

An Evaluation of Emulsifier Cost Versus Processing Energy Cost

It has been stated many times that, when generating an emulsion, an increase in mechanical energy can decrease the required level of emulsifier in a formulation. This does not mean that by increasing mechanical energy, ad infinitum, the emulsifier can be eliminated. The emulsifier or surfactant has more than one role. It aids in formation of the emulsion by lowering interfacial tension and stabilizes the emulsion against coalescence and breaking. The mechanical energy input interacts with the role of the emulsifier as a means of aiding the formation of the emulsion.

In order to test this theory, experiments were conducted at the APV Homogenizer Group Customer Product Testing Laboratory in Massachusetts. This project compared three processing devices which generate different levels of mechanical energy. One of the devices was a typical mixer-emulsifier, consisting of a rotor attached to a rotating shaft with a fixed stator surrounding the rotor blades.

In operation the material is drawn into the stator, where it is mixed and sheared between the rapidly revolving rotor blades and the stator. There are many such devices on the market today, and they all appear to operate on the same principle. The second piece of apparatus used was a model 15M laboratory homogenizer with a capacity of 15 gallons per hour and a maximum, continuous operating pressure of 8000 psig. The third device evaluated was a model HS-2 laboratory-scale Hydroshear[®] system, which utilizes velocity gradients in a spiral fluid flow to generate high-shear fields and emulsifying action.

The emulsion generated consisted of 10% paraffin oil (Saybold viscosity 80-90 at 100°F.) and varying amounts of emulsifier and water. The emulsifier was oleic acid dissolved in the oil and Triethanolamine dissolved in the water phase. The ratio of oleic to TEA was 1.86 to 1.0. The emulsions were all prepared at room temperature.

The emulsions were made with the "mixer-emulsifier" device by slowly adding the oil phase to the water phase and permitting the device to work on the emulsion for 5 minutes at 1900 rpm. Allowing any additional mixing time resulted in the generation of a large amount of foam but did not produce any change in average particle size. Less mixing time brought about uncertainty concerning the thoroughness and completeness of mixing.

The emulsions were made on the homogenizer by slowly adding the oil phase to the water phase in the infeed hopper of the homogenizer. The ingredients in the hopper were continuously mixed using a simple, low-speed stirrer. The same size batch was prepared in all cases. The premix for the Hydroshear was also made with a stirrer, but preparation was not done in the infeed hopper. It should be noted that, when preparing a premix with a low-speed stirrer, the most critical factor is the rate at which the oil phase is added to the water. A slow addition of the oil phase allows each small portion of the oil to be completely mixed into the water, producing a more uniform premix.

TB-61 An Evaluation of Emulsifier Cost
Page 2

The emulsions were analyzed using a Coulter Nano-Sizer, which uses laser light-scattering and Brownian motion to determine a weight average diameter of the dispersed oil phase. The particle-size distributions were similar for emulsions generated with each piece of equipment; however, the homogenizer samples indicated a slightly more narrow particle-size distribution. None of the emulsions showed a bimodal distribution.

The attached graph shows the comparison of average oil droplet diameter versus weight percent of emulsifier in the formulation. Using the mixer/emulsifier device, the average particle size could not be read on the Nanosizer until the emulsifier level reached 1.25%, because any lower level produced an emulsion with such a large average size, that it was off the scale of the Nanosizer and was unstable. It can be seen that, as the emulsifier level increases, the curve approaches a constant value for the average particle size. It is obvious from the curve that, as the emulsifier level increases, the emulsion quality improves.

The HS-2 Hydroshear system did a better job than the mixer at low emulsifier levels. Note, also, that the HS-2 performed more rapidly than the intense high shear mixer, which had to work on the emulsion for five minutes. This confirms many previous HS-2 experiments, which demonstrated the Hydroshear's excellent performance as a low-energy emulsifying device. The samples produced on the laboratory-scale homogenizer are significantly better than those produced with the mixer at low levels of emulsifier. At 2000 psig the homogenizer generated an emulsion using only 0.25% surfactant, which is equivalent to the mixer at about 2.00% surfactant. The difference in curves is quite significant, because the cost of the emulsifier is more important than the extra energy cost, due to operating the high pressure homogenizer. The following three examples illustrate the importance of considering energy versus emulsifier cost.

Case #1. . . Compare the emulsions from the homogenizer and mixer at a diameter of .405 micrometers of 4000 psig with 0.25% emulsifier for the homogenizer and 2.25% emulsifier for the mixer. The homogenizer at this pressure requires 1.434 kw of energy. (The laboratory-scale homogenizer is less efficient in energy use than a production-scale machine.) In order to process the two-kilogram sample, the time required on the laboratory-scale homogenizer was .0352 hours. At 5¢ per kilowatt hour the energy cost on the homogenizer was .25¢. The emulsifier cost was 1.10¢, assuming about \$1.00 per pound for emulsifier. The mixer at 1900 rpm draws about 218 watts for five minutes. Therefore, its energy cost would be .091¢, a cost much lower than the homogenizer; however, the emulsifier cost for the mixer would be 9.92¢. Therefore, the homogenizer used .161¢ more in energy than the mixer, but the mixer used 8.82¢ more emulsifier. Thus, the emulsifier cost was 55 times greater than the energy cost.

CASE #1	EMULSIFIER USED	PROCESS TIME	ENERGY COST	EMULSIFIER COST	NET COST PER SAMPLE
High Sheer Turbine Mixer	2.25%	.0833 hrs.	.091 cents	.091 cents	10.0 cents
High-Pressure Homogenizer @ 4000 psig	0.25%	0.352 hrs.	1.10 cents	.252 cents	1.35 cents

Case #2 . . . Compare the homogenized emulsion at 4000 psig and 1.50% emulsifier with the mixer at 3.00% emulsifier. The energy cost for the homogenizer was .262¢, and the emulsifier cost was 6.61¢. The mixer exhibited an energy cost of .091¢. Surfactant cost at 3.00% emulsifier was 13.23¢. Therefore, the homogenizer used .161¢ more in energy than the mixer, but the mixer used 6.62¢ more for emulsifier. Thus, the emulsifier cost was 41 times greater than the energy cost.

TB-61 An Evaluation of Emulsifier Cost
Page 3

CASE #2	EMULSIFIER USED	PROCESS TIME	ENERGY COST	EMULSIFIER COST	NET COST PER SAMPLE
High Sheer Turbine Mixer	3.00%	.0833 hrs.	.091 cents	13.23 cents	13.3 cents
High-Pressure Homogenizer @ 4000 psig	1.50%	0.352 hrs.	.252 cents	6.61 cents	6.86 cents

Case #3 . . . Compare the emulsion from the Hydroshear system at 1.00% emulsifier with the mixer at 1.35% emulsifier. The Hydroshear processes about 2.0 gallons per minute, and the energy use at the pressure generated is about two kilowatts. The processing time for the sample was .0044 hours. At 5¢ per kilowatt hour the energy cost was .0044¢ . The energy cost for the mixer was 0.91¢. the emulsifier cost for the mixer was 5.95¢. Therefore, the Hydroshear used about one-half the energy and saved about 25% of the cost of the surfactant. It should be noted that the Hydroshear can be used in a continuous processing system, while the mixer is limited to batch processing.

CASE #3	EMULSIFIER USED	PROCESS TIME	ENERGY COST	EMULSIFIER COST	NET COST PER SAMPLE
High Sheer Turbine Mixer	1.35%	.0833 hrs.	.091 cents	5.95 cents	6.04 cents
Low Energy Hydroshear @250 psig	1.00%	.044 hrs.	.044 cents	4.41 cents	4.45 cents

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