Photographic data on the influence of the composition, preparation method, time and fuel system on the size of water droplets in a fuel-water emulsion

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A B S T R A C T
The article presents the data collected during the research aimed at understanding the influence of the composition, mixing time and time between the production and application of the fuel-water emulsion, as well as the influence of the fuel pump of the miniature gas turbine GTM-120 on the droplet size of the fuel-water emulsion. Emulsions with a water content of 3 to 15% and an emulsifier content of 1 to 3% were tested. The basic fuel in the conducted tests was Jet-A1 with the addition of 5% oil. The data presented include microscopic photos of emulsions in fifteen combinations of the amount of water and emulsifier, photos of emulsions pumped by a fuel pump operating at loads corresponding to the engine running from idle to full power. The data also include photos of the emulsions during their production, the time of mixing the water with the remaining ingredients, and photos of the emulsions the day after their preparation.

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Specifications Table

| Subject          | Energy   |
|------------------|----------|
| Specific subject area | Fuel Technology |
| Type of data     | Image    |
| How the data were acquired | Microscope Delta Optical MET 200TRF, Camera DLT Cam PRO 10MP |
| Data format      | Raw      |
| Description of data collection | Data were obtained by microscopic photography of fuel-water emulsions. An emulsion sample, in order to be photographed, was taken from the central part of the volume of the previously prepared mixture using a glass pipette, and then it was transferred to a microscopic glass slide and photographed in the shortest possible time. |
| Data source location | Institution: Warsaw University of Technology, Institute of Thermal Technology, Department of Aviation Engines  
|                     | City: Warsaw, Nowowiejska 21/25 Street, 00-665 Warsaw  
|                     | Country: Poland |
| Data accessibility | Repository name: Zenodo  
|                   | Data identification number: 10.5281/zenodo.6519701  
|                   | Direct URL to data: https://doi.org/10.5281/zenodo.6519701 |

Value of the Data

- The data allow estimating the influence of the energy supplied in the mixing process and the amount of water as well as the amount of emulsifier on the droplet size of the discrete phase of an emulsion. They make it possible to obtain information on the influence of the gear fuel pump on the size of water droplets in the emulsion pumped through the fuel system of a miniature gas turbine for the operating ranges from idle to maximum load. They also allow for inference about the changes in the droplet size distribution of the discrete phase of the emulsion taking place one day after its production.
- The dataset may be of use to researchers dealing with the combustion of emulsion fuels and researchers dealing with surfactants and stability of emulsions.
- On the basis of these data, it is possible to select the composition and the method of preparation of the emulsion that will be optimal for future experiments.

1. Data Description

The data in the form of microscopic photos of the fuel-water emulsion were placed in fifteen folders marked with Roman numerals from I to XV. The contents of individual folders and the interpretation of the names of photos in JPG format is described below.

- **I**
  The folder contains three consecutive photos of the calibration glass with an increment of 0.01 mm.

- **II**
  The folder contains photos of an emulsion containing 1% emulsifier and 3 to 15% water. The names of the individual photos were given according to the diagram shown in Fig. 1.

- **III**
  The folder contains photos of the emulsions containing 2% of emulsifier and 3 to 15% of water. The convention of names of photos in the folder is as shown in Fig. 1.
**Fig. 1.** Convention for marking data in folder II; (a) percentage of water in the emulsion, (b) percentage of surfactant in the emulsion, (c) serial number of the photo taken on the sample.

**Fig. 2.** Convention for marking data in the VI folder; (a) percentage of water in the emulsion, (b) percentage of surfactant in the emulsion, (c) mixing time of the emulsion (stage II) expressed in minutes, (d) serial number of the photo taken on the sample.

- **IV**

  The folder contains photos of the emulsions consisting of 3% of emulsifier and 3 to 15% of water. The convention of names of photos in the folder is consistent with Fig. 1, with the proviso that the additional number at the end of the photo name informs about the number of the photographed sample, if there were more than one of them. The samples are numbered from zero.

- **V**

  The folder contains photos of the fuel-water emulsions taken approximately one day after their production. The convention of names of photos in a folder is consistent with Fig. 1, with the proviso that the additional marking at the end of the name ",_d" identifies photos of this group.

- **VI**

  The folder contains photos of the emulsions containing 3% of water and 2% of emulsifier, which were produced with different times of mixing the water with the remaining ingredients of the emulsion by means of a mechanical stirrer. The method of reading the markings of photos in the VI folder is shown in Fig. 2.

- **VII**

  In the folder there are photos of the emulsion containing 6% water and 2% emulsifier, which were produced with a variable time of mixing the water with the remaining components of the emulsion by means of a mechanical stirrer. The convention of naming photos is consistent with Fig. 2.

- **VIII**

  In the folder there are photos of an emulsion containing 9% water and 2% emulsifier, which were produced with a variable time of mixing water with the remaining emulsion components by means of a mechanical stirrer. The convention of naming photos is consistent with Fig. 2.
• IX

In the folder there are photos of an emulsion containing 12% water and 2% emulsifier, which were produced with a variable time of mixing water with the remaining emulsion components by means of a mechanical stirrer. The convention of naming photos is consistent with Fig. 2.

• X

In the folder there are photos of an emulsion containing 15% water and 2% emulsifier, which were produced with a variable time of mixing water with the remaining emulsion components by means of a mechanical stirrer. The convention of naming photos is consistent with Fig. 2.

• XI

The folder contains photos of a fuel-water emulsion consisting of 3% water and 2% emulsifier. The photos show the emulsion previously pumped through the fuel pump of the miniature gas turbine GTM-120. The load of the fuel pump reflected its operation in five states of engine load expressed by the rotational speed of the shaft. The photo naming convention is shown in Fig. 3.

The photos whose name contains the word "reference" instead of the simulated rotational speed of the gas turbine, refer to the photo of the emulsion taken from the sample, but not pumped by the fuel pump.

• XII

The folder contains photos of a fuel-water emulsion consisting of 6% water and 2% emulsifier. Marks and other information in accordance with those for folder XI.

• XIII

The folder contains photos of a fuel-water emulsion consisting of 9% water and 2% emulsifier. Marks and other information in accordance with those for folder XI.

• XIV

The folder contains photos of a fuel-water emulsion consisting of 12% water and 2% emulsifier. Marks and other information in accordance with those for folder XI.

• XV

The folder contains photos of a fuel-water emulsion consisting of 15% water and 2% emulsifier. Marks and other information in accordance with those for folder XI.

2. Experimental Design, Materials and Methods

The presented data were collected as part of preliminary research on the use of fuel-water emulsion as an alternative fuel for gas turbines. They were aimed at verifying the suitability of
Table 1
Mass fraction of surfactant components.

| Surfactant ingredients |       |
|------------------------|-------|
| Rokwin 80              | 50.00 |
| Rokanol RZ4P11         | 25.00 |
| Rokanol DB3            | 22.50 |
| Rokafenol N8           | 1.67  |
| Water                  | 0.83  |

Fig. 4. Mechanical stirrer, dimensions expressed in millimeters.

the emulsion prepared on the basis of the emulsifier described below as a fuel. The effect of the application of these fuel-water emulsions and emulsifier on the operating parameters and emission from a miniature gas turbine was described in [1–4].

The continuous phase of the tested emulsions was a mixture of Jet-A1 produced by the Polish refinery PKN Orlen and AeroShell Turbine Oil 500 in a mass ratio of 95: 5. The surfactant was a mixture of four emulsifiers and demineralized water (Table 1). The emulsifiers included in the surfactant were produced by PCC SE.

All emulsions were prepared by mixing the ingredients with a mechanical agitator with a power of 550W (Fig. 4), in a two-step process. In the first step, the mixture of Jet-A1 with the addition of oil was mixed with the surfactant, the mixing time was 5 minutes. As a second step in preparing the emulsion, water was added to the resulting mixture and a 5-minute mixing process was performed, except where mixing time was variable. In all cases, the percentage of water and surfactant in the emulsion is the mass fraction of the total mixture. A Radwag Wlc 2/a2 balance was used to measure the amount of emulsion ingredients.
The experiment was divided into four main parts, in which the variables were:

- The amount of water (3–15%) and emulsifier (1–3%) in the fuel-water emulsion.
- The mixing time (stage II) of the emulsion.
- Time since emulsification.
- Volumetric output of the fuel pump through which the emulsion was flowing.

In order to obtain data concerning the influence of the amount of water and emulsifier on the microscopic parameters of the emulsion, emulsions containing 3, 6, 9, 12, 15% water and 1, 2 and 3% emulsifier in all possible combinations were prepared and then photographed. It was decided to test fuel-water emulsions with a water content of up to 15%, because it is the amount of fuel additive that allows to conduct tests on a turbojet engine in a wide range of engine load without modifying the fuel system, in order to adapt it to the increased fuel mixture expenditure [5]. On the other hand, the range of the amount of added emulsifier to the emulsion was defined to be a typical amount of surfactant added to stabilize the emulsion in combustion engine combustion issues [5–7].

The influence of the mixing time on the parameters of the emulsion was tested for all the above-mentioned water contents and the 2% emulsifier content. The mixing time of water with the previously prepared mixture was changed from 2.5 to 15 min with an interval of 2.5 min (180 s). The emulsions pumped by the fuel pump contained 2% emulsifier and five variants of water content. About a day after production, the emulsion was photographed for seven water-emulsifier combinations.

The total amount of emulsion contained in one sample was 300 g, except in cases where the emulsion was pumped through the fuel pump, then a 1500 g sample of the emulsion was prepared. In the case of data collected in order to estimate the effect of the amount of water and emulsifier as well as the mixing time on the size of the water droplets, after the emulsion preparation process was completed, it was photographed no longer than 120 s.

In order to obtain data on the influence of the fuel system element of the miniature gas turbine, i.e. the fuel pump, on the droplet size of the discrete phase, the fuel-water emulsion was pumped through the AERIOS 7 rotary positive displacement pump, simulating the load it would be subjected to during the operation of the turbine, powered by emulsion fuel, with rotations of 40, 60, 80, 100 and 120 rpm. During the experiment, the volume of liquid corresponding to the volume of fuel flowing through the pump at the analyzed operating points of the GTM-120 turbine operating on unmodified (base) fuel was pumped through the pump, increased by the volume of water and emulsifier included in the emulsion. The base fuel consumption included in the emulsion was kept at the level corresponding to the fuel consumption during the operation of the turbine on unmodified fuel, because it was assumed that the use of fuel-water emulsion as the fuel of the GTM-120 turbine would not significantly change the base fuel consumption. As a result, the fluid flow pumped by the fuel pump was increased by the volume of components added to the fuel, similarly to the J79-GE-10 turbojet engine [5]. The volumetric fuel consumption at the operating points 40, 60, 80, 100 and 120 rpm of the GTM-120 turbine, operating on the base fuel, was adopted as 115, 170, 230, 325, 510 ml/min, respectively, in accordance with previous studies [8]. In order to reflect the load of the fuel pump during its operation at individual operating points of the gas turbine, the dependence of the voltage at the fuel pump terminals on the volumetric output of the pumped liquid was determined experimentally. In order to convert the mass flow into the volume flow of emulsions for Rokwin 80, Rokanol RZ4P11, Rokanol DB3, Rokafenol N8, their densities were assumed in accordance with the data sheets of these products to be 0.97 g/cm³, 0.97 g/cm³, 0.93 g/cm³ and 1.06 g/cm³, respectively. Whereas, the density of Jet-A1 was estimated to be 0.82 g/cm³ based on volume and weight measurements. The obtained value is within the range of possible values of this parameter included in the product specification sheet.

The test was performed according to the following procedure. The emulsion from a 1500 g portion, prepared immediately before the test, was pumped to the drainage installation until the voltage at the fuel pump terminals was stabilized at the expected value. For each of the fifteen combinations of the composition of the fuel-water emulsion, the value of the voltage expected at
the terminals of the fuel pump was modified based on the previously determined characteristics, so as to ensure the flow of the base fuel being the continuous phase of the emulsion, appropriate for a given operating point. After the voltage at the pump terminals had stabilized, a sample was taken and photographed immediately. The fuel line supplying the emulsion to the fuel pump was 2200 mm long and had an inside diameter of 2 mm, and the outlet line from the pump was 1600 mm long and the same diameter.

The study used a Delta Optical MET 200TRF microscope equipped with an eyepiece with 10 times magnification and a 40 times magnification objective. The photos were taken with the DLT Cam PRO 10MP camera. The photos taken have a resolution of 3584 \times 2748 pixels. After taking the photos, no treatments were given. Each photo included in the data has the date of its taking and time (CET). Some photos have a scale. All photos were taken with the same test equipment and software parameters and settings. The data includes photos of the calibration glass with an elementary scale of 0.01 mm, made in the settings consistent with the experiment.

Ethics Statements

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.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT Author Statement

Pawel Niszczota: Conceptualization, Investigation, Methodology, Data curation, Writing – original draft; Marian Gieras: Supervision, Conceptualization, Resources, Funding acquisition, Writing – original draft.

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