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EXPERIMENTAL INVESTIGATION OF A DUAL PRESSURE SWIRL INJECTOR FOR LIQUID BIOFUELS

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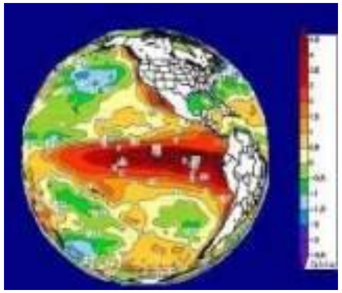
MOTIVATION

ENERGY

Most of the energy in the world, ~ 85 %, comes from combustion processes which are used for transportation, power generation, industrial processes, etc.

GLOBAL WARMING

Combustion processes are the main cause of pollution and climate change.



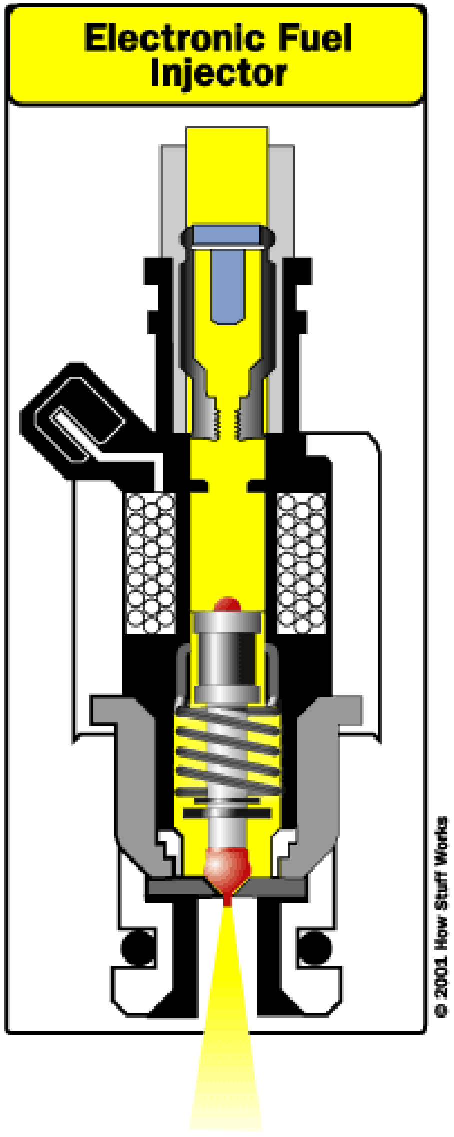
BIOFUELS

Biofuels can reduce the impact of combustion processes.

MOTIVATION

ATOMIZATION PROCESS

Liquid fuels require atomization to increase their superficial area and to improve mixing and vaporization.



FUEL INJECTORS

Engines and burners require fuel injectors to atomize fuels and form sprays.

BIOFUEL ATOMIZATION

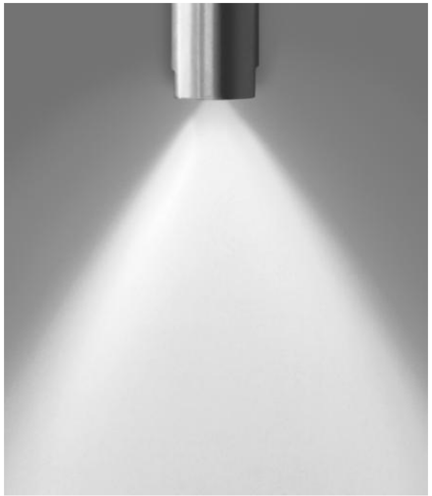
Ethanol and biodiesel are not fully miscible.
A dual pressure swirl injector could help mixing.

OBJECTIVE

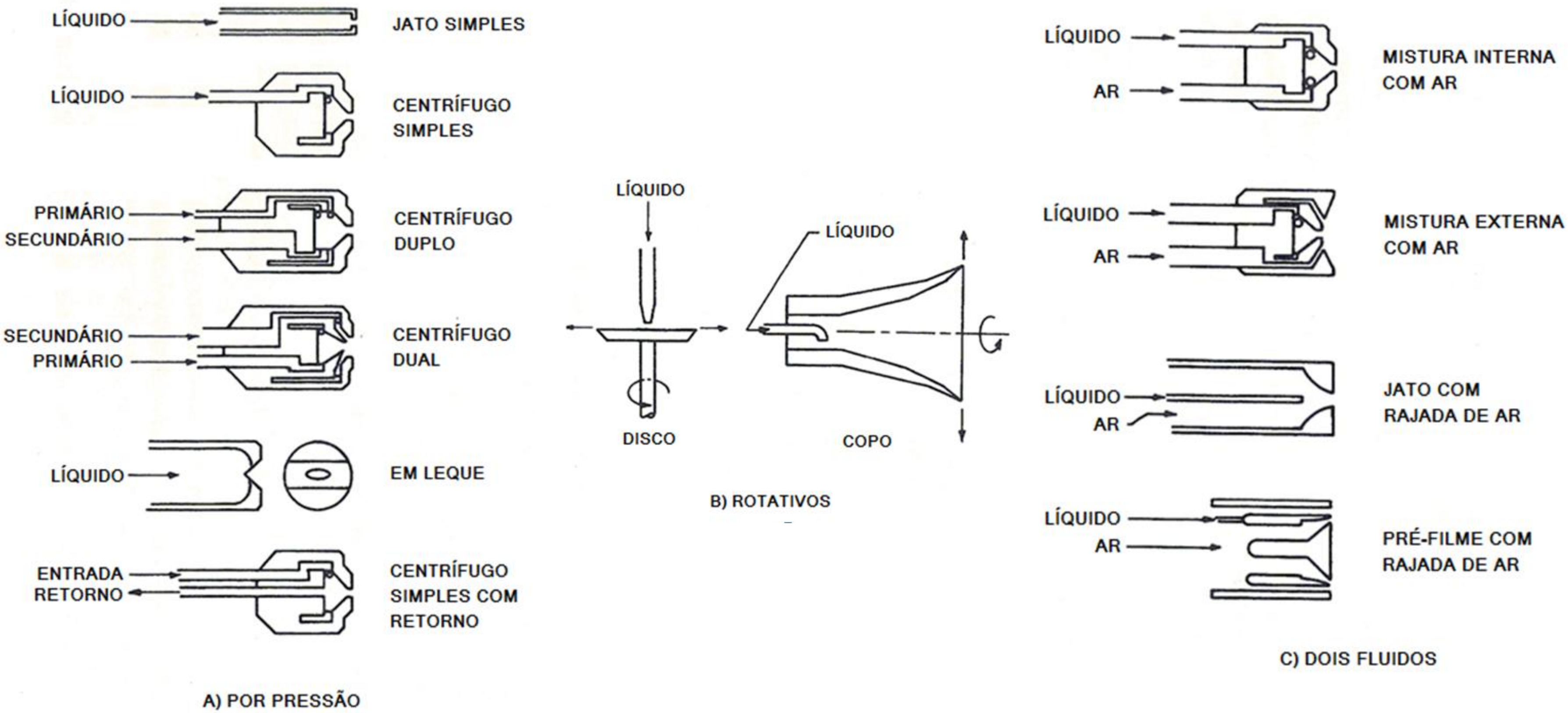
To present results of an experimental investigation of a dual pressure swirl injector for atomization of biofuels.

The atomization characteristics of the injector were obtained in a test bench specially developed for this research:

- discharge coefficients
- average droplet diameters
- distribution of droplet sizes
- spray cone angles,
- mass distributions
- effects of injection pressures
- mass flow rates

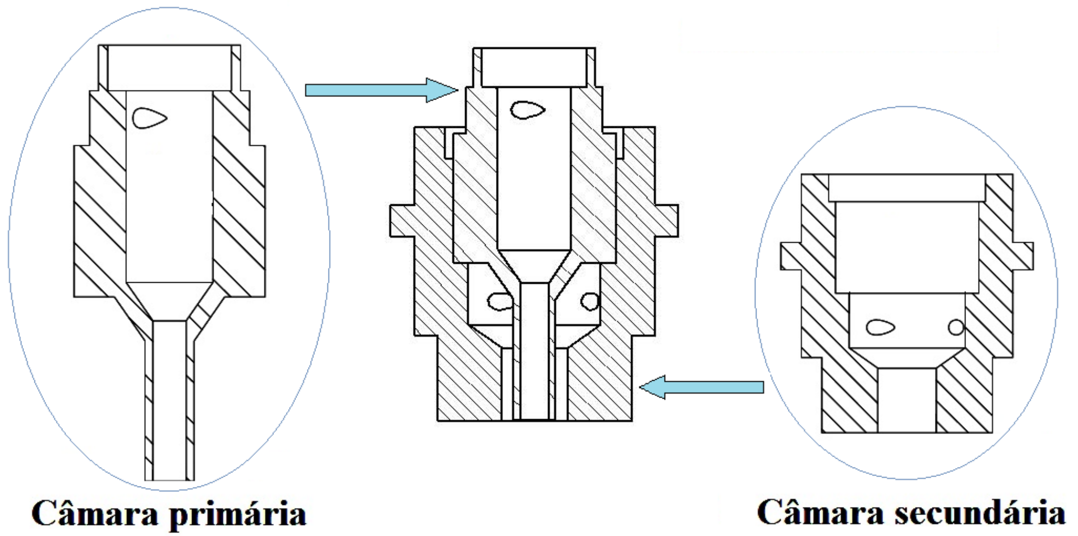


INJECTOR TYPES



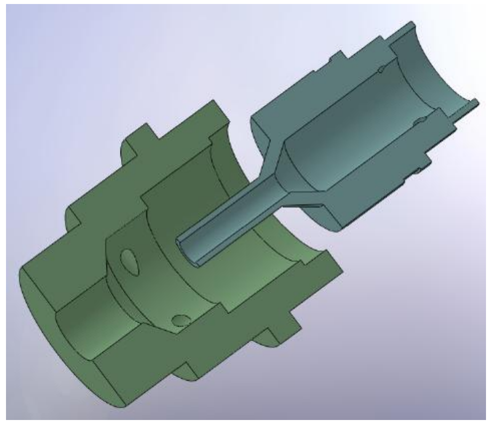
Adapted from Lefebvre (1989)

INJECTOR DESIGN

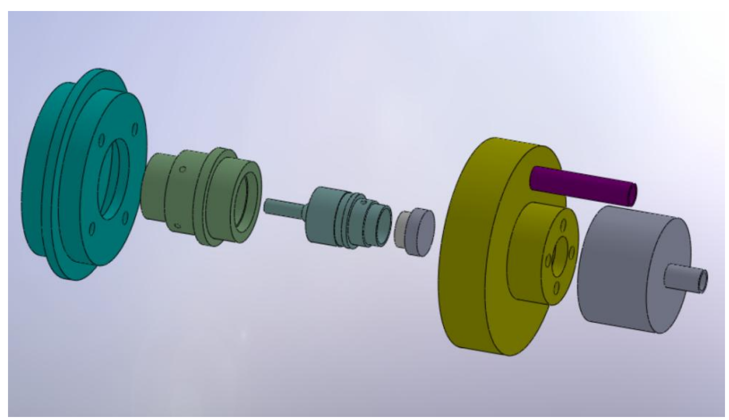


Scheme of a dual pressure swirl injector

INJECTOR PROTOTYPE

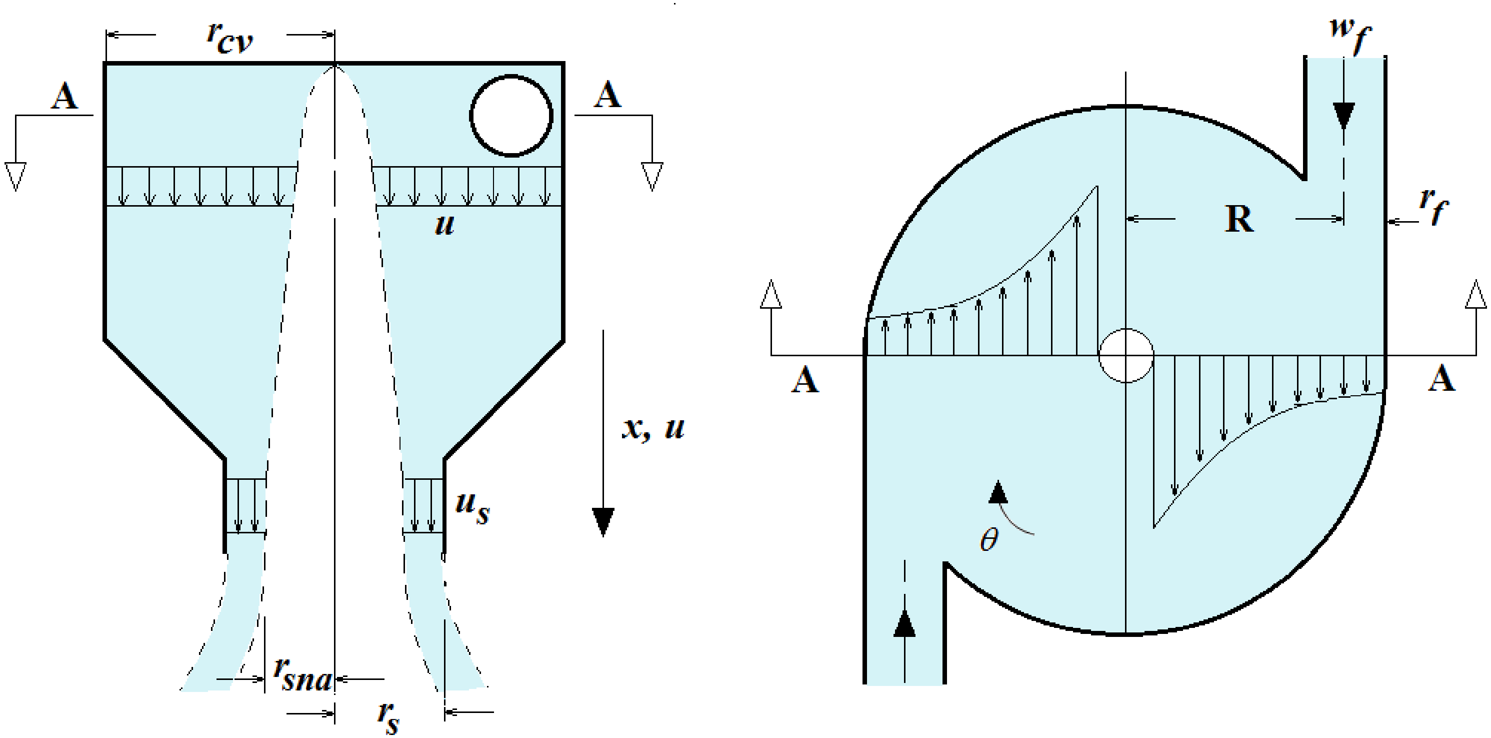
 

View and photo of the injector



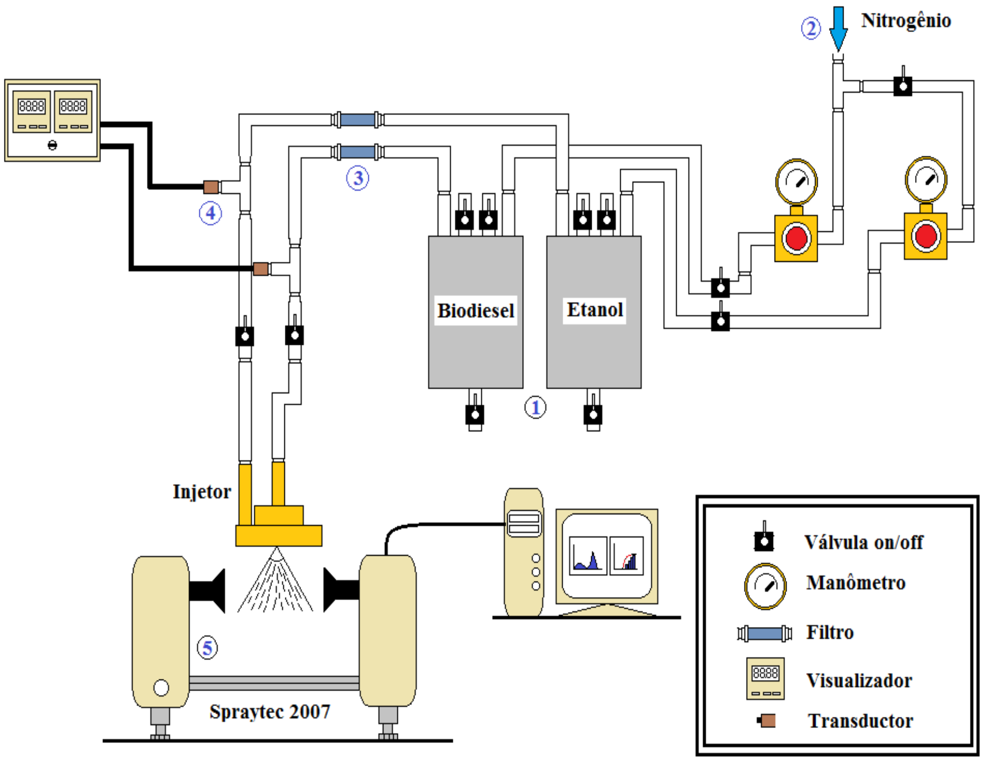
View of the feed system

FLOW INSIDE THE INJECTOR



Flow inside the primary chamber

METHODOLOGY – TEST BENCH

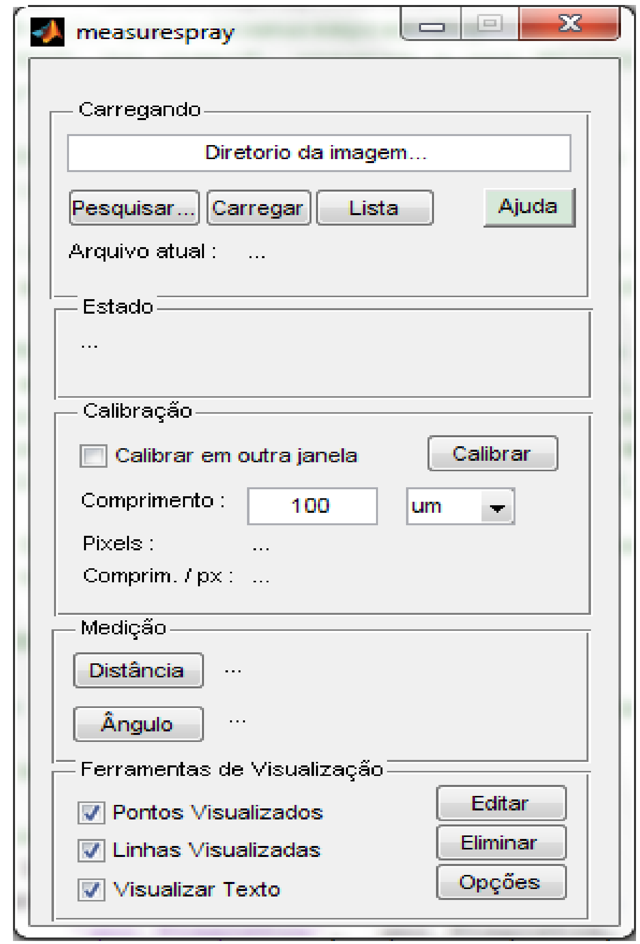


Test bench for spray caracterization.

METHODOLOGY - DROPLET SIZES

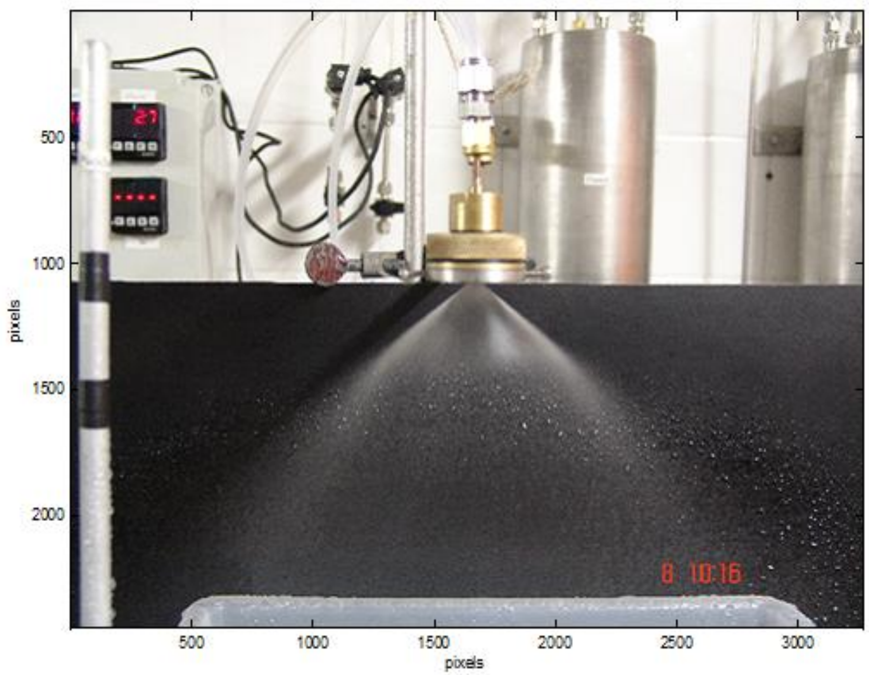
Laser diffraction system for determination of average diameters, cumulative distribution and frequency of droplet sizes.

METHODOLOGY – SPRAY ANGLES

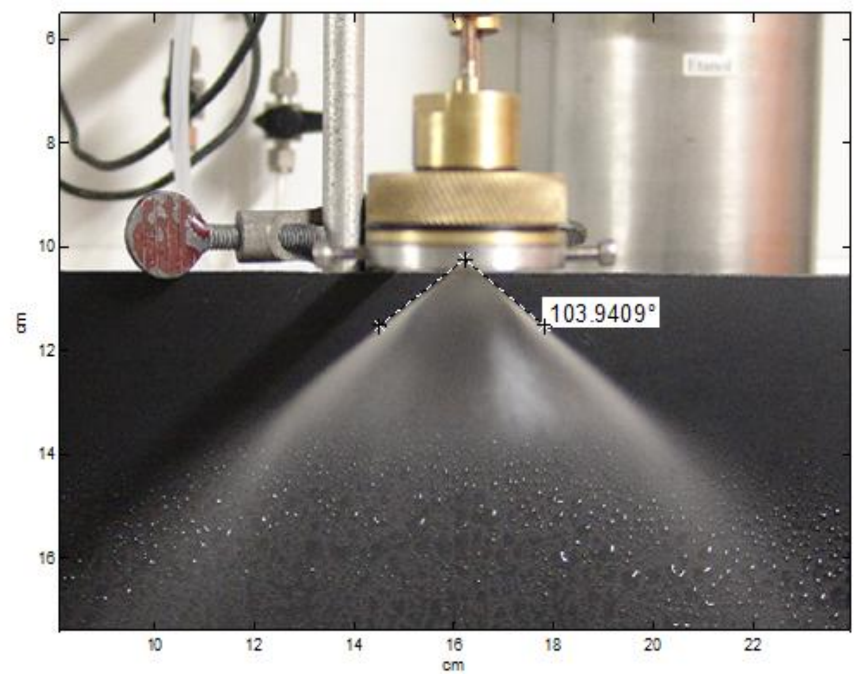


Spray angle measurement: digital camera and software developed.

SPRAY ANGLES



a)



b)

Image not adjusted

Image adjusted by software

Spray angle measurement

DISCHARGE COEFFICIENTS

Experimental discharge coefficients:

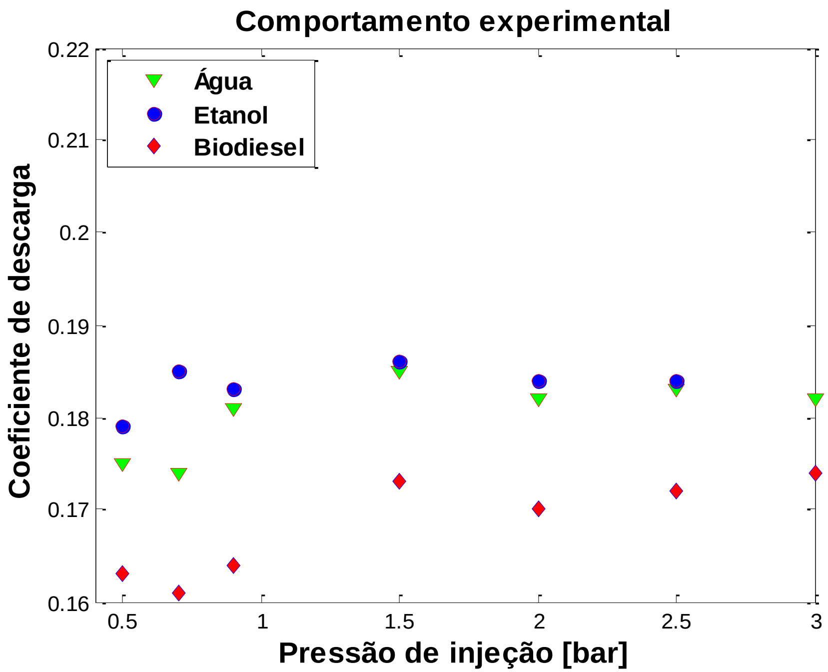
$$C_d = \frac{\text{experimental mass flow rate}}{\text{maximum theoretical flow rate}} \Rightarrow C_d = \frac{\dot{m}_{\exp}}{\dot{m}_{ideal}}$$

$$C_d = \frac{\dot{m}_{\exp}}{A_s \sqrt{2\,\rho_L\,\Delta P}}$$

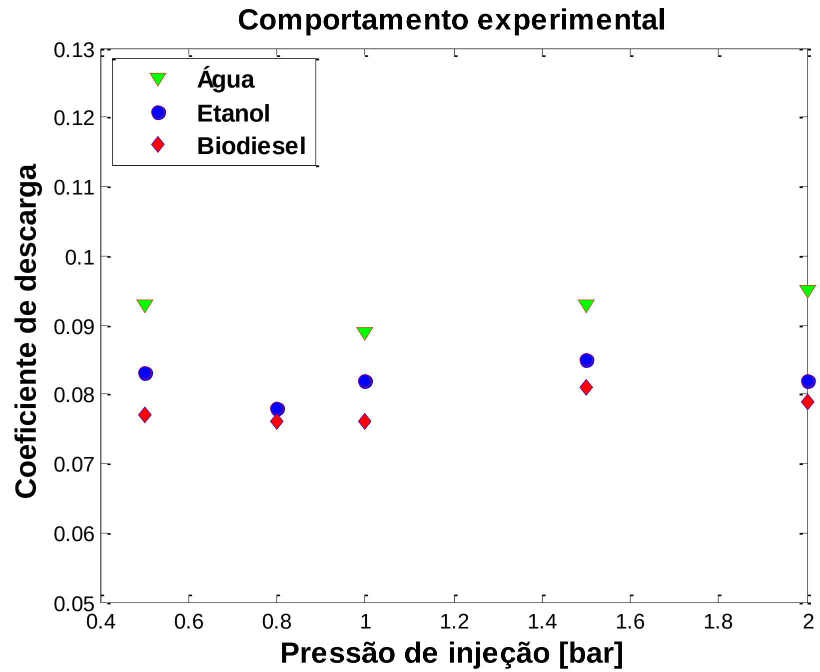
Semiempirical discharge coefficients:

- **Carlisle**
- **Ritz – Lefebvre**
- **Jones**
- **Ballester – Dopazo**

DISCHARGE COEFFICIENT RESULTS

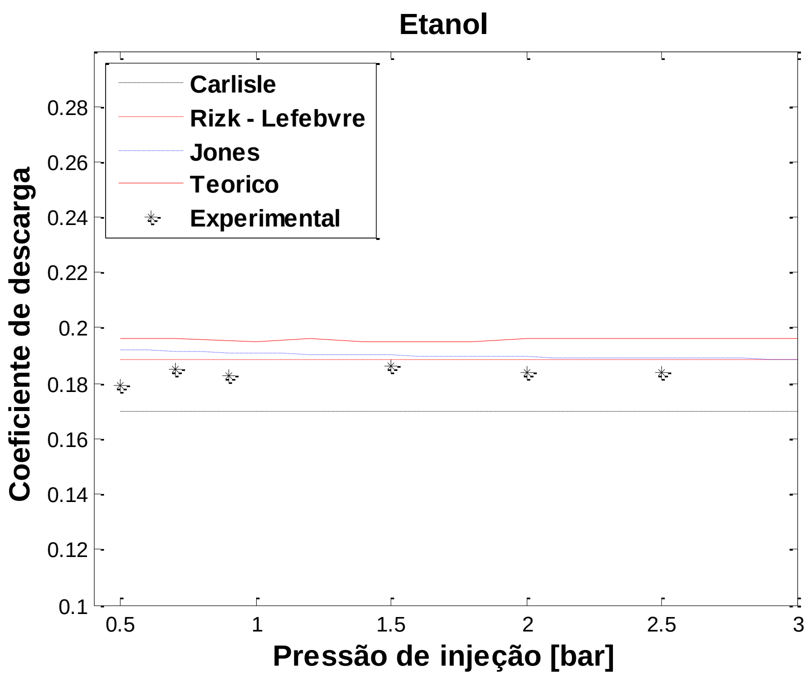


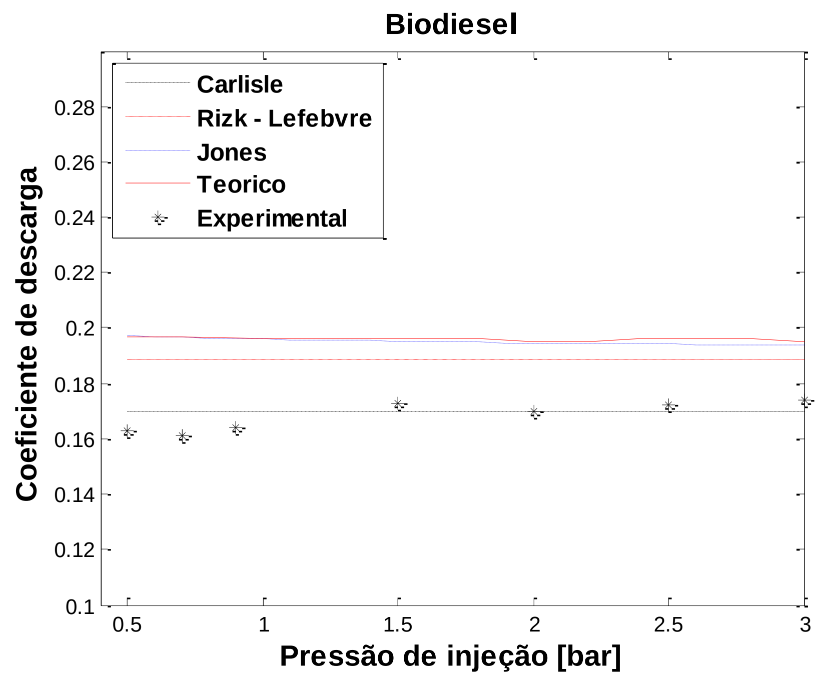
Primary chamber



Secondary chamber

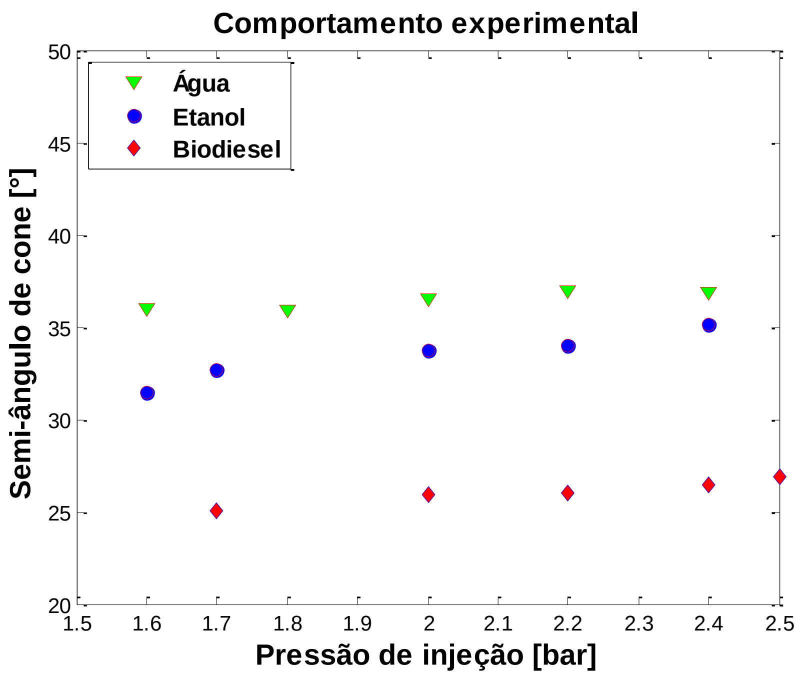
DISCHARGE COEFFICIENT RESULTS



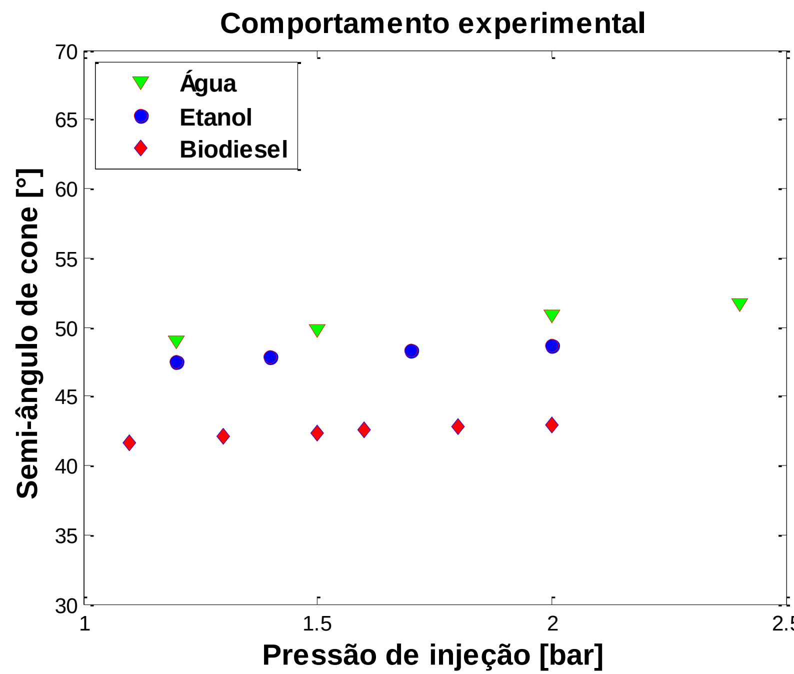


Primary chamber

SPRAY ANGLE WITH SINGLE FLUIDS

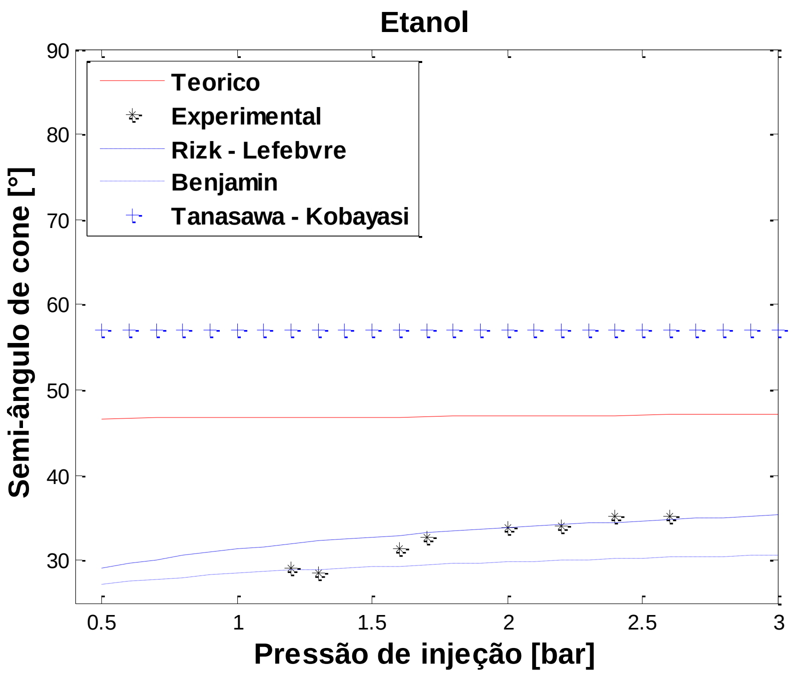


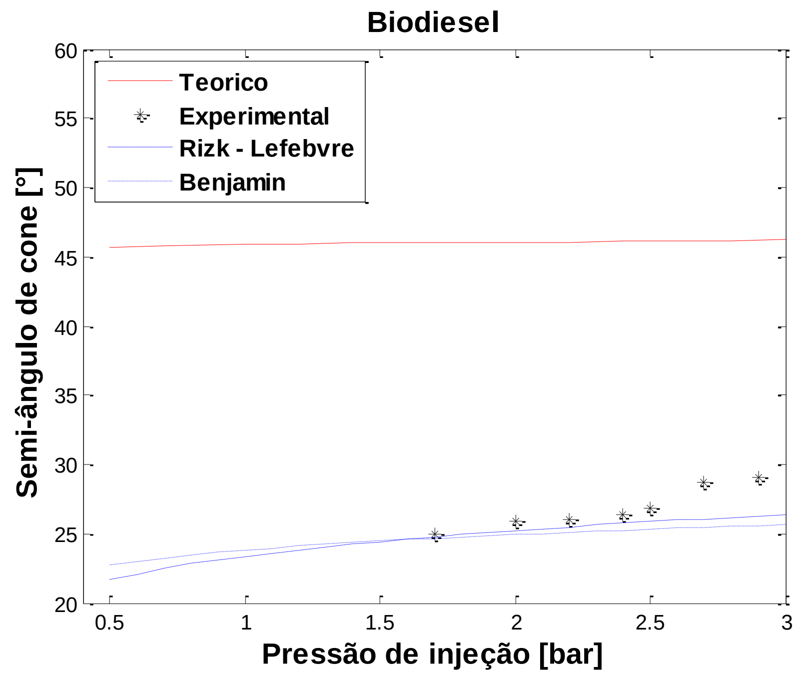
Primary chamber



Secondary chamber

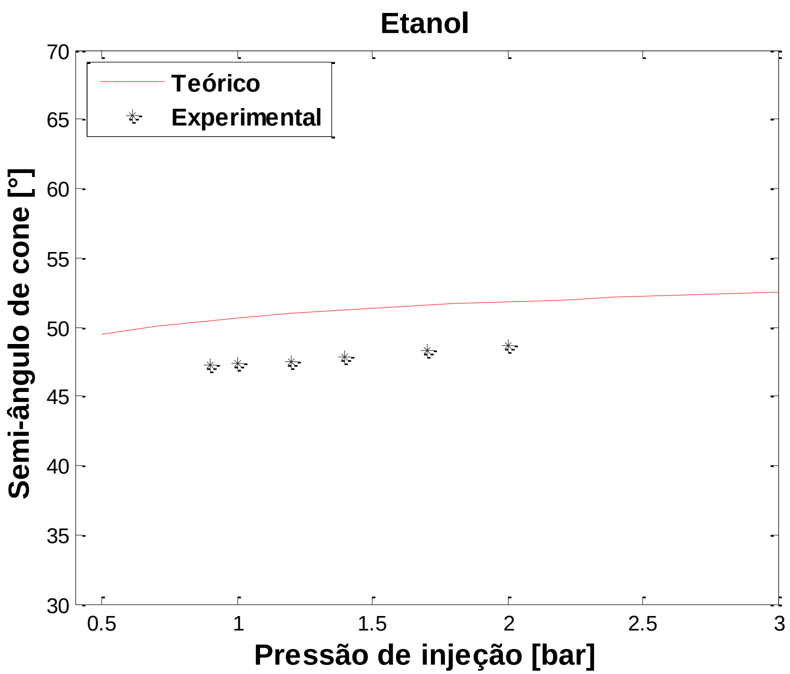
SPRAY ANGLE WITH SINGLE FLUIDS

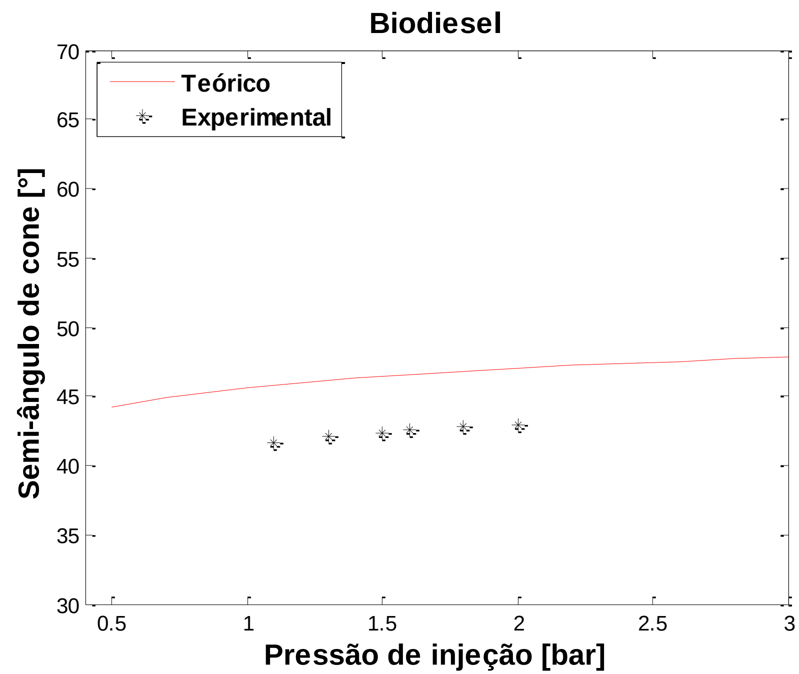




Primary chamber

SPRAY ANGLE WITH SINGLE FLUIDS

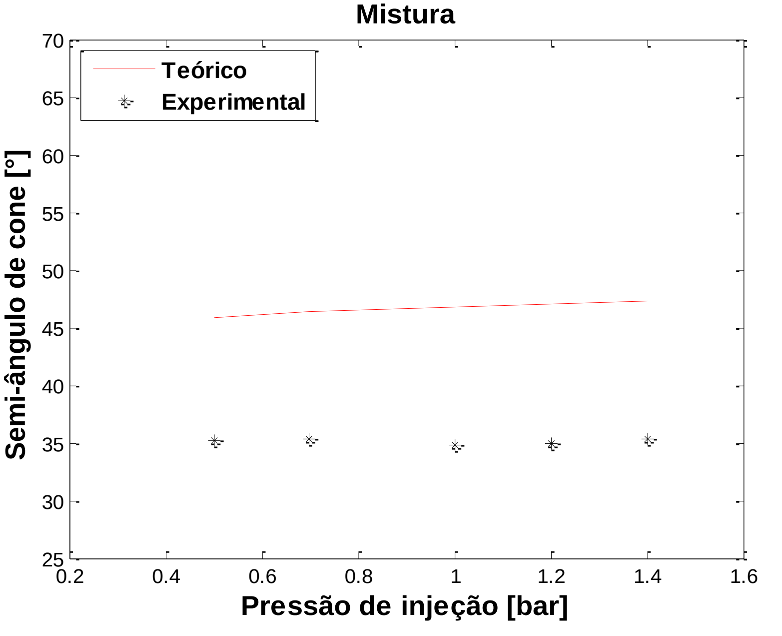




Secondary chamber

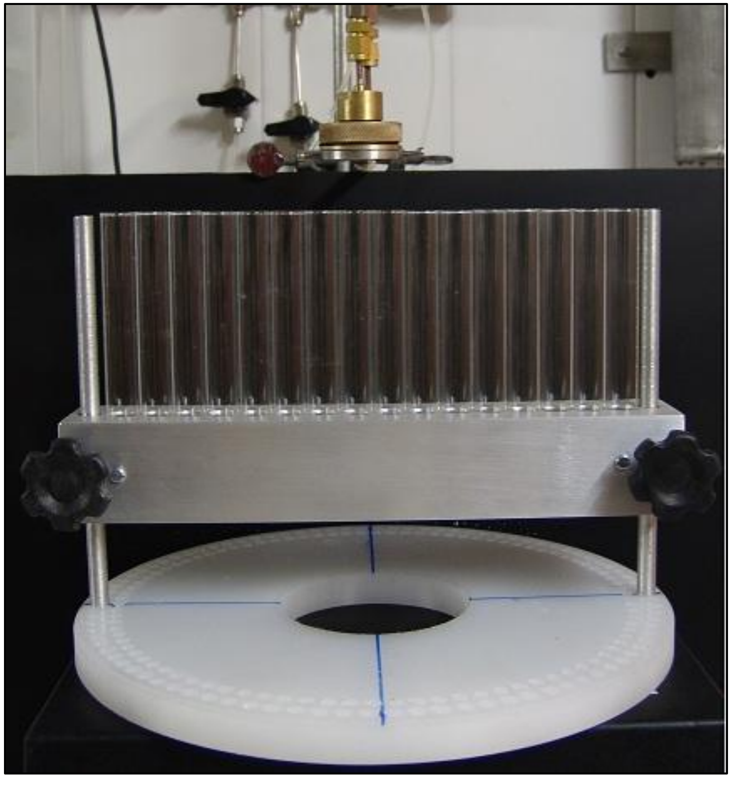
SPRAY ANGLES WITH BOTH FLUIDS

Spray of the ethanol and biodiesel mixture with 1 bar manometric pressure.



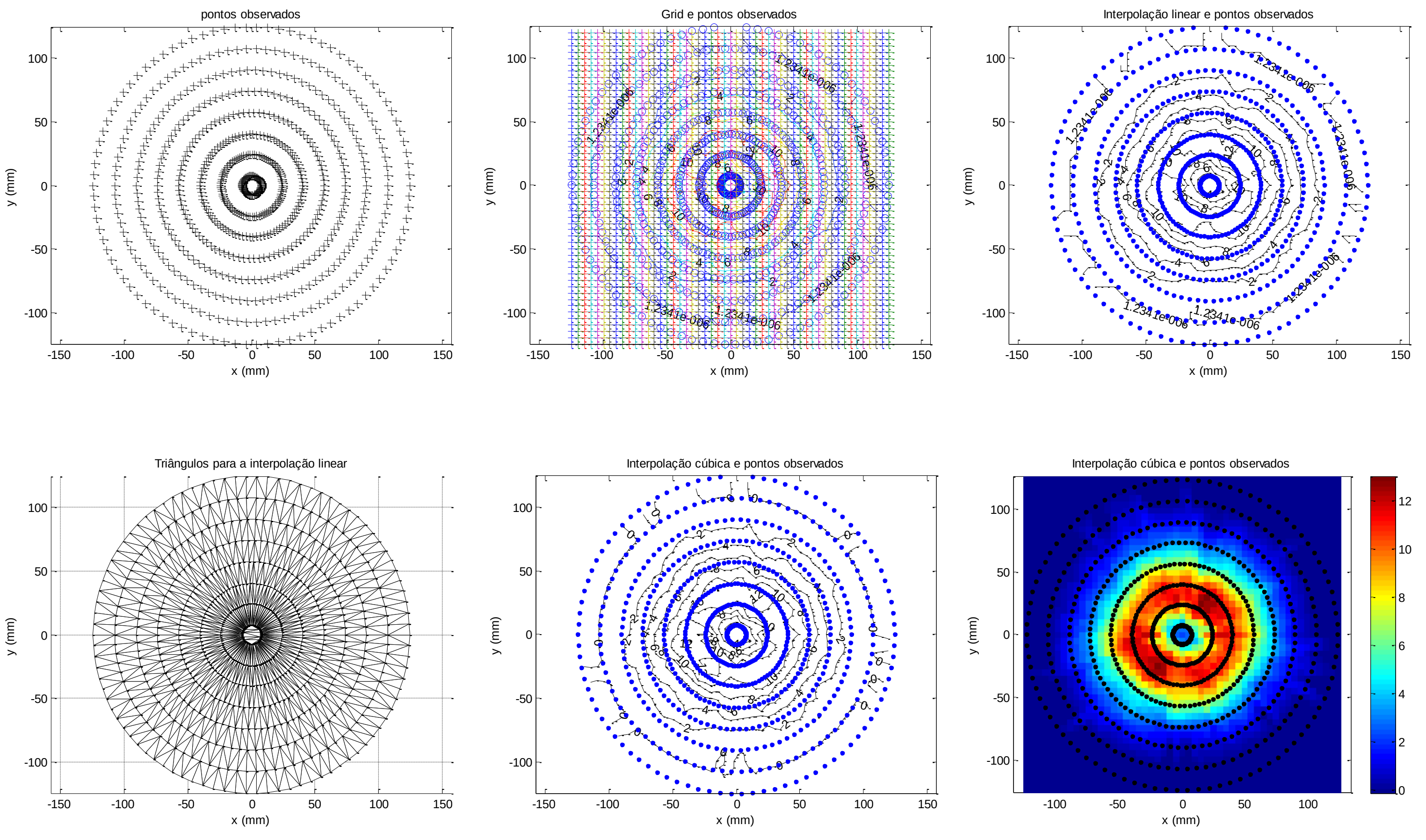
Spray angle formed by ethanol and biodiesel mixtures for different injection pressures.

METHODOLOGY - MASS DISTRIBUTION



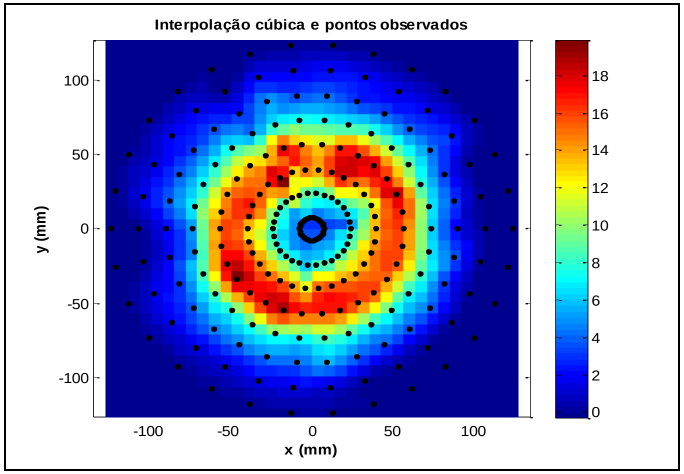
Patternator system with radial spacing 10 mm and angular spacing of 4^{o}

MASS DISTRIBUTION – DATA TREATMENT

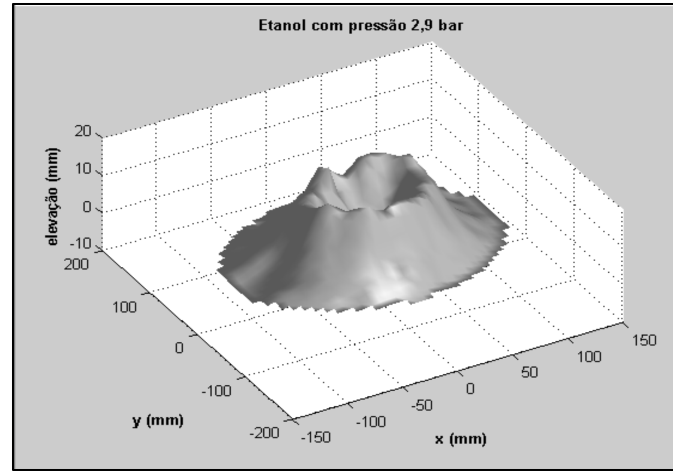


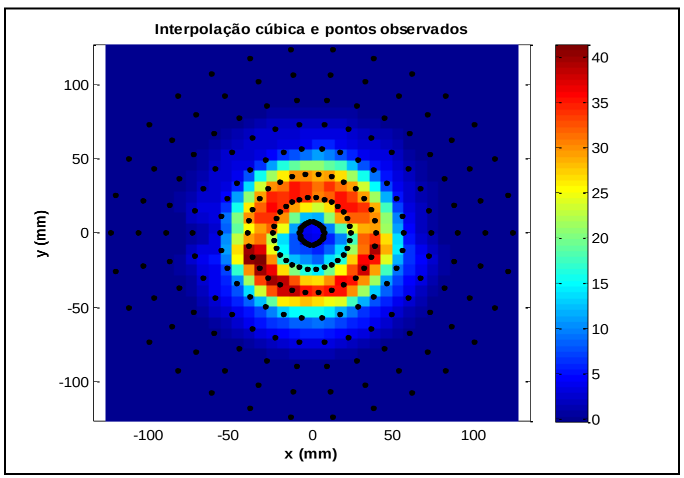
Software developed for mass distribution analysis

MASS DISTRIBUTION - RESULTS

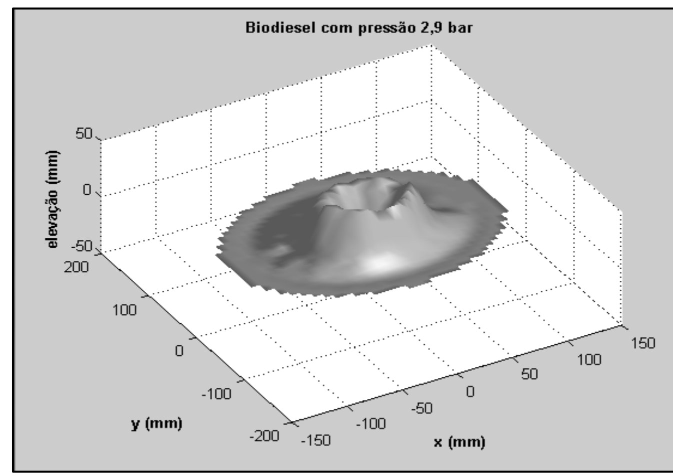


Ethanol



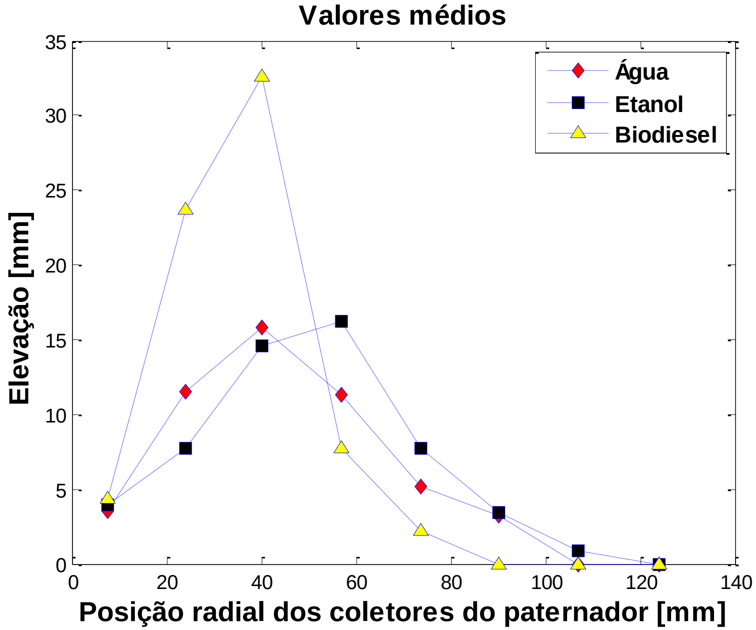


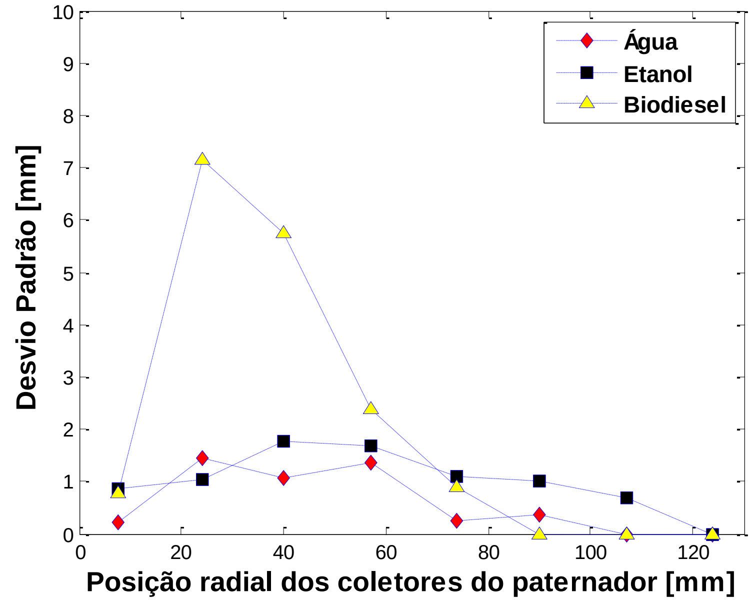
Biodiesel



Results of mass distribution for the primary injector.

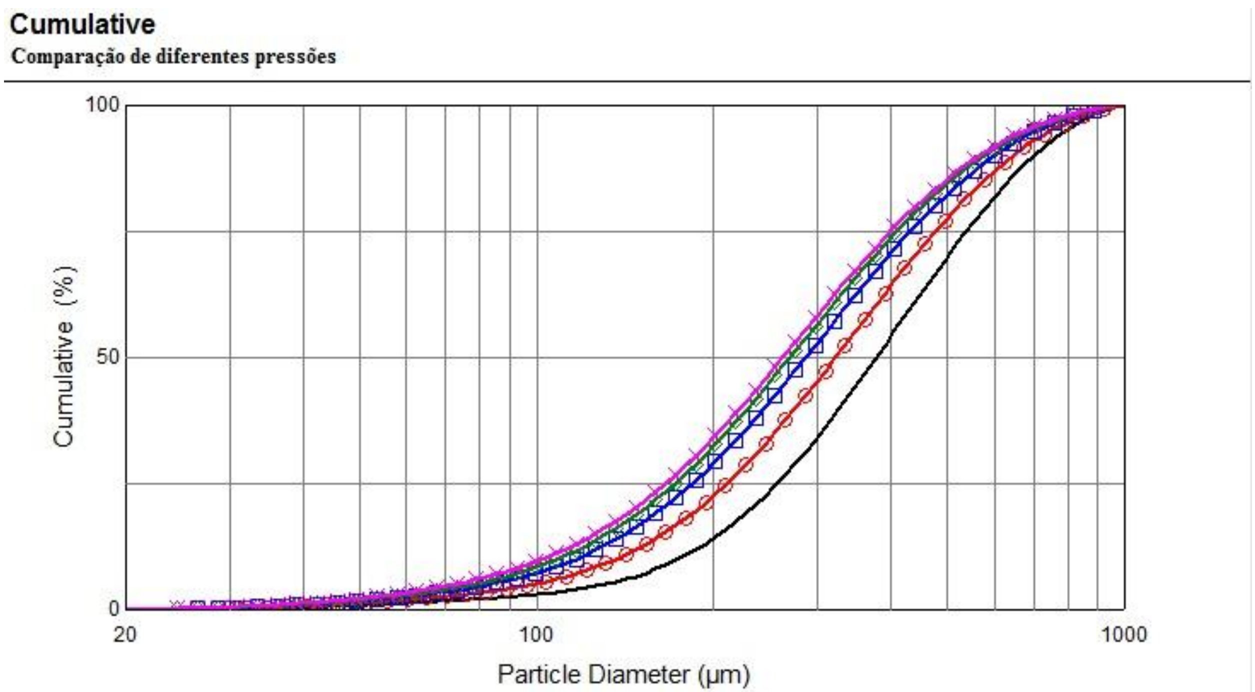
MASS DISTRIBUTION - RESULTS





Average values and standard deviation of the mass distribution with P_{inj} = 2.9 bar man.

DROPLET SIZE CUMULATIVE DISTRIBUTION



	File	Dx(10)	Dx(50)	Dx(90)	Transmission
[V]	Etanol 1.4 bar	173.75	377.82	699.98	65.25
[V]	Etanol 1.6 bar	135.94	322.14	645.69	66.36
[V]	Etanol 1.8 bar	116.16	286.60	600.88	66.10
[V]	Etanol 2 bar	107.93	269.78	575.69	67.40
[V]	Etanol 2.2 bar	102.05	262.06	565.01	68.05

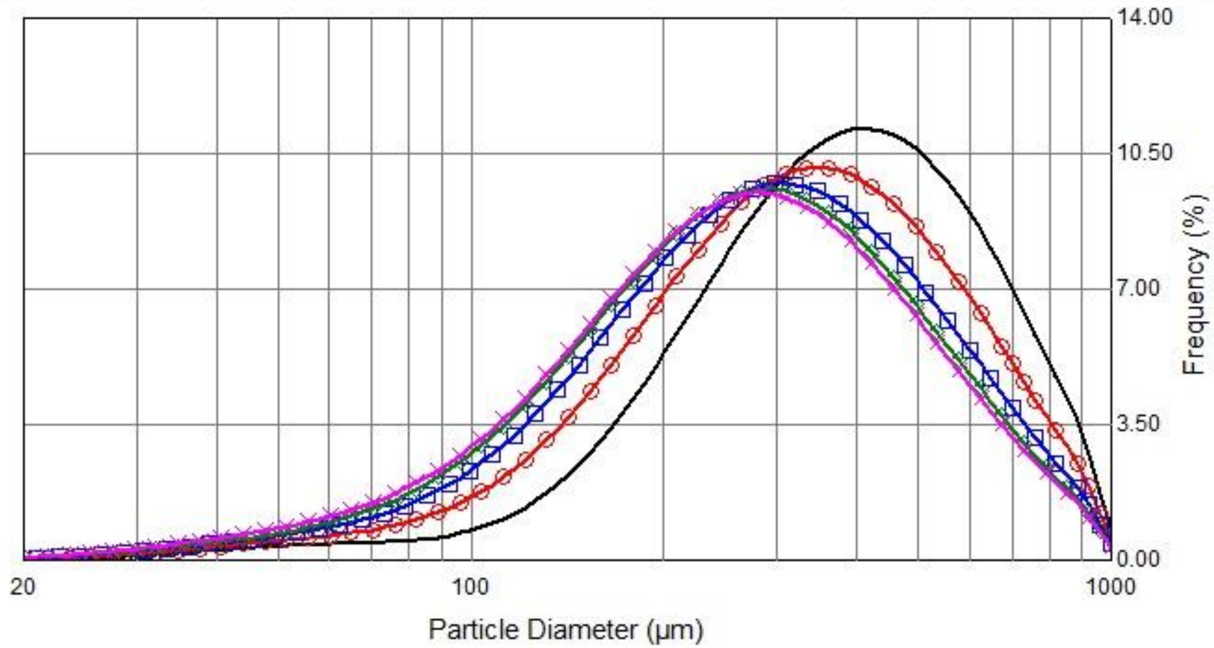
[V]=Volume [N]=Number

ETHANOL - Primary chamber

DROPLET SIZE FREQUENCY

Frequency

Comparação de diferentes pressões



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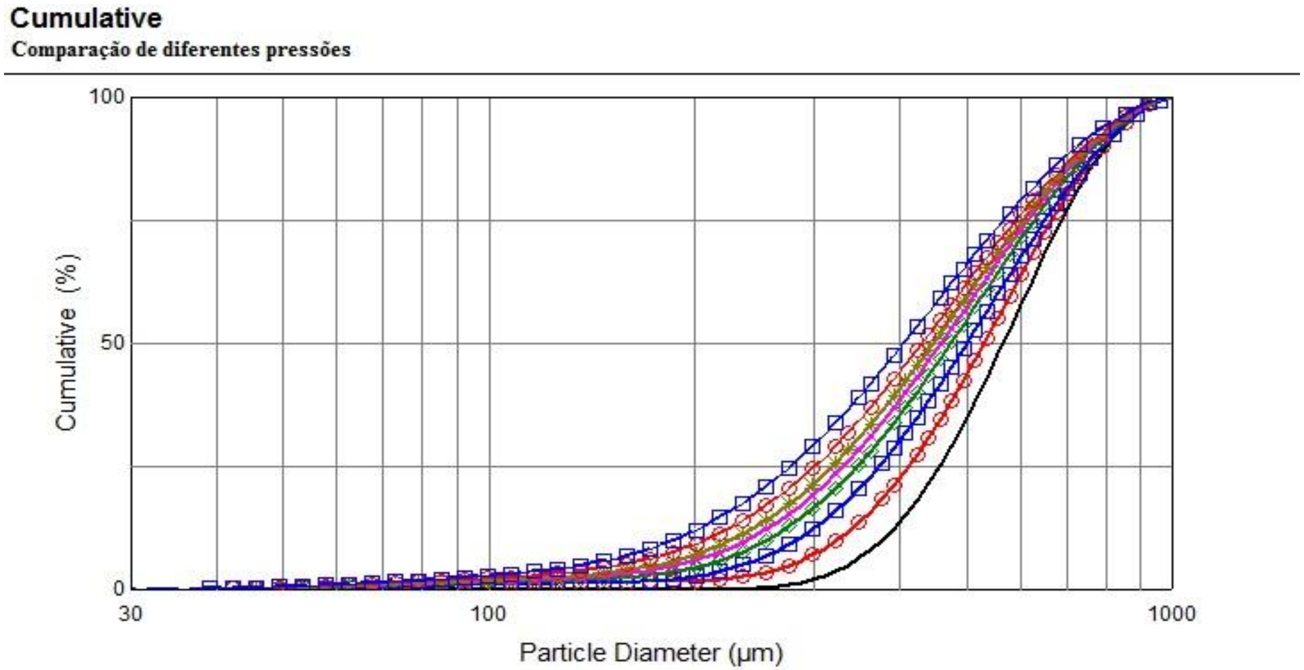
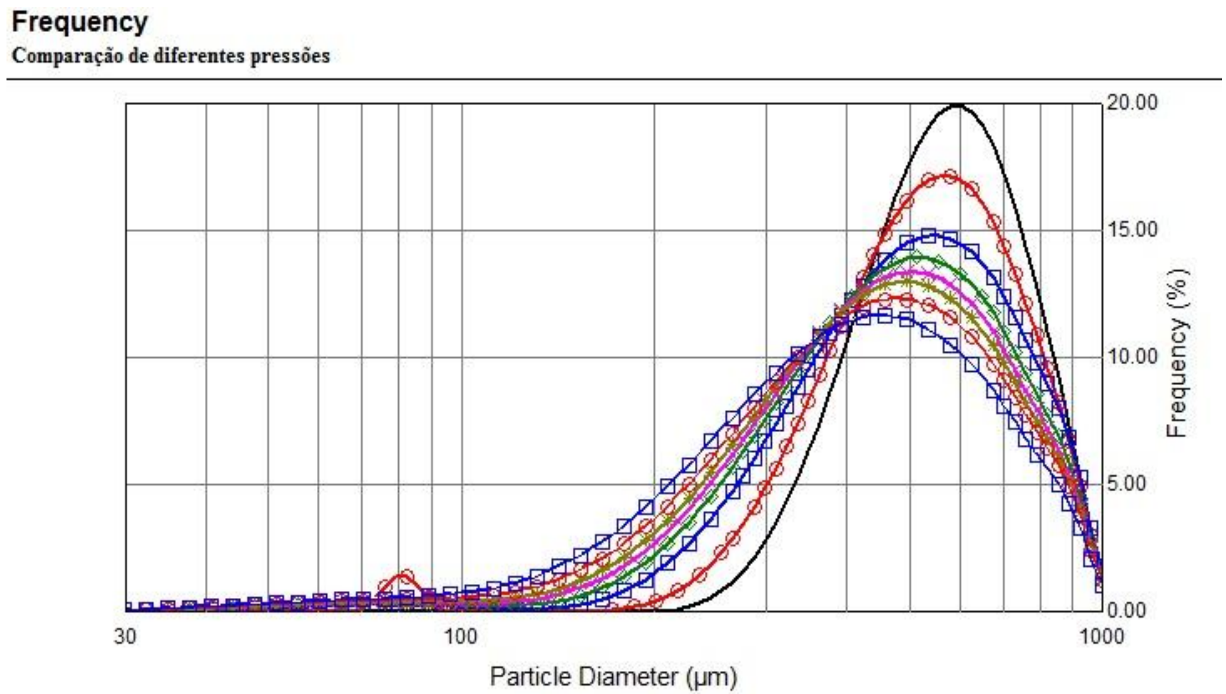


	File	Dx(10)	Dx(50)	Dx(90)	Transmission
[V]	Biodiesel 1 bar	375.39	564.94	798.73	86.49
[V]	Biodiesel 1.4 bar	322.63	529.96	788.29	81.11
[V]	Biodiesel 1.6 bar	280.82	499.83	787.84	83.87
[V]	Biodiesel 1.8 bar	254.55	473.38	768.98	85.27
[V]	Biodiesel 2 bar	237.68	457.95	758.38	85.57
[V]	Biodiesel 2.2 bar	225.45	446.00	750.44	85.81
[V]	Biodiesel 2.4 bar	207.04	429.85	743.59	85.89
[V]	Biodiesel 2.6 bar	186.39	404.76	724.31	85.78

[V]=Volume [N]=Number

BIODIESEL - Primary chamber

DROPLET SIZE DISTRIBUTION



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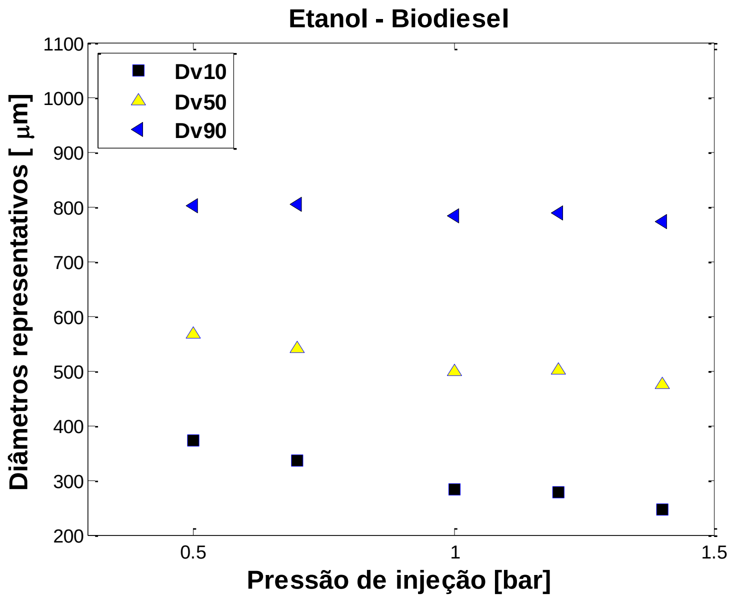
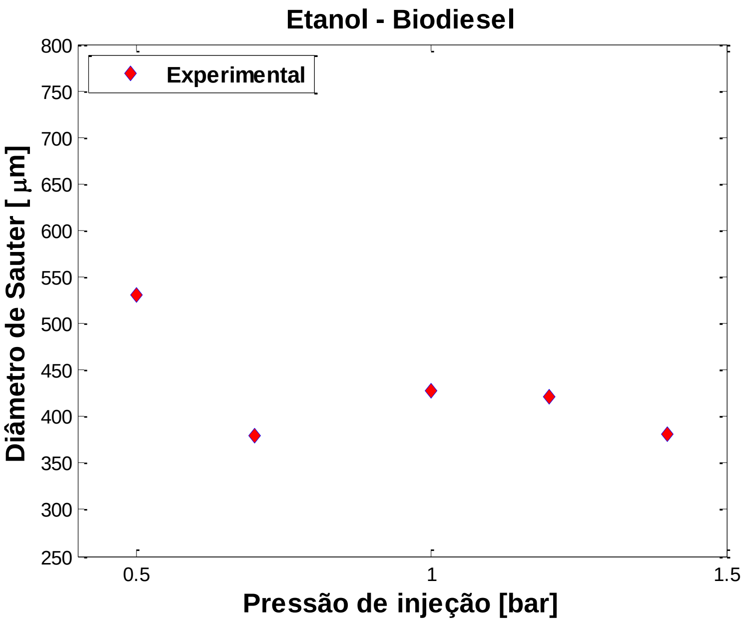
[V]=Volume [N]=Number

BIODIESEL - Primary chamber

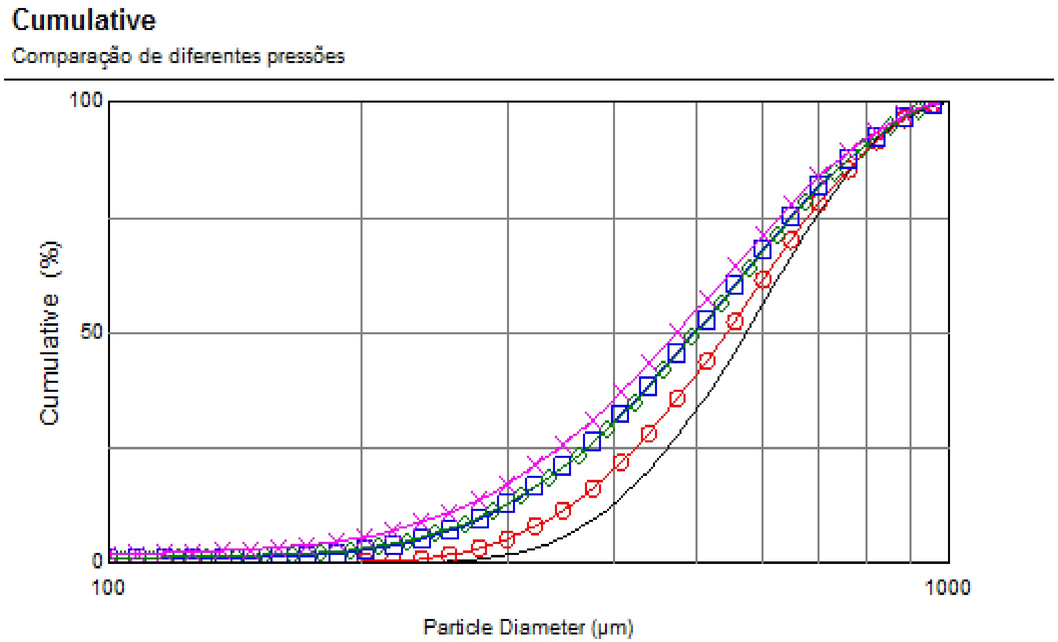
REPRESENTATIVE DIAMETERS – BOTH FUELS





Representative diameters for ethanol and biodiesel injected simultaneously.

DROPLET SIZE CUMULATIVE DISTRIBUTION

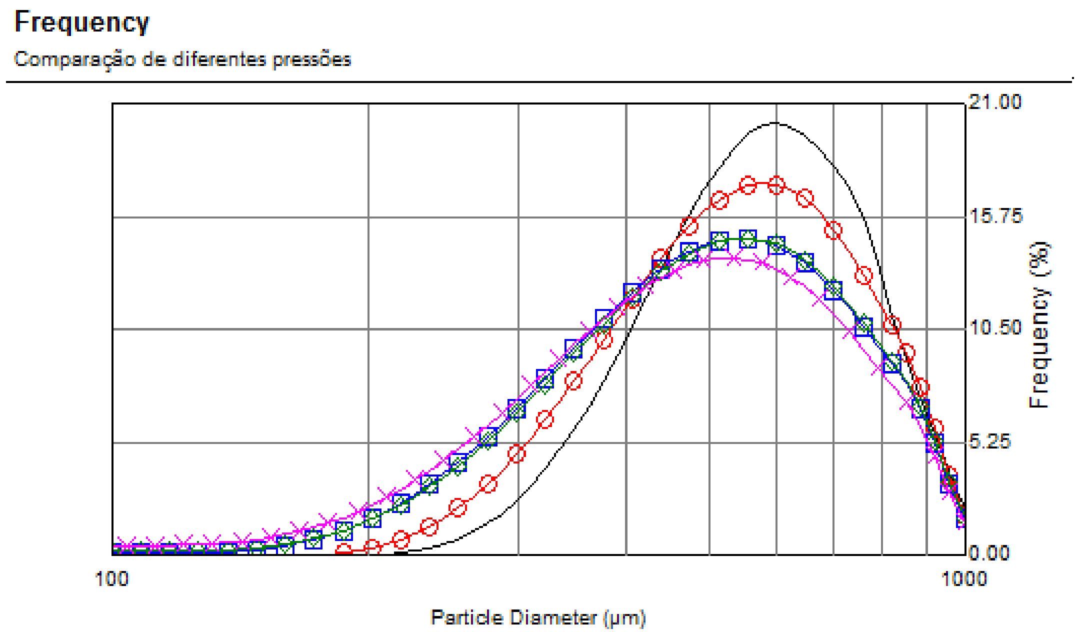


	File	Dx(10)	Dx(50)	Dx(90)	Transmission
[V]	Biodiesel - etanol 05bar	380.54	573.25	802.64	87.88
[V]	Biodiesel - etanol 07bar	336.95	543.10	804.57	88.36
[V]	Biodiesel - etanol 1bar	278.66	497.56	786.66	86.88
[V]	Biodiesel - etanol 1.2bar	276.56	500.25	789.14	79.29
[V]	Biodiesel - etanol 1.4bar	245.60	474.64	771.81	78.70

[V]=Volume [N]=Number

Cumulative distribution of droplet diameters for simulaneous injection of ethanol and biodiesel.

DROPLET SIZE FREQUENCY



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[V]=Volume [N]=Number

Frequency of droplet diameters for simultaneous injection of ethanol and biodiesel.

CONCLUSIONS

A dual pressure swirl injector has been characterized for using biofuels.

It was verified that droplet diameters decrease with injection pressures when fuels are injected individualy through each injector chamber.

However when hydrous ethanol is injected through the primary chamber and soy biodiesel is injected through the secondary chamber, both at the same pressure, this tendency is not always observed .

When ethanol is injected in the secondary chamber and biodiesel is injected in the primary chamber it was not possible to colide the two spray cones, due to liquids viscosities and injector geometry.

It is suggested as future work the analysis of different pressures in the two chambers, tests at high er pressures, transient phenomena analysis, droplet velocity measurement, variation in the injector geometry, analysis of the primary chamber step depth.

The methodology can be applied in the analysis of injectors used in cars, airplanes and industry.

THANKS FOR YOUR ATTENTION!

Questions?