DEVELOPMENT OF EMULSION FUEL MIXER SYSTEM

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ABSTRACT

It is an uncommon belief that an emulsified biodiesel may assist in lowering diesel engine emissions such as Nitrogen Oxide, NO_x and other harmful forms of particulate matter whilst maintaining its performance. Emulsion is essentially a dispersion phenomenon in which the dispersed phase is composed of small globules of a liquid. This study entails the development of an emulsifier for emulsified biodiesel which incorporates the design and fabrication of the mixer system. By utilizing the static mixer, this study describes the obtaining process of water in oil emulsifications which assisted by tween 80 and span 80 surfactants. This is ensued by data collection and analysis from the emulsified biodiesel product obtained from the aforementioned fabricated mixer system. The quality of the product was evaluated by the stability of the dispersion phase. By this research, the system were able to produce the emulsified biodiesel but it didn't comply the desired result as the product dispersed only a few minutes due to injector problems.

ABSTRAK

Kajian ini bertujuan untuk mengkaji minyak biodiesel beremulsi yang mampu membantu dalam mengurangkan pelepasan Nitrogen Oksida, NO_x dan lain-lain zarah merbahaya oleh enjin diesel disamping mengekalkan prestasi enjin tersebut. Emulsi ialah sejenis fenomena penyebaran zarah cecair apabila fasa yang tersebar terdiri daripada globul-globul kecil cecair lain. Kajian ini menerangkan tentang pembangunan berkenaan pengemulsian untuk biodiesel beremulsi di mana ia melibatkan proses mereka bentuk dan juga membina mekanisma bagi sistem campuran tersebut. Dengan mengaplikasikan pengadun statik di dalam sistem tersebut,emulsifikasi air di dalam minyak yang dibantu oleh "surfactants" tween 80 dan span 80 dapat dihasilkan. Ia dapat dipastikan melalui pengumpulan data dan analisis daripada produk yang terhasil daripada mekanisma sistem campuran yang dibina tersebut. Kualiti produk biodiesel beremulsi dinilai melalui kestabilan fasa campuran sehingga berapa lama ia akan kekal dalam fasa itu. Hasil kajian menunjukkan sistem ini mampu untuk menghasilkan produk biodiesel beremulsi. Namun begitu, ia tidak berjaya untuk mencapai keputusan yang diharapkan apabila produk itu sebati hanya beberapa minit sahaja berpunca daripada masalah suntikan bahan campuran.

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LIST OF SYMBOLS

NO_x	Nitrogen oxides
H_20	Water
B20	20% of biodiesel

LISTOFABBREVIATIONS

O/W	Oil-in-water emulsions
W/O	Water-in-oil emulsions
HLB	Hydrophilic lipophilic balance
MIG	Metal inert gas
TIG	Tungsten inert gas

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND STUDY

A development of an emulsifier for biodiesel fuel is a project that requires an improvement of the existing emulsification process on biodiesel fuel. Emulsion is basically a dispersion phenomenon which the dispersed phase is composed of small globules of a liquid. This process is used in a wide range of fields such as pharmaceutical, cosmetics and food production and not limited to the production of biodiesel fuel.

Water in oil emulsion has existed since the turn of the century. It was one of the efficient methods for emulsification process. However, it must be noted that only recently the stability and quality of emulsion are able to be controlled which in turn deems it advantageous. Emulsification of biodiesel fuels in essence reduces the nitrogen oxide levels, particulate matter and opacity apart from enhancing the combustion process.

The improvements on the emulsified biodiesel product may be performed by means of chemical reaction improvement, molecular bonding and methods of operation. As for this project, the enhancement of the emulsified biodiesel is done by improving the emulsifier machine. Nevertheless, a proper method is required to ensure desired results could be achieved. The volume of surfactant, emulsifying temperature, emulsification time and mixing time are significant to ensure the emulsion stability.

1.2 PROBLEM STATEMENT

It is a priori that biodiesel fuels are able to be an alternative fuel in replacing the conventional diesel fuel. Biodiesel fuels produce less emission compared to diesel engine. It is renewable as it is made from vegetable oils and fats. The biodiesel fuel is compatible with the existing vehicle fuel system, combustion parts and also control system.

However, a potential problem of this prospective fuel replacement surfaced which affects the vehicle operation. This transpires due to the accelerated dilution of the oil by the fuel which may lead to the reduction of the durability and fuel performance.

Nonetheless, of late the price of diesel fuel had reach the maximum price over US$100 per barrel [1] which surpasses the price during the oil crisis circa 1980. The current demand is exceeding the production of quality diesel fuel. By viewings this issue from an environmental point of view, the present consumption of conventional diesel fuels will eventually lead to the increase of harmful emission to the air and to a larger extent contributing to global warming.

Therefore, an alternative to the existing diesel fuel that has lower harmful emission, inexpensive and able to maintain the performance of the engine is of importance. The objective of this study is to develop an emulsified biodiesel facility in order to mitigate the aforementioned problems. An emulsified biodiesel fuel which has good emulsion stability is desired. This is achieved by applying the proper and suitable method with an optimum ratio of water, biodiesel and the surfactant to produce good emulsion. It is hoped that the rig could be utilized by the industry in order to exploit emulsified biodiesel.

1.3 OBJECTIVE

The objective of this project is to develop an emulsifier for emulsified biodiesel fuel.

1.4 SCOPE

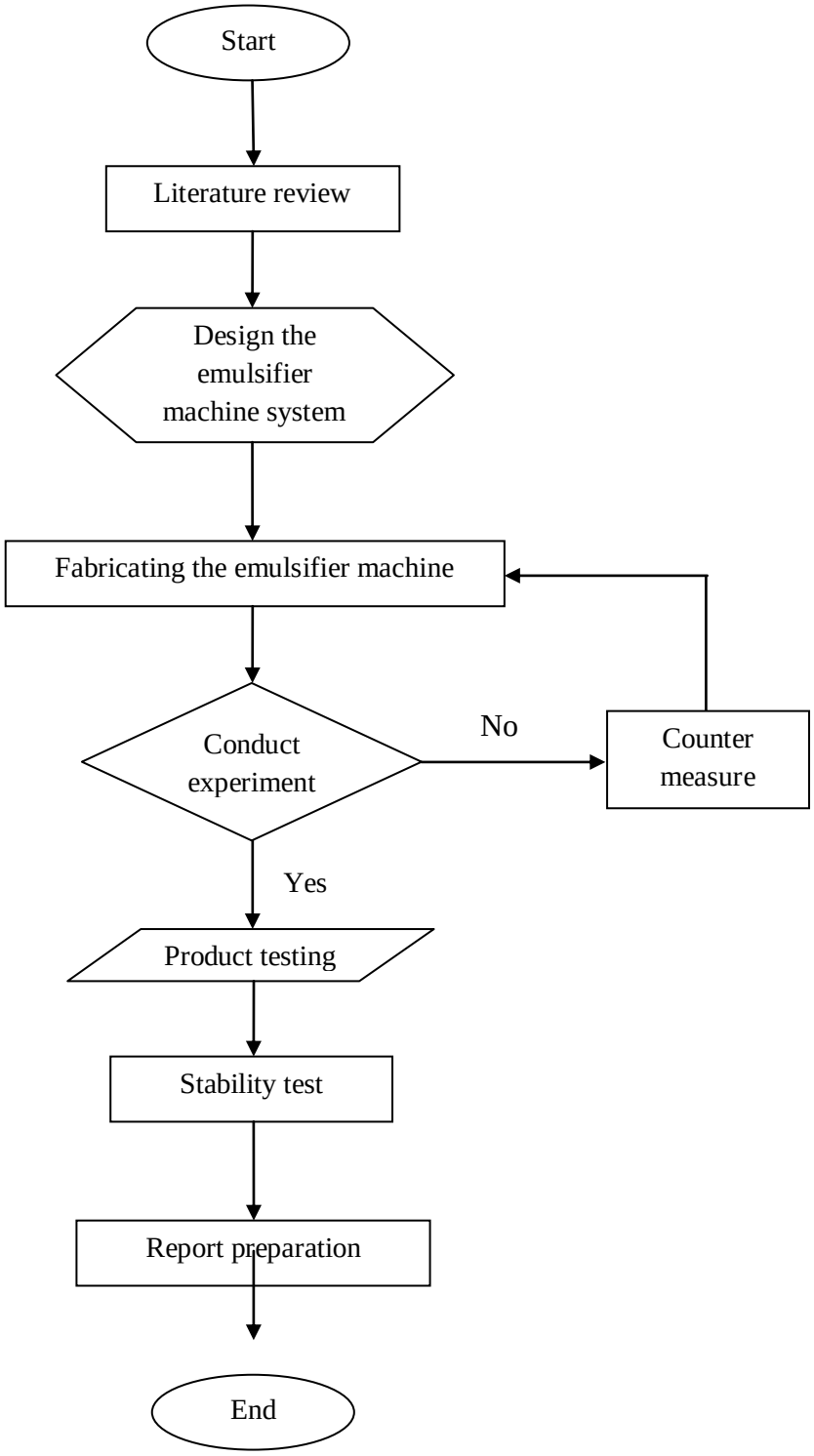
In order to accomplish this project, the following tasks are fulfilled

a. Designing the emulsifier machine system
b. Fabricating the emulsifier machine
c. Experimental testing on the emulsified biodiesel product
d. Data gathering and analysis of the results obtained from the experimental work

1.5 HYPOTHESIS

At the end of this project, it is expected that the designed emulsifier machine is able to produce emulsified biodiesel product of acceptable quality.

1.6 FLOW CHART



CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

A diesel-powered vehicle is popular among the heavy-load transportation such as truck, bus, lorry and construction vehicle. This is due to the higher fuel efficiency compared with gasoline-powered vehicles. However, even though the diesel engines can give convenience in our daily lives, it also comes out with smokes. The smokes as mentioned by Seung-Hun Choi [2] contains many types of toxic pollutants including hydrocarbons, carbon monoxide, nitrogen oxides (NO_x).

A lot of studies regarding biodiesel fuel had been done in previous years. A biodiesel is a renewable fuel that was derived from vegetable oil, animal fat, or waste cooking oil [3]. This century, a renewable fuel such as biodiesel fuel with less exhaust emissions is a must for a daily life. Biodiesel fuel blends are one option that currently being researched as an alternative to energy diversity and a reduced from depending on petroleum in the transportation sector. Hence, researches and scientific community worldwide have focused on development of biodiesel to optimize the process in order to meet the standards and specifications needed for the fuel to be used commercially without effecting on the durability of the engine [4].

The study of emulsions has been started since 19 of century. It was performed on 1980s with the termed “Emulsols”. An emulsion is formed when two immiscible liquid are mixed together. According to Kenneth [5] the study was to determined the chemical and physical properties required of the oil in order to form these emulsions. They were purposed to produce more available base oils which can be used without

sacrifice in performance. The overall conclusion stated from the journal was a formulation of maximizingthe medium of viscosity mineral base oil and a sulfonate type emulsifier could be used with extreme pressure and anti-wear additives to form a stable emulsions. In the same century, some study had proved that the formulation and stability of the fuel droplets are depends on two capable factors which were the migration behavior of the surfactant at the droplets interface and also the merging of the droplets into resulting more stable mixture.

The study of emulsions has been often carried on in several of ways and methods. The dispersions of two or more non miscible fluids are produced for many applications [2]. The systems which obtained from homogenization of two or more not miscible fluids can be classified as emulsions, mini-emulsions or micro-emulsions depending on the size of the particles dispersed in the continuous phase. The systems were operates through a help of one or several additives such as surfactants and co-surfactants. The additive is able to lower the surface energy of the interface of the produced mixture.

2.2 EMULSIFIER

Researchers have found a low-cost way to lower hazardous emissions in diesel engine by mixing water with biodiesel in addition with an emulsifier. A traditional biodiesel fuel may produce nitrogen oxides which able to pollute the atmosphere and pose a threat to human health. By adding an emulsifier, water and biodiesel mix in much more stable condition by providing a strong bonding and came out with a better result.

When oil and water are mixed together and forcefully shaken, a dispersion of oil droplets in water and vice versa is formed. When the shaking stops, the phases will start to separate each other. However, when an emulsifier is added into the system, the droplets will remain dispersed. An emulsifier generally is a substance that can assists and act as a catalyst in the formation of a mixture and it also promotes the stability of an emulsion [6]. This substance can come in many different forms and from various classes. Basically it consists of a molecule with two different ends. One end will bonds

with water, which is called the hydrophilic head and the other bonds with oil or similar substance, which is called the hydrophobic tail.

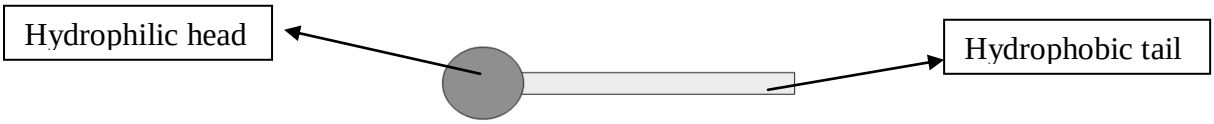


Figure 2.1: Hydrophobic Tail and Hydrophilic Head

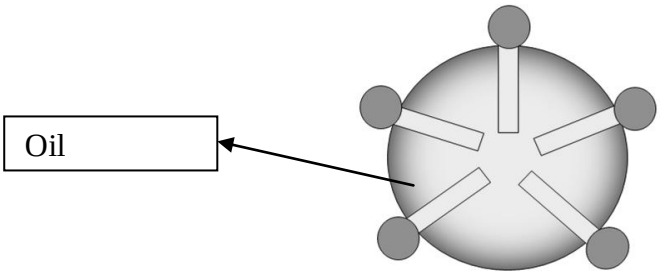


Figure 2.2: Oil-in-Water configuration

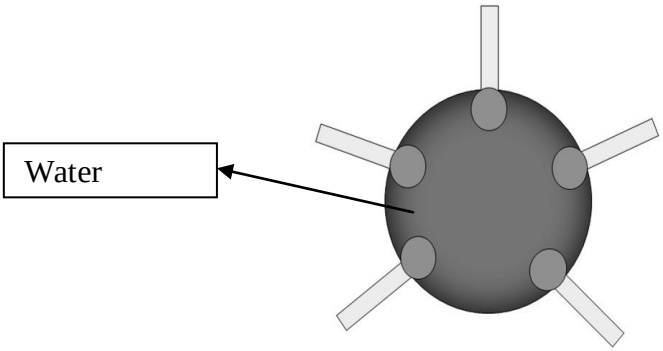


Figure 2.3: Water-in-Oil Configuration

To improve stabilities of the formation of the emulsion, the emulsifier were added to the chemical combination of the oil and water substance. The emulsifier will create a protective barrier around the oil molecules. As mentioned by M. Nuraini [6] there would be three main criteria that play an important role during emulsification process. Firstly, in order to form an emulsion; it must require an availability of two immiscible liquids. Secondly, the emulsion is formed by applying mechanical energy to generate the droplets. Finally is the presence of an agent processing partial solubility in both phases which known as emulsifier.

The outcome of the combination of water, biodiesel, and emulsifier mainly is a lower emission biodiesel fuel. By adding water into the biodiesel oil, it provides high oxygen in the fuel. The corresponding amount of fuel is replaced by water which resulting a lower combustion temperature. Thus more amount of fuel can be burnt. According to Agung [7] the cylinder average temperature became low due to the evaporation of the water. Thus it will reduce the fuel consumption due to the higher oxygen content.

2.3 TYPE OF EMULSIONS

Generally, the most common classification of emulsion is by the polarity of the dispersant phase. Water is one of the working fluid in most of the applications while the other one will be oil based fluids. Therefore emulsions are generally indicated as dispersions of water droplets in oil for water-in-oil emulsions, W/O or oil droplets in water for oil-in-water emulsions, O/W [2]. Most of the properties of the emulsion systems such as stability, viscosity, were depend on the droplets size of the dispersion fluids.

There will be three main factors that play an important role during the emulsifications process. The first one is the availability of two immiscible liquids. Second is the emulsion is formed by applying mechanical energy to generate droplets which is the critical step in the emulsification process. The third is the presence of an agent processing partial solubility in both phases which are known as emulsifier.

2.3.1 Water-in-Oil (W/O) Emulsion

When the oil phase serves as the continuous phase, the emulsion will known as water-in-oil (W/O) emulsion. As stated by Chiaramontia [2], the water-in-oil emulsion have been prepared by adding the surfactant into diesel oil and thereafter adding the bio-oil to the resulting mixture. An example for the emulsion is the emulsification of heavy lubricating oil with casein as the stabilizer can also be classified as water-in-oil type. The very simple step of making water-in-oil emulsions is to add the water very slowly to the oil phase which already contain with the emulsifier. Keep on stirring continuously while adding the water in order to make sure the water did not pool up excessively on the surface. Therefore, the water can be added into the oil in several ways; by stratified fuel–water injection, through the preparation of stabilized (W/O) emulsion fuel, continuously into the air stream via a single point system or periodically through intake valves via a multi-point system [7].

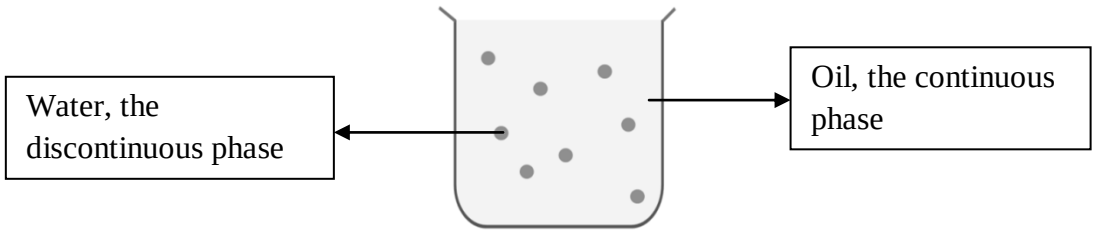


Figure 2.4: Water-in-Oil emulsion

2.3.2 Oil-in-Water (O/W) Emulsion

When the oil phase is dispersed as globules throughout an aqueous continuous phase such as water, the system is referred as an oil-in-water (O/W) emulsion [8]. Oil-in-water emulsions have been formulated by performing the addition of the bio-oil to the surfactant and thereafter mix with the diesel oil during the emulsification process. As per example, emulsion of a light petroleum such as kerosene and water with casein as the stabilizing is the oil-in-water type of emulsion. To produce an oil-in-water emulsion the method is by adding the water and oil into one container and heat it up to 66°C - 80°C [9].

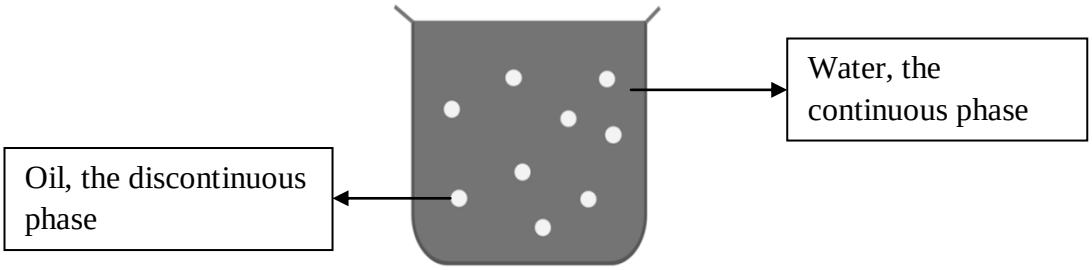


Figure 2.5: Oil-in-Water emulsion

The things that need to be put concern here is, an emulsions is not simply be called water-in-oil emulsion by simply adding a water phase into the oil phase. And it was also not be determined by the ratio of the water and the oil of the emulsification process. As example, an emulsion contained 15% oils and 75% of water is not definitely a water-in-oil emulsion. The element that determined whether the emulsification is water-in-oil or oil-in-water is the emulsifier.

2.4 EMULSIFYING AGENT

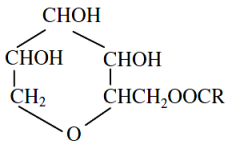
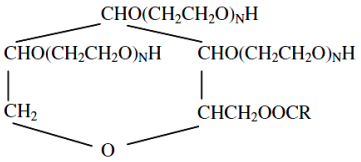
An emulsifying agent or also known as surfactants is a substance which will do stabilization, formation, breaking interfaces, wetting, spreading, adhesion and others through an emulsification process. It will also reduce the surface tension between the oil and water whilst increasing their contact area. The lyophobic and lyophilic groups in them are capable to accumulate at the interfaces between solids, gases and also liquids [10]. There were many types of emulsifying agent that exist as a surfactant. The choice of the emulsifying agent, which can avoid the emulsion's breaking, is a procedure achieved by several empirical rules. These rules are built on the primary condition for an emulsifier to be efficient in a two phase, two-liquid emulsion. The emulsification were greatly influenced by hydrophilic lipophilic balance (HLB) number [2]. The HLB number give the meaning of the emulsifier is optimal in a water-oil system where the properties of the oil match with the surfactants. This can be happen when the lipophilic group absorb the oil phase while the hydrophilic group absorb the water upon the mixture [11]. Below is the emulsifier characterized by the HLB [12]:

Table 2.1: The HLB range

HLB Range	Use
4 – 6	W/O emulsifiers
7 – 9	Wetting agents
8 – 18	O/W emulsifiers
13 – 15	Detergents
10 – 18	Solubilizers

A Gemini surfactant had been prove that it can assist a good emulsification process as it has much finer and better distributed water droplets. It has a long hydrocarbon chain, a spacer, an ionic group, a second ionic group and another hydrocarbon tail. It also known as a double tailed surfactants and are significantly more surface-active [10]. Two surfactant to be look for which is Tween 80 surfactant and Span 80 surfactant. The Tween 80 which the HLB is 15 while Span 80 the HLB is 4.3 to be believed can increase the attractive force and in the mean time will reduce the interfacial tension between oil phase and water phase.

Table 2.2: Properties of surfactants Span 80 and Tween 80 [11]

Surfactant	HLB	Specific gravity	Chemical structure
Span 80 (sorbitan monooleate)	4.3	0.98	
Tween 80 (polyoxyethylene sorbitan Monooleate)	15	1.08	

To calculate on how much emulsifier (A) need to blend with emulsifier (B) to achieve the desired HLB value of X, the equation is as follows [13]:

$$\%(\mathrm{A}) = \frac{(\mathrm{X} - \mathrm{HLB_B}) \times 100}{\mathrm{HLB_A} - \mathrm{HLB_B}} \quad (1)$$

$$\%(\mathrm{B}) = 100 - \%(\mathrm{A}) \quad (2)$$

The combined HLB for both surfactants was calculated as follows [11] :

$$\mathrm{HLB_{AB}} = \frac{\left[(\mathrm{H_A} \times \mathrm{W_A}) + (\mathrm{H_B} \times \mathrm{W_B})\right]}{(\mathrm{W_A} + \mathrm{W_B})} \quad (3)$$

Where A and B refer to different surfactant used. H_A and H_B were represents to HLB values of those surfactants respectively. W_A And W_B will be representing the weight of the surfactants.

Emulsions stability is given by the days of observing the complete phase separation and the test was performed at room temperature. It was important to focus that the HLB number for a certain surfactant will contribute the balance between its hydrophilic/lipophilic properties.

2.5 EMULSIFICATION METHOD

2.5.1 External Force Emulsification by Using a Static Mixer

In order to blend two or more liquids into a homogenous mixture, a static mixture can be used where its ability can split and hold the products to achieve a blended output [14]. A static mixer consists of inline, motionless, mixer elements. The flow of the fluid can be in laminar flow or turbulent flow. Blending of fluids, heat transfer, and solids blending are the unit operations of the static mixer [15]. To determine the mixing mechanism and the mixer design it is depend on whether the flow is laminar, turbulence or in the transition between this two. For the static mixer, it is usually blended in a laminar regime with a low Reynolds number. The fluid will divided into a large number of fine layers when the phase is divided, deformed, stretched, back mixed, recombined by the static mixer blades or element.

The method is applied when two immiscible liquids are being transported through the static mixer by two gear pumps. In the experiment investigated in by N. Kiss, 2011 [15], two static mixer with different inner diameter were used. Each of them was installed with 10 mixer elements. By this method a relationship between the parameters and material properties can be predicted precisely. It prove that the correlation were also applicable in other material systems and static mixer scale [15].

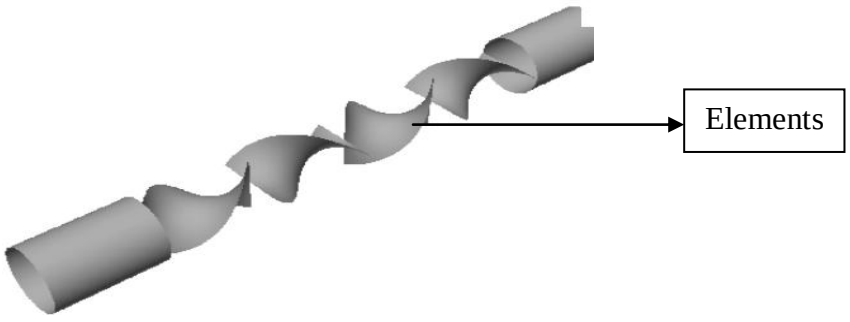


Figure 2.6: Static mixer

2.5.2 Emulsion via Ultrasonic Technology

An emulsion via ultrasonic technology is a method introduced based on the principle of double emulsion-solvent extraction [16]. The process uses a flow-through ultrasonic cell for the preparation of the primary emulsion, in combination with a static micro mixer for the production of the double emulsion. The microspheres were prepared from poly (lactic-co-glycolic acid) (PLGA), and bovine serum albumin (BSA) served as model protein for microencapsulation. The BSA-in-PLGA (w/o) emulsions produced by the ultrasonic flow-through cell exhibited mean droplet sizes of <700 nm. Further processing into microspheres of 15-40 micron mean diameter resulted in approximately 70% BSA encapsulation efficiency. The presented technology offers a great potential for aseptic microsphere production for any batch-sizes suitable.

2.5.3 Emulsion via conductive method

This method is based upon adding a small amount of an electrolyte to the emulsion. If the conductance increases, the emulsion is oil-water type and if there is no significant change it is water-in-oil type.

Study made by William Seifriz, [17] the emulsions were made from 35 distillation fractions of petroleum oils. It was proved to be as set forth in the first part of the studies of two types emulsion, oil-in-water and water-in-oil, with an intermediate zone of instability. The emulsions which made from hydrocarbon distillates to a specific gravity, and stabilized with an aqueous dispersion of casein, are of the oil-in-water type. Petroleum distillates above 0.857 specific gravity form fine stable of water-in-oil emulsions when it was stabilized with casein. The behavior of certain petroleum oil emulsions stabilized with case in the presence of electrolytes bears no distinct relation either to the valences of the ions or to the surface tension changes between the oil and the aqueous casein occasioned by the electrolytes.