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Data Article

Experimental data regarding the effects of urea addition into liquid fuel to combustion enhancement of a low NO_x gas turbine combustor

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ABSTRACT

The article presents the data regarding the experimental characterization of combustion of liquid jet A1 with addition of urea-water emulsion. A liquid-fuel gas turbine derived burner operating in non-premixed mode under three different equivalence fuel/air ratios was used. The data were collected, with and without urea addition, with two high speed visualization systems which acquired the broadband and spatially and spectrally resolved chemiluminescence emissions. Chemiluminescence images of OH^* were acquired using an intensified camera system with a narrow-band filter at approximately 310 nm CWL, while the chemiluminescence images of CH^* were recorded with a 436 nm CWL. Measurements of exhaust temperature and NO_x, CO and CO_2 emissions have been also performed. The data presented here are related to the article entitled "COMBUSTION PERFORMANCE OF A LOW NO_x GAS TURBINE COMBUSTOR USING UREA ADDITION INTO LIQUID FUEL" [1].

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Specifications Table

Subject	Engineering
Specific subject area	Energy, combustion
Type of data	Image Figure Matlab files
How data were acquired	Memrecam GX-1F camera of NAC Image Technology with a Sigma Macro lens 105 mm set-up at f/0.5 aperture Intensified CCD camera, composed by the Phantom M320S camera equipped with a Lambert intensifier, coupled with interchangeable narrowband filters: one characterized by 307.1 nm center-wavelength (CWL) for the OH^* chemiluminescence emission, and other one with a 436 nm CWL for the methylidyne radical radicals (CH^*) Pollutant emissions analyser: PG-350E Horiba Fuel mass flow meter: VSE 0.02 flow meter Air mass flow calculated by the Labview® control platform using the data measured by the pressure sensor Nuova Fima ST18 and a T-type thermocouple.
Data format	Raw
Parameters for data collection	Temperature, pressure, OH^* emissions, CH^* emissions, NO_x, CO, CO_2
Description of data collection	The experimental campaign was performed in a low NO_x gas turbine combustor using a liquid fuel with and without urea-water emulsion. The experimental data were collected at ambient pressure and preheating the air at 410 K. The fuel was fed to the spray injector at 7 bar by a pump. Fuel/air ratio was fixed at three different values: 0.36, 0.24 and 0.18. Chemiluminescence images of OH^*, and CH^* emissions were acquired using an intensified camera system with narrow-band filters. Measurements of exhaust temperature and NO_x, CO and CO_2 emissions have been also performed.
Data source location	Institution: University of Salento, Department of Engineering for Innovation, Green Engine Lab City: Lecce Country: Italy
Data accessibility	Repository name: Mendeley data Direct URL to data: https://data.mendeley.com/datasets/2tjc68s5vf/3
Related research article	Donato Fontanarosa, Maria Grazia De Giorgi, Giuseppe Ciccarella, Elisa Pescini, and Antonio Ficarella. Combustion performance of a low NO_x gas turbine combustor using urea addition into liquid fuel, Fuel, 2020, 119701, ISSN 0016-2361, https://doi.org/10.1016/j.fuel.2020.119701.

Value of the Data

- The present dataset provides an extended description of lean non-premixed swirl-stabilized combustion of air and Jet-A1 sprays with and without urea-water solution addition.
- The dataset is appropriate for those research communities who are involved in developing numerical CFD codes for turbulent spray combustion simulation, and designing novel low-NO_x gas turbine combustors.
- These experimental data provide a characterization of the combustion performance in terms of combustion efficiencies, pollutant emissions and flame dynamics, which would allow for validation and verification of new numerical CFD models, as well as for comparisons with novel low-NO_x gas turbine combustors using different geometries and/or NO_x reduction strategies.

1. Data Description

The experimental data refer to the combustion performance and the flame dynamics of a turbulent swirled gas turbine combustor. The experimental test matrix is reported in Table 1, where the last column on the right indicates the correspondence of each test case with the test case numbering used in [1].

The provided data are summarized and described in the following:

- Combustion performance data: gas flue temperature, NO_x, CO_2, CO, O_2. The test rig control platform acquired the gas flue temperature at 4 Hz, and its average value and standard deviation are reported in the file **COMBUSTION_PERFORMANCE.xlsx** – sheet denoted as **OPERATING_CONDITIONS**, in combination with the controlled data inlet gas temperature (kept constant at 410 K), the fuel mass flow rate (kept constant at $1{\cdot}10^{-3}$ kg/s) and the total air mass flow rate (varied between $40{\cdot}10^{-3}$ kg/s and $80{\cdot}10^{-3}$ kg/s depending on the overall equivalence ratio of each test case). Instead, pollutant emissions were simultaneously acquired by means of the portable gas analyser model PG-350E Horiba, at sampling frequency of 1 Hz. The uncertainties of NO_x, CO, O_2 and CO_2 emissions measurements were at worst ±1% f.s.v, with sensitivities of 1 ppm for NO_x, CO and O_2 emissions, and 0.01% for CO_2 emission. The average value and the standard deviation of each specie concentration are reported in the file **COMBUSTION_PERFORMANCE.xlsx** - sheet denoted as **EMISSIONS**. For each test case, the data files **rawData_test#.xlsx** contains the raw signals of both gas flue temperature (sheet

Table 1
Experimental test matrix. The last column on the right indicates the correspondence of each test case with the test case numbering used in [1].

Test case	Φ	H_2O[wt%]	urea[wt%]	Raw Data Files	Reference test case in [1]
Test 1	0.36±0.02	0	0	*test1_BB.mat* *test1_OH.mat* *test1_CH.mat* *COMBUSTION_PERFORMANCE.xlsx* *rawData_test1.xlsx*	1
Test 2	0.36±0.02	2.5	2	*test2_BB.mat* *test2_OH.mat* *test2_CH.mat* *COMBUSTION_PERFORMANCE.xlsx* *rawData_test2.xlsx*	7
Test 3	0.24±0.009	0	0	*test3_BB.mat* *test3_OH.mat* *test3_CH.mat* *COMBUSTION_PERFORMANCE.xlsx* *rawData_test3.xlsx*	8
Test 4	0.24±0.009	2.5	2	*test4_BB.mat* *test4_OH.mat* *test4_CH.mat* *COMBUSTION_PERFORMANCE.xlsx* *rawData_test4.xlsx*	9
Test 5	0.18±0.007	0	0	*test5_BB.mat* *test5_OH.mat* *test5_CH.mat* *COMBUSTION_PERFORMANCE.xlsx* *rawData_test5.xlsx*	10
Test 6	0.18±0.007	2.5	2	*test6_BB.mat* *test6_OH.mat* *test6_CH.mat* *COMBUSTION_PERFORMANCE.xlsx* *rawData_test6.xlsx*	11

named **flueGasTemperature**) and pollutant emissions (sheet named **emissionRaw**), where the symbol "#" denotes the specific test case number.

- Luminosity matrix of the VIS images. The images were taken at 1 kHz over 1 s of investigated time. The resolution of each frame is 1240×1024 pixel^2 (calibration factor equal to about 0.041 mm/pixel). Here, only 100 images are provided corresponding to 0.1 s of investigated time. For each test case, a 3D matrix of $1024 \times 1240 \times 100$ elements is provided in Matlab workspace data format: **test1_BB.mat, test2_BB.mat, test3_BB.mat, test4_BB.mat, test5_BB.mat, test6_BB.mat**. The file access is open and free: it has been successfully verified by means of the open source toolbox GNU Octave v6.1 using the function *load(•w)*, and by means of the open source toolbox Python v2.7 importing the library SciPy and then using the function *scipy.io.loadmat(•)*. Into each Matlab data file, three variables have been stored:
  - *YIC*: 3D single-precision data type tensor, size $1024 \times 1240 \times 100$. Each row of the tensor represents the y-coordinate space of the image (units: pixels) made of 1024 spatial steps at a specified time point. Each column of the tensor represents the x-coordinate space of the image (units: pixels) made of 1240 spatial steps at a specified time point. The number of time points is 100, sampled at 1000 Hz frequency: therefore, the investigated temporal window is 0.1 s.
  - *nImages*: integer scalar. It is the number of images stored into the YIC tensor.
  - *Fs*: double-precision scalar. It is the sampling frequency equal to 1000 Hz.
- Luminosity matrix of the OH* images. The images were taken at 1 kHz over 1 s of investigated time. The resolution of each frame is 1574×966 pixel^2 (calibration factor equal to about 0.067 mm/pixel). Here, only 100 images are provided corresponding to 0.1 s of investigated time. For each test case, a 3D matrix of $966 \times 1574 \times 100$ elements is provided in Matlab workspace data format: **test1_OH.mat, test2_OH.mat, test3_OH.mat, test4_OH.mat, test5_OH.mat, test6_OH.mat**. The file access is open and free: it has been successfully verified by means of the open source toolbox GNU Octave v6.1 using the function *load(•)*, and by means of the open source toolbox Python v2.7 importing the library SciPy and then using the function *scipy.io.loadmat(•)*. Into each Matlab data file, three variables have been stored:
  - *YIC*: 3D single-precision data type tensor, size $966 \times 1574 \times 100$. Each row of the tensor represents the y-coordinate space of the image (units: pixels) made of 966 spatial steps at a specified time point. Each column of the tensor represents the x-coordinate space of the image (units: pixels) made of 1574 spatial steps at a specified time point. The number of time points is 100, sampled at 1000 Hz frequency: therefore, the investigated temporal window is 0.1 s.
  - *nImages*: integer scalar. It is the number of images stored into the YIC tensor.
  - *Fs*: double-precision scalar. It is the sampling frequency equal to 1000 Hz.
- Luminosity matrix of the CH* images. The images were taken at 1 kHz over 1 s of investigated time. The resolution of each frame is 1574×966 pixel^2 (calibration factor equal to 0.067 mm/pixel). Here, only 100 images are provided corresponding to 0.1 s of investigated time. For each test case, a 3D matrix of $966 \times 1574 \times 100$ elements is provided in Matlab workspace data format: **test1_CH.mat, test2_CH.mat, test3_CH.mat, test4_CH.mat, test5_CH.mat, test6_CH.mat**. The file access is open and free: it has been successfully verified by means of the open source toolbox GNU Octave v6.1 using the function *load(•)*, and by means of the open source toolbox Python v2.7 importing the library SciPy and then using the function *scipy.io.loadmat(•)*. Into each Matlab data file, three variables have been stored:
  - *YIC*: 3D single-precision data type tensor, size $966 \times 1574 \times 100$. Each row of the tensor represents the y-coordinate space of the image (units: pixels) made of 966 spatial steps at a specified time point. Each column of the tensor represents the x-coordinate space of the image (units: pixels) made of 1574 spatial steps at a specified time point. The number of time points is 100, sampled at 1000 Hz frequency: therefore, the investigated temporal window is 0.1 s.
  - *nImages*: integer scalar. It is the number of images stored into the YIC tensor.
  - *Fs*: double-precision scalar. It is the sampling frequency equal to 1000 Hz.

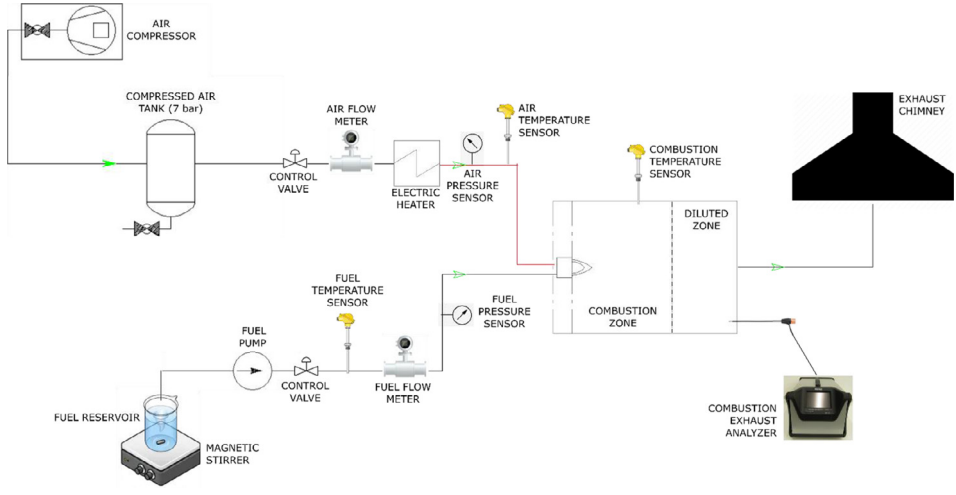


Fig. 1. Sketch of the experimental apparatus [3].

2. Experimental Design, Materials and Methods

The data were acquired during experiments that were carried out at the Green Engine laboratory of the University of Salento in Lecce – Italy, where a 300 kW liquid-fuelled swirling combustor was used in a non-premixed mode [2,3]. The sketch of the overall experimental apparatus is shown in Fig. 1. The burner has the inner diameter equal to 14 cm and the length equal to 29 cm. The air passage consists of an inner annular air tube that is equipped with eight-septa, 45° swirler, and an outer coaxial tube. Liquid fuel is supplied at 7 bar and it is injected by a single-hole nozzle by Monarch 1.20 45° R with 45° injection angle.

The operating control parameters are monitored by the National Instruments LabVIEW® integrate platform. The VSE 0.02 flow meter is used to measure the mass flow rate of fuel, while the air mass flow is evaluated using the pressure measurements given by the pressure sensor Nuova Fima ST18 and the temperature measurements by T-type thermocouples. Pollutant emissions were acquired by the PG-350E Horiba analyzer system. More details are present in [1–3].

High-speed flame visualisations were performed in both visible and UV spectral ranges, by means of the Memrecam GX-1F camera, equipped with a Sigma Macro lens 105 mm set-up at f/0.5 aperture, and an intensified CCD camera (Phantom M320S camera equipped with a Lambert intensifier and UV lens 78 mm with f/3.8 aperture). The Memrecam GX-1F acquired flame images for each experimental test at 1000 Hz acquisition rate, with resolution of 1280 pixels x 1024 pixels. For the UV acquisition narrow optical band-pass filters were used: a 307.1 nm center-wavelength (CWL) filter for the OH^* chemiluminescence emission and a 436 nm CWL for the methylidyne radical radicals (CH^*) chemiluminescence emission. For each test condition, the ICCD camera performed acquisitions at 1000 Hz, with 1574 pixels x 966 pixels resolution. The ICCD intensifier gain was set to 800 and 900 for CH^* and OH^* acquisitions, respectively.

Concerning the experimental test matrix (Table 1), three equivalence ratios Φ were investigated, i.e. 0.36 (test cases 1 and 2), 0.24 (test cases 3 and 4) and 0.18 (test cases 5 and 6). In particular, the total air flow rate ranged between $40{\cdot}10^{-3}$ kg/s and $80{\cdot}10^{-3}$ kg/s with a ratio of 1:11 between primary and secondary air flow, respectively. Instead, the fuel flow rate was kept constant at $1{\cdot}10^{-3}$ kg/s. The inlet air was pre-heated at 410 K, and the combustion occurred at atmospheric pressure.

The experimental data refer to the use of urea-water solution in Jet-A1 aiming to reduce the NO_x emission without affecting the combustion performance of combustor. To this regard, the neat Jet-A1 (test cases 1, 3, and 5) have been compared to the use of 2.5 wt% water-2 wt%

urea in Jet-A1 fuel. This last one was prepared by the Institute of Nanotechnology (NANOTEC) in Lecce (Italy). Concerning production process, water and solid urea were added into a proper tank containing the specified amount of Jet-A1. Therefore, the resulting mixture was homogenized by using a UltraTurrax T25 homogenizer operating at 14,000 rpm for at least 5 min. Instead, during experiments the emulsion homogeneity was ensured by continuous agitation by means of the magnetic stirring plate model Buo Qua SH3.

In the present data paper, the datasets of the visible, OH^* and CH^* chemiluminescence images contain 100 images acquired at 1000 fps, corresponding to 0.1 s investigated time.

Ethics Statement

The authors declare that they have given due consideration to the protection of intellectual property associated with this work. The work doesn't involve the use of human or animal subjects. Moreover, the authors declare that there are no known conflicts of interest associated with this publication.

CRediT Author Statement

Maria Grazia De Giorgi: Conceptualization, Methodology, Supervision, Writing; **Giuseppe Ciccarella:** Conceptualization, Resources; **Donato Fontanarosa:** Methodology, Investigation, Data Curation, Formal Analysis, Writing; **Elisa Pescini:** Data Curation; **Antonio Ficarella:** Resources, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have or could be perceived to have influenced the work reported in this article.

Data Availability

RESEARCH DATA (Original data) (Mendeley Data)

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