Several Aspects of the Atomization Behavior of Various Newtonian Fluids with a like-on-like Impinging Jet Injector

G. Bailardi*, M. Negri, H.K. Ciezki‡
DLR – German Aerospace Center,
Institute of Space Propulsion
Lampoldshausen, D-74239 Hardthausen, Germany

Abstract

The objective of the here proposed publication is to present the breakup behavior of a large number of Newtonian fluids under ambient pressure and temperature conditions together with average droplet diameters. Due to the large number of liquids with different densities, viscosities and surface tensions together with the variation of the jet exit velocity up to 80 m/s a large parameter range could be covered. Thus dimensionless numbers cover the ranges for the Ohnesorge number Oh from 0.027 to 4.1, for the Reynolds number Re from 10^1 to 10^5 and for the Weber number We from 10^1 to 10^5.

Introduction

Impinging jet injectors are often used for the atomization of storable liquid fuels and oxidizers in rocket engines due to their simplicity, low manufacturing costs, good atomization and mixing characteristics. A large number of studies has been published on impinging jet injectors since the '60es, see e.g. Taylor [1], Dombrowski and Hooper [2], Hasson and Peck [3], Heidmann [4], Anderson, Ryan and Santoro [5], Ibrahim et al. [6], Li and Aschgriz [7], Lai, Huang and Jiang [8], etc. Majority of the published investigations, as far as we know from open source literature, was conducted with Newtonian fluids and are in most cases dedicated to distinct liquids, e.g. kerosene, water or water solutions. Thus the breakup behavior in dependence upon various parameters like pressure, viscosity, velocity, etc. and dimensionless numbers like Reynolds and Weber numbers is not completely presented up to now. E.g. a very first attempt was made by Ciezki et al. [9], who used some distinct fluids with different viscosity, density and surface tension values so that a first regime diagram as a *Re*-*We*-plot could be presented for ambient pressure conditions.

Materials and Methods

In the present work 13 fluids have been investigated. The experimental setup consists of a cartridge with the fluid to be investigated, a hydraulic driving unit and a modular injector unit. The injector arms of the injector unit are mounted on movable rotary tables so that the impingement angle as well as the pre-impingement length can be varied easily. The injector tips (nozzles) can easily be changed for the variation of the nozzle exit diameters and the internal injector geometry. For the present investigation an impingement angle of 90° and a pre-impingement length of 5 mm were chosen. For the visualization of the spray characteristics the shadowgraph-technique was used, together with two CCD cameras, one parallel and one perpendicular to the plane of the injectors, and two Nanolite spark lights as light sources. A Malvern Spraytec was used to measure droplets sizes.

Results and Discussion

In the following only some obtained results are presented shortly due to limited space. Thus only one Newtonian fluid is selected as example for presentation in Fig. 1. This figure shows shadowgraph images of the spray behavior of Ethane-1,2-diol for four different jet exit velocities $\bar{u}$. Each of the left images show the view perpendicular to the fluid sheet, which is produced at the impingement point of the two fluid jets, and the right images the view parallel to the sheet. The images show different break-up modes with increasing jet exit velocities. Comparing different fluids (which cannot be presented in this abstract) it can be seen that at equal $\bar{u}$ different break-up modes occur. In the proposed paper the breakup behavior of the investigated fluids will be described detail. Furthermore the different occurring break-up modes will be arranged in a regime diagram depending on e.g. Reynolds and Weber number. Average droplet diameters were determined by making use of a Malvern Spraytec. Figure 2 presents the Sauter mean diameters SMD (or $D_{3,2}$) in dependence upon the jet exit velocity. It can be seen that for all investigated fluids the SMD decreases with increasing jet exit velocity. The proposed paper will give a detailed description and evaluation of obtained results.

‡ Corresponding author: Dr. Helmut K. Ciezki, helmut.ciezki@dlr.de

* Master degree student from Polytechnic of Milan

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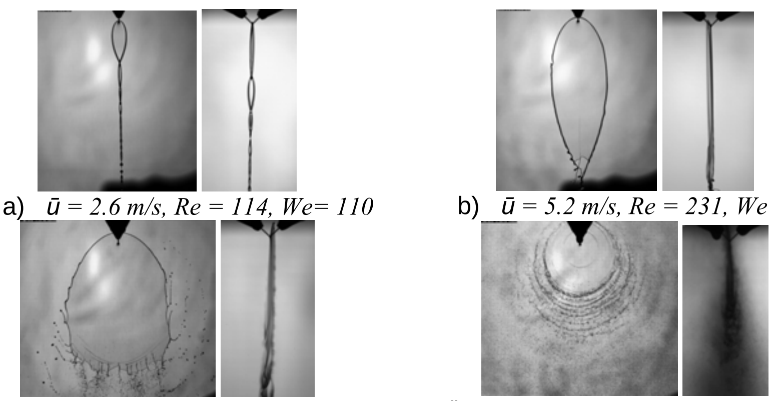

a) $\bar{u}$ = 2.6 m/s, Re = 114, We= 110 b) $\bar{u}$ = 5.2 m/s, Re = 231, We = 439

c) $\bar{u}$ = 6.5 m/s, Re = 289, We= 707 d) $\bar{u}$ = 28 m/s, Re = 1269, We= 13284

Figure 1: Shadow images of the spray behavior of Ethane-1,2-diol at different injection speeds. Oh = 0.0833

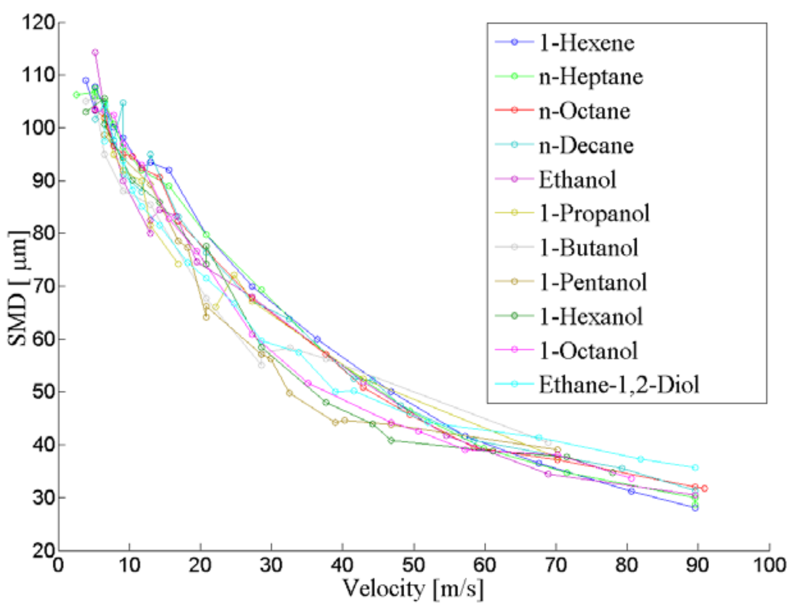

Figure 2: Average droplet diameter (as Sauter mean diameter SMD) of various Newtonian liquids in dependence upon the jet exit velocity.