very narrow channels only symmetric flames, with either mushroom or tulip shapes, are formed at any intensity of heat losses. For wider channels the flames are non-symmetric for adiabatic walls or for small heat losses, and become symmetric as heat losses increase.

We study by numerical simulations the effect of heat losses on the structure of premixed flames freely propagating in narrow channels of planar and circular cross sections, using kinetics of the Arrhenius type and assuming constant transport properties and unit Lewis number (see [1] for further details on the formulation). It is shown that in fairly narrow channels only symmetric flames are formed at any intensity of heat losses. The response curve (flame velocity versus heat losses) takes in this case a typical C-shaped form, as shown in Fig. 1 for a=5, where a is the channel width h scaled with the flame thermal thickness δ_T: there is a maximum critical value of the heat loss intensity above which flame propagation is impossible. This value depends also on the intensity of the mass flow rate in the channel m (Fig.1 corresponds to $m=0$).

The structure of the flame changes noticeably in wider channels. In these cases the flame results to be non-symmetric when heat losses are sufficiently small (or zero). Nevertheless it was found that with a gradual increase in heat losses the flame shape becomes symmetric again. This can be appreciated in Fig.1 for the cases with $a > 5$, and in Fig. 2 for $a = 10$. As expected, for sufficiently wide channels (e.g. the case $a=15$ in Fig.1), flame extinction does not occur, not even for very large values of the heat losses parameter, which would correspond to isothermal (cold) walls. It is important to note that the critical quenching width depends on the intensity of the gas mass flow rate, and that near this critical value the flame remains symmetric. The detected symmetry of the flames near the critical value can facilitate the calculation of the critical extinction parameters, of importance for practical applications. We also want to note the appearance of multiplicity of steady-state regimes when flames with symmetric and non-symmetric shapes can coexist.

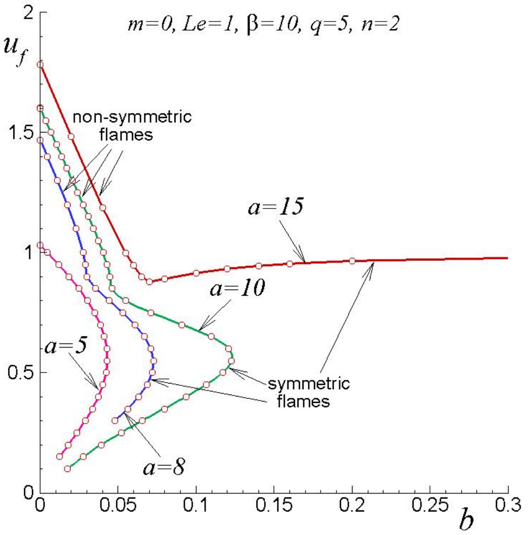

Figure 1. Computed flame velocity u_f (with respect to the wall and scaled with the laminar planar flame speed), calculated as a function of the heat-loss intensity $b = \frac{\lambda_w \delta_T}{\lambda_g h_w}$, with λ_w and λ_g the wall and gas thermal conductivities, δ_T the flame thickness and h_w the wall thickness in planar channels with reactants mass flow rate $m=0$.

---

*Corresponding author. E-mail: carmen.jimenez@ciemat.es

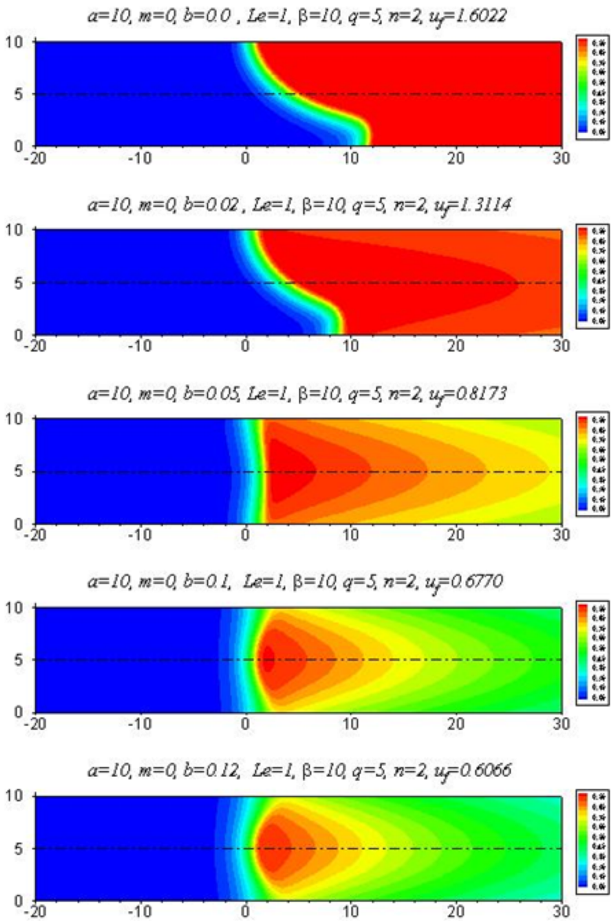

Figure 2. Structure of flames (colour isotherms) with increasing heat-loss intensity *b* calculated for a planar channel with width $a=10$ and reactants mass flow rate $m=0$.

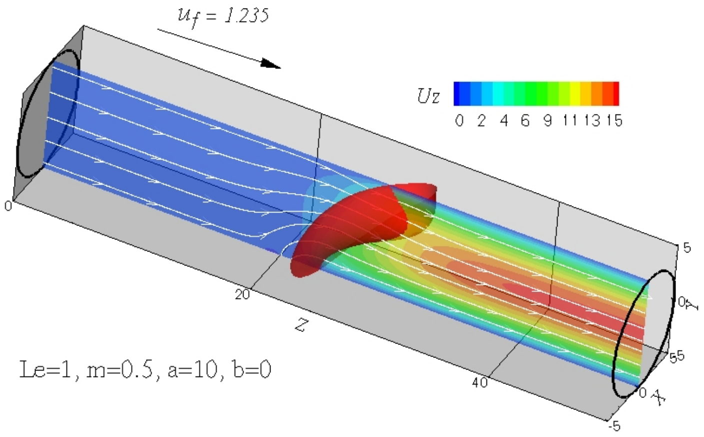

Figure 3. An example of a 3D non-symmetric flame in a channel of circular cross section.

CONCLUSIONS

We study in this paper the influence of heat losses in the flame shape and the quenching width when Le=1 flames propagate freely in narrow channels. These results may be useful for the design of micro combustion devices, and for safety issues in combustion systems, given that the flame propagation speed is closely related with its shape and surface.

References

[1] Dejoan A., Jiménez C., Kurdyumov V.N., *Combust. Flame* **209**: 430–440, 2019.