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Development of water-diesel emulsion through the employment of vibration

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Development of water- diesel emulsion through the employment of vibration

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Abstract. With this study, we want to analyse the different techniques used to develop emulsions and then apply a new mechanism to manufacture a water-in diesel emulsion that would be stable for a relatively long period. After the research on previous studies, we confidently applied the knowledge acquired during the time of personal study and the research to develop a system that brought us to keep in a semi-stable state an emulsion of water and diesel for a period of 24 hours. In this research we are not focusing on one of the two aspects that should be noted once you study emulsions: we are trying to develop a stable emulsion through the employment of vibrations without considering the employment of such emulsion in an engine, for the moment.

Nowadays we are facing many issues regarding the way the environment has been treated in the last 500 years. With the advent of the modern industry and the discovery of the importance of oil, also environmental problems grew unnoticed. Many have been the studies that tried to improve the quality of the technologies to separate, mainly, the emulsions that developed from accidents [6, 7, 8, 9].

The main objective that we want to pass with such paper is to give a glance at the literature behind the emulsification process and to support our novelty of manufacturing an emulsion through a technology that, at first sight, doesn't seem optimal. Our research is based on the idea that for another decade, humans will still rely on fossil fuels because most of the economy is based around fossil fuels products and because the investments in technology for the development of energy through alternative sources is still not reliable at 100%. We want to accomplish the development of a stable water-in-oil emulsion (WOE) which would encourage what we consider one of the first steps for an ecologic transaction: achieving a high-performance fuel that can be used with the technology developed nowadays (or at least with minimal changes to it) but without the environmental problems linked to it [10-15].

The physical phenomenon that we want to employ is low-frequency vibrations applied to a sample of water and oil. We focused on this idea because we realized that it would be possible to employ low ranges of frequencies, that we already develop in our daily life, to create emulsions that would be used again. In this way, it would be possible, for example, to employ the acoustic pollution developed by trains passing through tunnels in urban areas to develop our emulsion. We want to employ the so-called "whole body" vibration which can be found for ranges below 80 Hz. Within this range, we have frequencies that cause walls, floors and ceilings of rooms to vibrate, and we want to employ the same mechanism. By positioning our setup on a mechanical exciter, we want to bring maximum stress to our fluids and study how they react with each other. In this first practical study, we don't want to employ any emulsifier to create a stable emulsion [16], but only to verify if, without very sophisticated tools, we can destroy the surface tension between the two fluids and obtain reliable results for future studies.

It is even possible to forecast how much an emulsion can be kept in a stable state through the Stokes law of states. This one explains that:

$$V = d^2 \cdot (D_p) \cdot \frac{g}{18 \cdot h}$$

wherein: V is the velocity of sedimentation (the closer to 0 the better it is); d is the diameter of the particles in the dispersed phase; D_p is the difference between the specific gravity of the internal and external phases; g is the acceleration due to gravity; h is the viscosity of the external phase.

When it is necessary to manufacture a combination of two fluids, we can call the results in two different ways. The result can be a solution, which is a clear and homogeneous mixture of soluble fluids (antifreeze, mouthwash, vinegar, etc.), or we can have an emulsion, a particular type of colloid that comprises the preparation of a metastable single phase of two insoluble materials (mayonnaise, homogenised milk, butter, etc.) [5]. These are called dispersed and continuous (or external phase) depending on which fluid is diluted in the other one. Emulsions are the concept we are studying and collecting information about. At the base of the formation of an emulsion, there is the concept of agitation of fluids in presence of a chemical substance, generally called an emulsifier. This compound, depending on its nature, determines the type of emulsion that we would obtain. For the reason that we want to obtain an emulsion of oil and water (more precisely, with continuous phase the diesel and dispersed phase the water), it is supposedly necessary to employ lipophilic or hydrophobic surfactants because they are oil-soluble and are effective to form water-in-oil emulsions [1]. What the scientific process suggests, is that, to define the perfect emulsifier for our experiment, we need at first to study the hydrophilic-lipophilic balance. After the determination of the HLB, we can proceed with the stabilisation of our emulsion, independently by the mechanism used. From a forehead deduction, we are supposing we will need a substance with an HLB between 0 and 5 due to the insoluble nature of the two fluids [2].

To manufacture an emulsion, we can employ two different types of machines. We are considering machines with movable parts and machines which need an external energy supply. The first set is determined then by two different sub-categories, depending on if they use rotary motion or translational motion [3]. These are called "low-" and "high-" speed agitators. Oscillating agitators proved to bring better results thanks to the creation of a vertical alternating motion of particles. By employing specific devices, it is possible to develop the so-called "ultrasonic emulsification". This is a particular method that requires high energy consumption and it has been proved to have low efficiency. The studies on rotor-stator devices have proved the high efficiency and high-quality stable emulsions by destroying the molecular compounds and by the intensification of the dissolution process. The only drawback studied was the high energy consumption. A thing that we understood but we don't think to achieve with this particular experiment, is the need to keep under control the fluctuations in temperature which would lead to dangerous results in the closed environment that we want to develop.

Another technology employed is the flow hydrodynamic static agitator. This technology allows obtaining quality emulsions with the only necessity of high maintenance to avoid the corrosion of the columns of the system. This technology, employed with the addition of a specific emulsifier, was studied to be efficient. It brought good results by studying the improvements of water-fuel emulsions with the employing of distilled water. The improvements were related to the reduction of the emissions of SO_2 and the reduction of the coke ability of the emulsion (with a possible reduction of the incrustation in the engine and gumming of the engine injectors [3].

Blending has been studied also to be a reliable process. In this technology, it is essential to have control not only the amount of energy employed but also the time [4]. With the combination of more processes, it has been proved to obtain stable emulsions by combining an emulsifier in the oil phase,

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then proceed with the heating up of the emulsification and then apply a stirring process. This last step is accompanied by the slow addition of water. Homogenisation also has found its employment in the industry. It is a mechanical treatment to decrease the particle size of the dispersed phase. This process can be accomplished by flowing under high pressure the desired emulsion through a small orifice acting on oil globules' diameter *r* (D in the Stokes law), by decreasing it and increasing the number of them. This brings to great advantages, for example, the tendency to separation is decreased and the stability is enhanced [2].

The vessel in which we developed our experiment is a six mounted hole plexiglass tube which is fixed to a B&K vibration exciter 4818 type through a base designed and developed by us in our laboratory. What we kept in mind during our experiments is that we could never fill the entire tube with fluid in order not to compromise the structural integrity of the tube. This one may have failed because we decided to close the tube and to create an environment with constant volume. This hypothesis was considered necessary for us because we wanted to take advantage of the motion caused by the air moving inside the vessel and enhance the mechanical excitation developed by the exciter (figure 1).

Figure 1. Clockwise order from upright: Plexiglas tube with connection to the vibration exciter (black) and cork to create a close environment (white); vibration exciter B&K type 4818; Vibration Research station software for the control of the gain given to the vibration exciter; B&K power amplifier type 2708 used to give the necessary energy to the vibration exciter.

In order to keep under control the energy passed to the vibration exciter, we used an accelerometer from PCB Piezotronics positioned at the base of the Plexiglas tube (figure 2.). The samples were then collected through a calibrated pipette and then placed in special cuvettes of 11∅ mm (figure 3).

Figure 2. PCB Piezotronics accelerometer with 9,70 mV/g of sensitivity and output bias of 10,9 VDC.

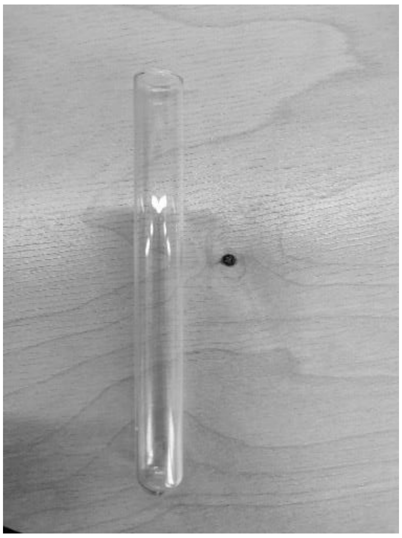

Figure 3. Example of cuvette used during our experiments.

The experimental part was divided into two phases from which we drew our conclusions. The first phase consisted of the filling of the vessel with 600 ml of filtered water and 200 ml of diesel. The subsequent analysis brought us to identify at around 43 Hz the resonance frequency of such amount. The volumes of the two fluids do not mean to be any specific. We wanted to study the setup in a condition where very little was the volume of air left and where the water was able to form an emulsion at the best with the diesel.

We then decided to hold at such frequency the fluids for ten minutes (due to equipment limitations). After ten minutes, we extracted samples from the upper part (what we consider to have been an unstable water-in-oil emulsion) and from the lower part (what we could consider to be an oil-in-water emulsion). The cuvettes were then sealed and left to be observed during a period of 24 hours.

The same approach was then used during the second phase of our experiment. Instead of filtered water, we wanted to understand if the same results could be obtained with distilled water.

What we achieved during the experimental part exceeded our expectations. From what we analysed during our previous studies, it was never studied how vibrations affect the emulsification process because, by incrementing the acceleration, it would be difficult for the emulsion to stay stable. Another factor necessary to have a stable emulsion is the presence of emulsifiers. This is why we decided to approach this experiment. From what we found; we could deduct is that the filtered water was able to emulsify with diesel for a period of around 24 hours. With a decaying in the stability that we were not able to appreciate with our equipment, we arrived at the supposition that the minerals and salts in the water somehow increased the stability of the emulsion (figure 4).

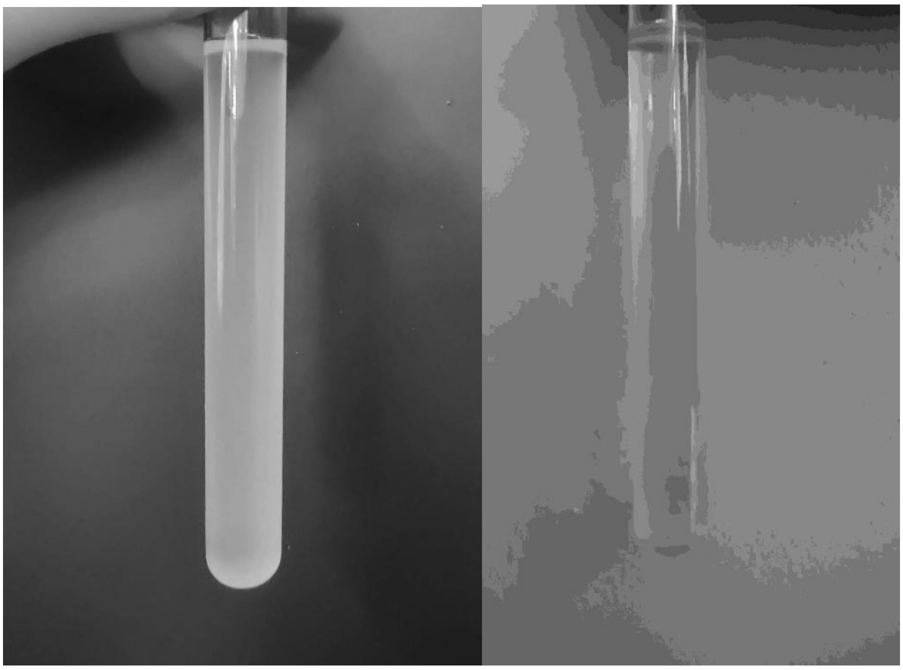

Figure 4. Water-in-diesel emulsion after 10 minutes after extraction (left) and after 24h (right).

A secondary fact that we noticed was the visual feedback. By comparing the emulsion and the sample of diesel that we kept for this time of analysis, we could notice the cloudy effect of this one due to the distortion of light (figure 5).

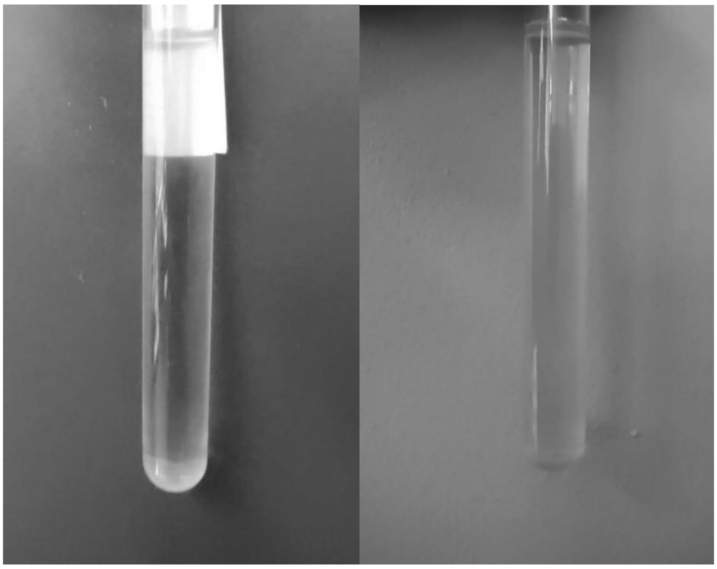

Figure 5. Visual feedback between pure diesel (left) and the water-in-diesel emulsion after 24 h.

For the study in which we employed distilled water, meanwhile, we were not able to achieve a stable emulsion. The two phases separated in a period of 10 minutes.

The difference in the results can have many reasons. One of the aspects that we should analyze as the next step is the influence of the minerals in the water in the emulsification process. The second fact, also the not perfection of the tube may have brought to discordant results.

A study on the assessment of water-diesel emulsions through experimental verification has been pursued. By following what previously studied, we realised that to keep our emulsion stable, because biphasic systems are unstable for nature (second law of thermodynamics), it is necessary to add an emulsifier with an HLB index of less than 5. What we found is that vibration within the limits of a "whole body" vibration can be employed to excite two immiscible fluids and develop an emulsion.

This concept will be kept clearly in mind because many studies also implied the possibility of not using emulsifiers but increase the number of liquids, having different characteristics, which can be present in the emulsion and define a sort of stability without the employment of chemicals.

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