



HAL
open science

Investigation of a flame in a packed bed using a cylindrical geometry and single-side optical diagnostics

Mohammadhassan Khodsiani, Frank Beyrau, Benoit Fond

► **To cite this version:**

Mohammadhassan Khodsiani, Frank Beyrau, Benoit Fond. Investigation of a flame in a packed bed using a cylindrical geometry and single-side optical diagnostics. Optical Sensors and Sensing Congress 2022, Jul 2022, Vancouver, Canada. pp.LTu3B.3, 10.1364/LACSEA.2022.LTu3B.3 . hal-04048967

HAL Id: hal-04048967

<https://hal.science/hal-04048967v1>

Submitted on 28 Mar 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Investigation of a flame in a packed bed using a cylindrical geometry and single-side optical diagnostics

Mohammadhassan Khodsiani¹, Frank Beyrau¹, Benoit Fond^{1, 2*}

Chair of Technical Thermodynamics, Otto-von-Guericke-Universität Magdeburg, Universitätsplatz 2, 39106 Magdeburg, Germany

ONERA - The French Aerospace Lab, 8 rue des Vertugadins - 92190 Meudon, France

*benoit.fond@onera.fr

Abstract: The interaction of a flame and a two-dimensional packed bed is studied by a combination of optical techniques applied along a single optical access, which includes telecentric chemiluminescence imaging, laser doppler anemometry and phosphor thermometry. © 2022 The Author(s)

1. Introduction

In many industrial applications, a mixture of fuel and air burns inside the packed bed of particles to heat them up and thermally treat them. The position and extent of the flame determine the temperature distribution which influences the heat transfer between the particles and flame, and thus the product quality. This work implements non-intrusive optical diagnostics to study the interaction of a premixed methane-air flame with a packed bed. However, spherical packed beds used in the industry, being opaque, here a model geometry using cylindrical particles and a 2D burner is used. This results in a two-dimensionality of the flow and allows for line-of-sight optical access to the region in between the particles.

2. Methods

As depicted in the exploded view of Figure. 1 (a), the experimental setup comprises a burner and a packed bed of cylindrical particles on top. The cylinder arrangement and spacing is set to obtain similar level of porosity and flow geometry as a spherical packed bed. Stoichiometric CH₄/air mixture exits the slit surrounded by an air coflow. Here, the flame is stabilised between three internally cooled aluminum cylinders. An extended through optical access was designed as shown on Figure. 1 (b) to implement the optical diagnostics.

Phosphor thermometry, which exploits the temperature dependence of the luminescence of inorganic phosphor particles, was used to measure the surface temperature of the cooled cylinders. This is key to provide a thermal boundary condition for the simulation. Here, a 2 mm wide strip of YAG:Cr³⁺ was coated along the cylinder perimeter in the center of the burner, which was then excited by a 532 nm Nd:YAG laser beam steered and expanded between the three cylinders. The resulting luminescence emission is imaged by a high speed camera, to resolve the luminescence decay in two dimensions, which is then converted to temperature using calibration data. As Figure. 1 (c) depicts, luminescence of the excited YAG:Cr³⁺ in presence of the flame. There, dashed lines delineate the cylinders. Unfortunately due to imperfect beam steering between the three cylinders, in this example only the signal from the top and right cylinder were used to infer their respective temperature.

To locate the reaction zone, chemiluminescence imaging was also implemented. A telecentric lens was used to maintain the in-plane spatial resolution across the length of the cylinders. Finally to determine the local flow velocity, Laser Doppler Anemometry (LDA) was performed in back-scattering configuration with a 500 mm lens which lead to a 2.8 mm long probe volume. Chemiluminescence and phosphor thermometry were performed simultaneously, and chemiluminescence and LDA were also performed simultaneously but in separate runs.

3. Results

Figure 2 (a) and (b) are the results of combined LDA and chemiluminescence imaging for an inflow velocity of 0.3 m/s. Both gas phase velocity and chemiluminescence intensity are extracted along a vertical line. As shown in 2 (a), the flow is first accelerated to the contraction imposed by the two lower cylinders, which is followed by a deceleration to 0.6 m/s where the flame establishes itself as indicated by the position of maximum chemiluminescence intensity. Across the reaction zone, a strong acceleration is observed.

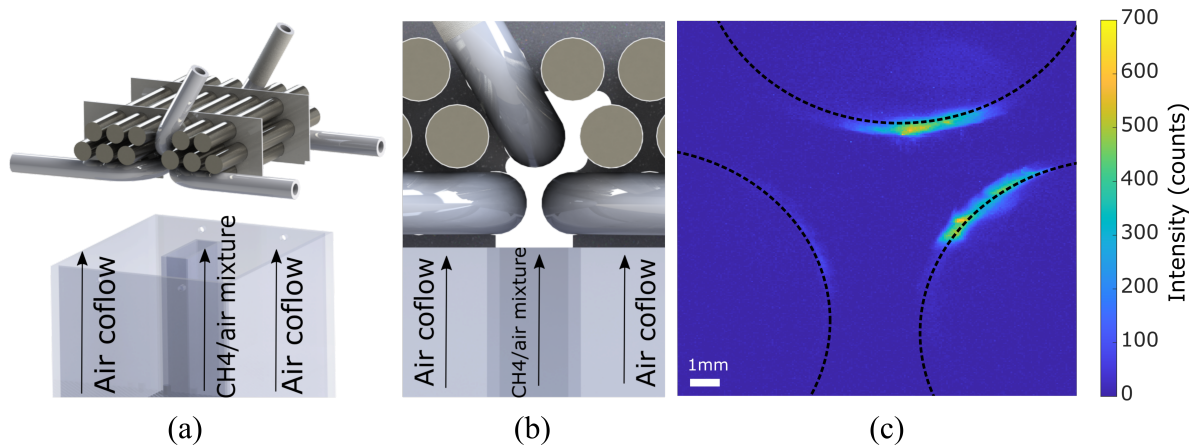


Fig. 1: Exploded view of the burner and cylindrical particles (a), close view to the region with line-of-sight optical access in between cooled cylinders (b), luminescence emanating from YAG:Cr³⁺ coated on cylinders (c)

Chemiluminescence together with phosphor thermometry was also performed for two inflow velocity conditions: 0.25 and 0.3 m/s as shown in 2 (c) and (d). In both cases, the temperature of the top cylinder is measured to be hotter than the bottom ones which can be explained by hotter and faster gases surrounding the top one. For the lower velocity condition, the flame stabilises closer to the contraction than for the 0.3 m/s case, and is flatter. Regarding the cylinder temperatures, the bottom cylinder temperature stays unchanged for the two flame conditions, while the top cylinder sees a temperature rise from 135°C to 139°C. This is because the smaller flame to top cylinder distance in the 0.3 m/s case leads to faster gases surrounding the top cylinder, and therefore more flame to cylinder heat transfer.

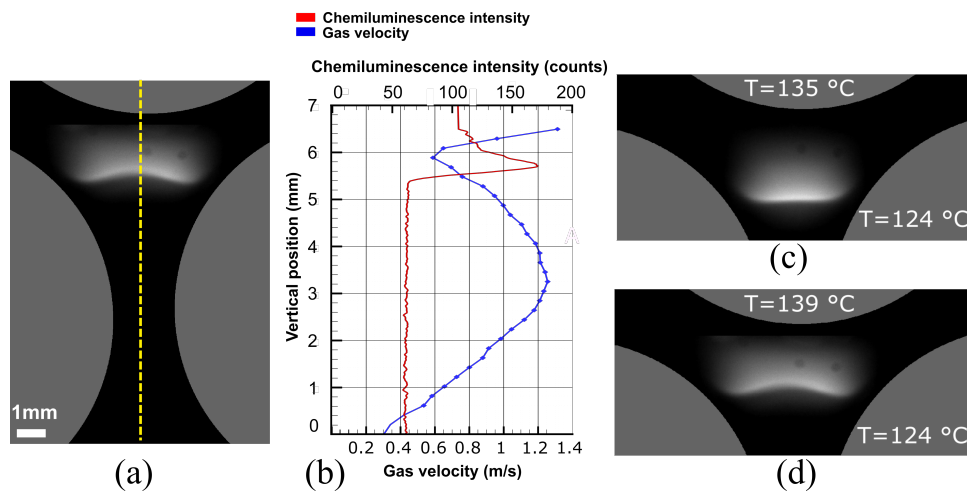


Fig. 2: Premixed methane flame in between the cylinders (a); gas phase velocity and chemiluminescence intensity along the yellow vertical line (b), phosphor thermometry on the cylinder surfaces for $\lambda = 1$ and inflow velocity of 0.25 m/s (c) and 0.3 m/s (d)

4. Conclusion

This work employed cylindrical particles to mimic flame-heated packed beds while allowing line-of-sight optical access to the flame region. Gas velocity in the flame region, flame position and also cylinder temperature are measured through laser Doppler anemometry, chemiluminescence imaging and phosphor thermometry. In the future, more flame conditions, and the case of uncooled ceramic cylinder will be studied, and the suite of optical diagnostics will be extended to include gas temperature measurements.

5. Acknowledgement

Funding by German Research Foundation (DFG), project 422037413 (SFB/TRR 287), is gratefully acknowledged.