

# Inline Emulsion Formation using IPM and FDM Mixing Technologies

P. Brown

## Introduction

The mixing of oil-based materials (lipid phase) with water-based materials (aqueous phase) is a key requirement in many areas of fluids processing. Oil and water are of course immiscible so that when they are mixed together, they will always separate over time. The degree to which the emulsion does not separate is called its "stability" and this is a critical performance parameter of any emulsion. Emulsions are generally described as being water-continuous when oil droplets are suspended in water and oil-continuous when water droplets are suspended in oil. The stability of an emulsion is primarily influenced by the droplet size of the discontinuous phase and the degree to which individual droplets can coalesce. Although it is possible to achieve small droplet sizes using chemical surfactants, in many cases it is necessary to minimise or even eliminate such chemicals from a mixture. Mechanical mixing therefore remains of critical importance in achieving small droplet sizes and minimising the interactions between droplets which give rise to coalescence.

In general, when applying mechanical mixing actions, the droplet size within the discontinuous phase of an emulsion is primarily determined by the amount of energy imparted to it. However, in reality both the way in which the energy is imparted and the way in which the material is treated in the post-stressing phase have been shown to be important in determining droplet size and coalescence rates. This document describes the configuration and use of Integral Pump Mixing (IPM) and Fluid Division Mixing (FDM) technologies in achieving emulsions of very high quality in production situations.

## Requirements for Inline Emulsion Formation

Emulsions can be formed in a continuous (inline) process using either single-pass or multi-pass operations from a standard material concentration or from one which is evolving over time. The inline mixers performing this emulsification can be single stage or multiple stage machines. In order to obtain a good emulsion it is necessary to consider certain operating conditions:

- The material presented to the stressing mechanism must be proportioned and dimensioned sufficiently finely to ensure that both phases (parts) of the material system are present simultaneously in the stressing region. The material presented to the stressing mechanism should therefore be pre-dispersed to some degree.

- Where an emulsifier is present, the time between premixing and stressing can be important to ensure that an adequate state of adsorption has been attained.
- If concentration is to be evolved in a primarily shear field, attention should be paid to the viscosity ratio and the Weber number. However, for extensional stressing these elements are less important – studies show that extensional stress is significantly more effective than simple shear stress in droplet break-up.
- The entry point of the second phase may be important for a particular material system; it may therefore be necessary to present the material into the mixer immediately ahead of the stressing zone.

## Methods and Configurations for Inline Emulsification using IPM

The IPM functions primarily as a nozzle homogenizer. The extensional flows in the nozzles account for the major part of the stress applied to the material – the stressing mechanism. This is in addition to the shear (mechanical and hydraulic) and extension that occur in the various annuli and cavities, as well as the impact stressing and hydraulic shearing (in turbulence and vortices) that occur in the post-stressing period.

For the IPM, the introduction of the second phase into the first may be performed as follows:

- A. For emulsion formation at a single concentration in single-pass mixing:
  - I) Pre-incorporating the second phase into the first phase as a batch in a vessel prior to passing to the mixer for single-pass mixing, or
  - II) Introducing the second phase into the first phase at some point along the inlet pipework, up to and including the inlet manifold to the mixer, or
  - III) Injecting the second phase directly into the suction zone of a single stage mixer, using a single injection point or a number of injection points arranged in an axial row, or
  - IV) Injecting the second phase directly into the suction zone of a particular stage of a multi-stage mixer, using one or more injection points arranged in an axial row.

*(Continued on page 2)*



- B. For emulsion formation at a single concentration in multi-pass mixing:

Pre-incorporating the second phase into the first phase as a batch in a vessel prior to passing to the mixer for multi-pass mixing.

- C. For emulsion formation at multiple concentrations in single-pass mixing:

- I) Injecting the second phase directly into the suction zone of a single stage mixer, using a number of injection points arranged circumferentially within the zone, or
- II) Injecting the second phase directly into the suction zone of a particular stage of a multi-stage mixer, using a number of injection points arranged circumferentially within the zone, or
- III) Injecting the second phase directly into the suction zones of more than one stage of a multi-stage mixer, using one or more injection points per zone.

- D. For emulsion formation at multiple concentrations in multi-pass mixing:

- I) Introducing the second phase into the first phase at some point along the inlet pipework, up to and including the inlet manifold to the mixer, or
- II) Injecting the second phase directly into the suction zone of a single stage mixer, using a single injection point or a number of injection points arranged in an axial row, or
- III) Injecting the second phase directly into the suction zone of a particular stage of a multi-stage mixer, using a number of injection points arranged circumferentially within the zone, or
- IV) Injecting the second phase directly into the suction zones of more than one stage of a multi-stage mixer, using one or more injection points per zone.

Note that the use of terms first phase and second phase also cover the mixing of a total of more than two phases, in which case the term "first phase" should be replaced with "starting phase" and the term "second phase" should be replaced with "next phase".

## Methods and Configurations for Inline Emulsification using FDM

For the FDM, the introduction of the second phase into the first may be performed as follows:

- A. For emulsion formation at a single concentration in single-pass mixing:

- I) Pre-incorporating the second phase into the first phase as a batch in a vessel prior to passing to the mixer for single-pass mixing, or
- II) Introducing the second phase into the first phase at some point along the inlet pipework, up to and including the inlet manifold to the mixer, or
- III) Injecting the second phase directly into one or more cavities in a single row of the mixer, using a single injection point or a number of injection points arranged circumferentially.

- B. For emulsion formation at a single concentration in multi-pass mixing:

Pre-incorporating the second phase into the first phase as a batch in a vessel prior to passing to the mixer for multi-pass mixing.

- C. For emulsion formation at multiple concentrations in single pass mixing:

Injecting the second phase directly into one or more cavities of more than one row of the mixer, using a number of injection points.

- D. For emulsion formation at multiple concentrations in multi-pass mixing:

- I) Introducing the second phase into the first phase at some point along the inlet pipework, up to and including the inlet manifold to the mixer, or
- II) Injecting the second phase directly into one or more cavities of one or more rows of the mixer, using a number of injection points.

Note that the use of terms first phase and second phase also cover the mixing of a total of more than two phases, in which case the term "first phase" should be replaced with "starting phase" and the term "second phase" should be replaced with "next phase".

In summary, it can be seen that a combination of FDM and IPM machines can provide a highly effective inline emulsification system with the FDM acting as a pre-blending shear unit and the IPM providing the high extensional stressing for droplet breakup. For this reason, the two machines are often combined within inline mixing systems.

[www.maelstrom-apt.com](http://www.maelstrom-apt.com)

For more information or to arrange a demonstration or trial please visit our website or contact:

Peter Brown - Tel: +44 1457 867777  
Fax: +44 1457 862207  
E-mail: [sales@maelstrom-apt.com](mailto:sales@maelstrom-apt.com)



**Maelstrom**  
Advanced Process Technologies