Experimental Dataset: Experimental Study on the Influence of Methane-Cofiring on Pulverized Coal Flames under Air and Oxy-Fuel Conditions

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Abstract

This data publication contains the quantitative values of the narrow-band imaging and laser Doppler velocimetry measurements published in the paper [1]. Experiments are carried out using a pilot-scale down-fired cylindrical combustion chamber equipped with a swirl burner. Studied operating conditions of flames of lignite/methane fuel mixtures have an identical thermal output of 40 kW_{th}, with the thermal output share of methane gradually decreasing from 50 vol.% to 0 vol.% while the lignite share (Rhenish lignite) increased from 50 vol.% to 100 vol.% (self-sustained condition). To visualize flame structure and to identify reaction zones, narrow-band imaging is employed. Narrow-band flame imaging is conducted at two different wavelengths (OH* and CH* radical band heads). A detailed flow field characterization of the respective flames is conducted by two-dimensional laser Doppler velocimetry measurements. Radial profiles of axial and tangential velocities have been determined using an optical long-range laser Doppler velocimetry (LDV) system operated in backscatter mode and mounted to a traverse. Solid fuel particles are used as flow tracers. Results and the experimental conditions from the present dataset are in depth described in the conference article "Experimental Study on the Influence of Methane-Cofiring on Pulverized Coal Flames under Air and Oxy-Fuel Conditions" from the present authors [1].

1 Experimental dataset

The present dataset is composed of 2 main *.zip* files based on the two different types of conducted measurements. Each of the *.zip* compressed files, contains the measurement results obtained for all 6 studied flames. Numerical values from experimental measurement results are given in tab separated *.txt* files. The six studied flames employ pulverized fuel, and have constant 40 kW_{th} output with the same stoichometry. Details about the fuel composition are given in table 4 and about operating conditions, in table 5. Flame naming can be summarized as follows:

- M20C20-AIR: Flame with a thermal power of 20kW pulverized Rhenish lignite and 20kW methane under air atmosphere

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- M10C30-AIR: Flame with a thermal power of 30kW pulverized Rhenish lignite and 10kW methane under air atmosphere
- M00C40-AIR: Flame with a thermal power of 40kW pulverized Rhenish lignite under air atmosphere
- M20C20-OXY33: Flame with a thermal power of 20kW pulverized Rhenish lignite and 20kW methane under oxy-fuel atmosphere
- M10C30-OXY33: Flame with a thermal power of 30kW pulverized Rhenish lignite and 10kW methane under oxy-fuel atmosphere
- M00C40-OXY33: Flame with a thermal power of 40kW pulverized Rhenish lignite under oxy-fuel atmosphere

The list of files in the dataset is the following:

1. 'LDV_Profiles_40kW_AIR&OXY33_CH4_C.zip', is a compressed file, containing six folders, each corresponding to a studied flame. Each folder contains six *.txt* files corresponding to the velocity profiles obtained at different axial locations in the combustion chamber (more details in section 1.1). The last three characters denote the axial position at which the profile was taken (whereby e.g. 03D corresponds to 0.3 d, 10D to 1.0d etc.). Full listing of the six files are as follows:
   (a) Folder: 'LDV-AIR-40kW-M00C40'
      i. 'AIR_40kW_M00C40_03D.txt'
      ii. 'AIR_40kW_M00C40_05D.txt'
      iii. 'AIR_40kW_M00C40_10D.txt'
      iv. 'AIR_40kW_M00C40_20D.txt'
      v. 'AIR_40kW_M00C40_40D.txt'
   (b) Folder: 'LDV-AIR-40kW-M10C30'
      i. 'AIR_40kW_M10C30_03D.txt'
      ii. 'AIR_40kW_M10C30_05D.txt'
      iii. 'AIR_40kW_M10C30_10D.txt'
      iv. 'AIR_40kW_M10C30_20D.txt'
      v. 'AIR_40kW_M10C30_40D.txt'
   (c) Folder: 'LDV-AIR-40kW-M20C20'
      i. 'AIR_40kW_M20C20_03D.txt'
      ii. 'AIR_40kW_M20C20_05D.txt'
      iii. 'AIR_40kW_M20C20_10D.txt'
      iv. 'AIR_40kW_M20C20_20D.txt'
      v. 'AIR_40kW_M20C20_40D.txt'
   (d) Folder: 'LDV-OXY33-40kW-M00C40'
      i. 'OXY33_40kW_M00C40_03D.txt'
      ii. 'OXY33_40kW_M00C40_05D.txt'
      iii. 'OXY33_40kW_M00C40_10D.txt'
      iv. 'OXY33_40kW_M00C40_20D.txt'
      v. 'OXY33_40kW_M00C40_40D.txt'
   (e) Folder: 'LDV-OXY33-40kW-M10C30'
      i. 'OXY33_40kW_M10C30_03D.txt'

ii. 'OXY33_40kW_M10C30_05D.txt'
iii. 'OXY33_40kW_M10C30_10D.txt'
iv. 'OXY33_40kW_M10C30_20D.txt'
v. 'OXY33_40kW_M10C30_40D.txt'

(f) Folder: 'LDV-OXY33-40kW-M20C20'

i. 'OXY33_40kW_M20C20_03D.txt'
ii. 'OXY33_40kW_M20C20_05D.txt'
iii. 'OXY33_40kW_M20C20_10D.txt'
iv. 'OXY33_40kW_M20C20_20D.txt'
v. 'OXY33_40kW_M20C20_40D.txt'

(g) 'metadata_LDV.txt', the metadata file, giving the experimental parameters of LDV measurements, such as laser properties, and the size of the measurement volume

2. 'Narrow_band_images_40kW_AIR&OXY33_CH4_C.zip', is a compressed file containing six folders, each corresponding to one studied flame. Each folder contains five *.txt* files , two of them are the intensity of narrow-band images obtained using different bandpass filters. The first two characters denote the radical band names (OH* and CH*). Two *.txt* files named as 'y_scale.txt' and 'x_scale.txt' to represent the axis of narrow-band images in unit of (mm). One *.txt* file named as 'metadata' contains the information about the measured flame condition and the settings of the experimental apparatus. Full listing of the four files are as follows:

(a) Folder: 'Narrow_Band_images_AIR_M00C40'

i. 'CH_M00C40.txt'
ii. 'OH_M00C40.txt'
iii. 'x_scale.txt'
iv. 'y_scale.txt'
v. 'Metadata_M00C40.txt'

(b) Folder: 'Narrow_Band_images_AIR_M10C30'

i. 'CH_M10C30.txt'
ii. 'OH_M10C30.txt'
iii. 'x_scale.txt'
iv. 'y_scale.txt'
v. 'Metadata_M10C30.txt'

(c) Folder: 'Narrow_Band_images_AIR_M20C20'

i. 'CH_M20C20.txt'
ii. 'OH_M20C20.txt'
iii. 'x_scale.txt'
iv. 'y_scale.txt'
v. 'Metadata_M20C20.txt'

(d) Folder: 'Narrow_Band_images_OXY33_M00C40'

i. 'CH_M00C40.txt'
ii. 'OH_M00C40.txt'
iii. 'x_scale.txt'

iv. 'y_scale.txt'
v. 'Metadata_M00C40.txt'

(e) Folder: 'Narrow_Band_images_OXY33_M10C30'

i. 'CH_M10C30.txt'
ii. 'OH_M10C30.txt'
iii. 'x_scale.txt'
iv. 'y_scale.txt'
v. 'Metadata_M10C30.txt'

(f) Folder: 'Narrow_Band_images_OXY33_M20C20'

i. 'CH_M20C20.txt'
ii. 'OH_M20C20.txt'
iii. 'x_scale.txt'
iv. 'y_scale.txt'
v. 'Metadata_M20C20.txt'

1.1 LDV profile data

The typical structure of the *.txt* files, using as example 'AIR_40kW_M00C40_03D.txt' is shown in figure 1. The first 11 lines contain information about the identifiers of the studied flame (i.e. AIR-M00C40), also about the thermal power P, local λ_l and global λ_g stoichiometric ratios of the flames. Lines 9 and 10 contain information about the relative and absolute distances from the burner where the profile was measured, respectively. Relative distance is shown as a factor of the burner diameter, $D = 49.2\,\mathrm{mm}$. The data is arranged in seven columns (also shown in Line 13 of the LDV text files) as follows:

- Column 1: Radial position R (mm).
- Column 3: Mean axial velocity component $\overline{V}$ (m/s).
- Column 5: RMS of the axial velocity component V_RMS (m/s).
- Column 2: Mean tangential velocity component $\overline{U}$ (m/s).
- Column 4: RMS of the tangential velocity component U_RMS (m/s).

1.2 Narrow band images

The typical structures of the *.txt* files for intensity i.e. 'CH_M00C40.txt', and positions i.e. 'x_scale.txt' are shown in figure 2. The datasets in 'x_scale.txt' and 'y_scale.txt' are x and y coordinates (in mm) of each pixel intensity given in intensity files. In order to create a narrow-band image, one should plot intensity text files as 2D contour image and use position text files ('x_scale.txt' and 'y_scale.txt') as numerical values on x- and y-axis.

All *.txt* files are set as tab seperated. Metadata of the measeruments i.e. Metadata_M00C40.txt' contains the information about the identifiers of the studied flame (i.e. AIR-M00C40), also about the thermal power P, local λ_l and global λ_g stoichiometric ratios of the flames. Moreover, the camera settings i.e. 'Pixel size' are listed in metadata files.

2 About the studied flames and experimental setup

Details about the combustion facility and the experimental methods employed can be found in previous published works. A detailed description of the combustion chamber and the main

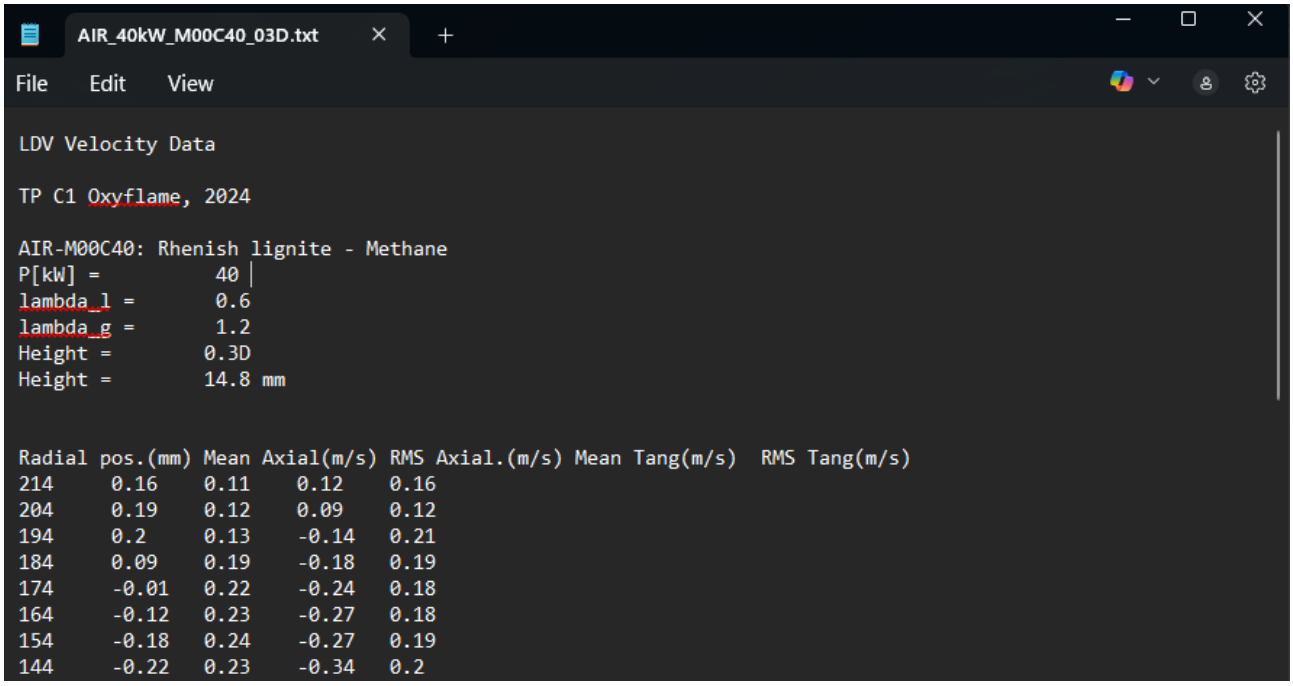

Figure 1: Typical *.txt* file containing information about measured velocity profiles, data is arranged in five columns

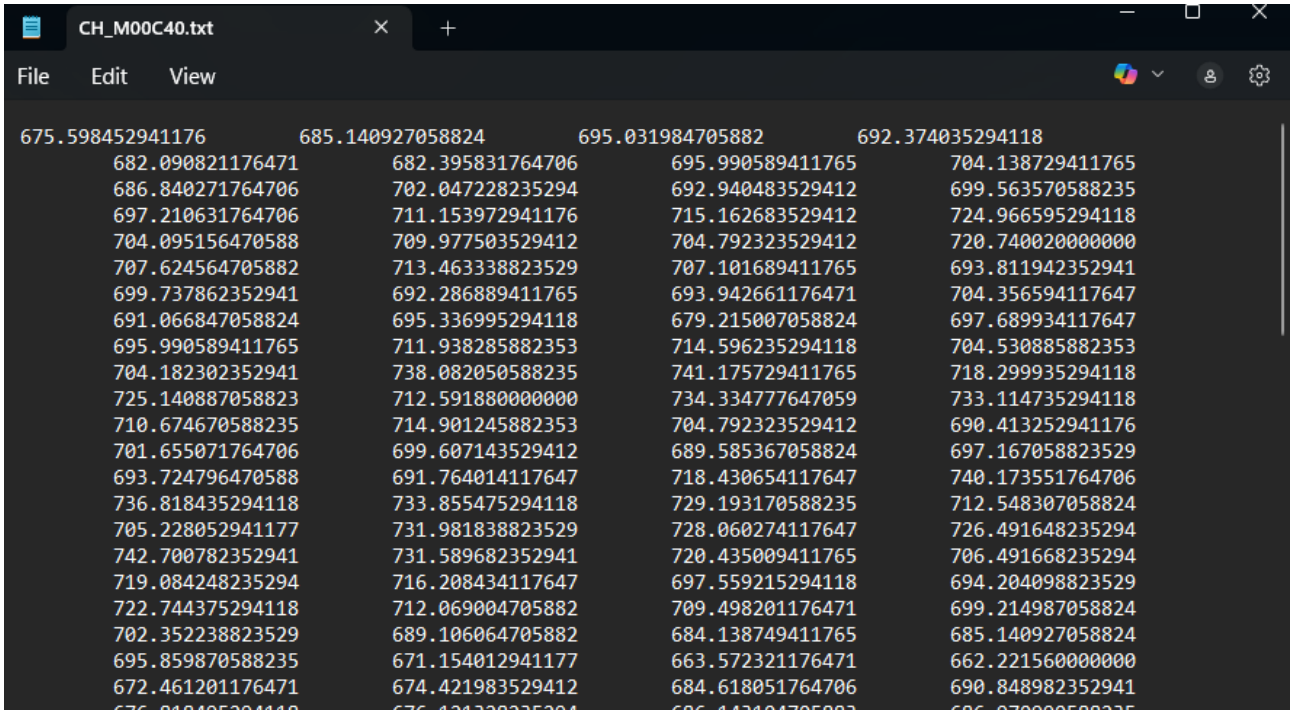

Figure 2: Typical *.txt* file containing the intensity or positional information of narrow-band imaging

components can be found in [2]. A detailed description of the 40 kW_{th} burner is available in [3]. For details on the experimental LDV and narrow-band imaging setups, please refer to [1].

Table 4 shows the ultimate and proximate analysis of walnut shell employed. Table 5 provides details about the investigated operating conditions, including gas mixture compositions, volume flows and gas temperatures at the burner inlets.

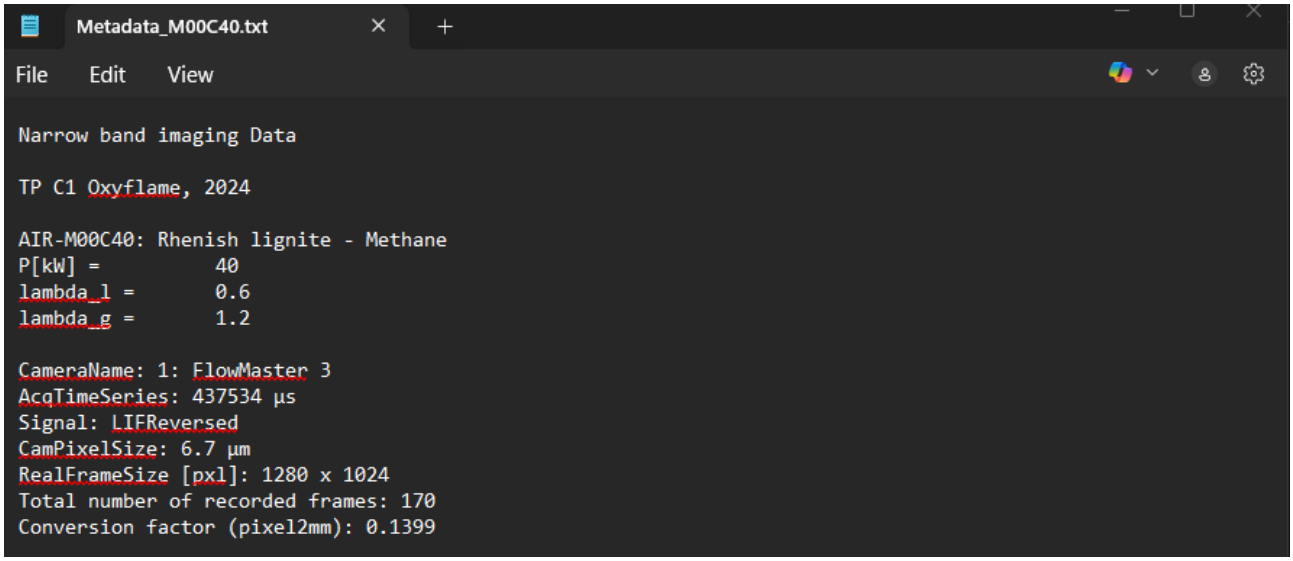

Figure 3: Typical *.txt* file containing the information about the measured flame condition and the settings of the experimental apparatus

Figure 4: Ultimate, proximate analysis and heating values of Rhenish lignite

Component		As received	Dry	Dry, ash-free
Carbon	[w %]	58.21	64.06	68.20
Hydrogen	[w %]	4.00	4.40	4.69
Nitrogen	[w %]	0.83	0.91	0.97
Sulfur	[w %]	0.37	0.41	0.43
Oxygen (as difference)	[w %]	21.94	24.14	25.71
Water	[w %]	9.13	-	-
Ash	[w %]	5.52	6.07	-
Volatiles	[%]	44.99	49.51	52.71
Lower heating value	[MJ/kg]	21.42	23.82	25.36
Higher heating value	[MJ/kg]	22.51	24.77	26.38

Figure 5: Operating conditions

Parameter	M00C40 -AIR	M10C30 -AIR	M20C20 -AIR	M00C40 -OXY33	M10C30 -OXY33	M20C20 -OXY33
Methane flow rate [m^3/h]	0.0	1.0	2.0	0.0	1.0	2.0
Lignite mass feeding rate [kg/h]	6.7	5.1	3.4	6.7	5.1	3.4
Thermal load [kW] of methane/lignite	00/40	10/30	20/20	00/40	10/30	20/20
Air/O_2/CO_2 [vol%]	100/0/0	100/0/0	100/0/0	0/33/67	0/33/67	0/33/67
Primary stream[a] [m^3/h]	12.1	12.1	12.1	7.7	7.7	7.7
Secondary stream[a] [m^3/h]	11.1	11.1	11.1	7.1	7.1	7.1
Staging stream[a] [m^3/h]	24.0	24.0	24.0	15.3	15.3	15.3
Bulk velocity [m/s] Primary[a]/secondary[a]/staging[c]	15.6/9.7/2.2			9.9/6.2/1.4		
Momentum flow[a,b] [$kg.m/s^2$].10^{-3} Primary/secondary/staging	64.1/26.0/17.8			37.7/15.4/10.5		

[a] STP = Standard temperature (0 °C) and pressure (1.013 bar)
[b] Initial momentum of the incoming gases at the exit section of the burner nozzles
[c] Calculated using temperature: 900 °C and pressure: 1.013 bar.

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The dataset: `https://doi.org/10.18154/RWTH-2025-04398`

References

[1] B. Özer, A. Maßmeyer, D. Zabrodiec, O. Hatzfeld, and R. Kneer, "Experimental Study on the Influence of Methane-Cofiring on Pulverized Coal Flames Under Air and Oxy-Fuel Conditions," in *30. Deutscher Flammentag*, 2021.

[2] D. Toporov, P. Bocian, P. Heil, A. Kellermann, H. Stadler, S. Tschunko, M. Förster, and R. Kneer, "Detailed investigation of a pulverized fuel swirl flame in CO_2/CO_2 atmosphere," *Combustion and Flame*, vol. 155, no. 4, pp. 605–618, 2008.

[3] D. Zabrodiec, J. Hees, G. Möller, O. Hatzfeld, and R. Kneer, "Pulverized coal swirl flames in oxy-fuel conditions: Effects of oxidizer O_2 concentration on flow field and local gas composition," *Proceedings of the Combustion Institute*, vol. 37, no. 4, pp. 4471–4478, 2019.