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DOM01 March 2008

DOMINO Workplans for 2007-2008 (Draft Workplans released in December 2007)

Gül N. Özcan

DOM02 February 2008

Dispersion of Nanoparticle Clusters in Liquids

Gül N. Özcan

Executive Summary

This report is prepared for DOMINO members to provide background on the break up of nanoparticle clusters in a liquid. Following on from a description of the process, the incorporation of nanoparticles in a liquid and break up of these are presented. Information on the different types of equipment widely used in industry is also given.

DOM03 March 2008

Rheology of Fine Particle Suspensions

Neil J Alderman

DOM04 April 2008

Draft Design Procedures for the Dispersion of Nanoparticle Clusters

DOM05 November 2008

Effect of Rotor-stator Geometry on Power and Flow Characteristics of Three in-line Rotor-Stators

Gül N. Özcan, Dominik Kubicki, Gustavo Padron

Executive Summary

This report details the results of a study undertaken within DOMINO on the power and flow

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characteristics of three in-line rotor-stators. These devices were also used to investigate the break up process of nanoparticle clusters within DOMINO.

The overall objective of the single phase study has been to:

Highlight the differences in the power and flow characteristics of three different mixer heads which would contribute towards the explanation of the results from break-up studies and ultimately on the discussions related to the choice of mixer head for this application.

The three devices studied were:

- inner General Purpose Disintegrating Head (GPDH) and an outer Square Hole Screen (SQHS),
- dual Emulsor screen (EMSC) from Silverson and
- Z unit from Ytron.

DOM06 May 2009

Effect of rotor-stator geometry on break up of silica nanoparticle clusters

Gül N. Özcan, Gustavo Padron

Executive Summary

In-line rotor-stator mixers are used in a wide range of energy intensive applications in the chemicals, food, personal, health care and applications numerous other applications for foam generation, chemical reactions, break up of liquid droplets or particle clusters. However there is limited published work on their performance and often process design and equipment selection must be done on a trial-and-error basis. This report presents the results of our study on the comparative performance of three different rotor-stator geometries for the break-up of nanoscale fumed silica clusters:

- Silverson/GPDH-SQHS,
- Silverson/EMSC and
- Ytron Z.

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DOM07 December 2008

DOMINO Workplans for 2008-2009

Gül N. Özcan

Executive Summary

This document provides the details of the work programme of DOMINO 2008-09 proposed for voting to the consortium members. Following on from a description of the project, the outlines of the proposed Work Packages are given in Section 3. The document will be finalised after the votes are received and work programme finalised based on this.

DOM08 December 2008

Results from preliminary experiments with two nanoclays

Neil J Alderman, Ainee Cheah, N. Gül Özcan, Gustavo Padron

Executive Summary

In this report, findings from an initial study with two nanoclays are presented.

Either an ultrasonic device or a stirred vessel equipped with a sawtooth impeller was used to prepare the dispersions. Samples taken at regular intervals under different operating conditions have been analysed through particle size measurements, X-Ray diffraction, rheology measurements and electron microscopy to monitor the dispersion process.

DOM09 June 2009

Particle-liquid affinity- DOMINO Results from 2007-08

Neil J Alderman, Ainee Cheah, N. Gül Özcan, Gustavo Padron

Executive Summary

In this report, findings from the first year programme of DOMINO are presented on particle-liquid affinity. The study was carried out using two types of nanoscale fumed silica particles:

- Aerosil 200V (hydrophilic)

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- Aerosil R816

in two liquids, both of a similar viscosity of about 10 mPa s:

- glycerol solution and
- silicone oil

Findings on incorporation of particles in a stirred tank using a narrow blade hydrofoil, rheology of dispersions from break up experiments and break up kinetics obtained using a large scale in-line rotor-stator and a small scale ultrasonic disperser are reported.

DOM10 June 2009

Results from preliminary experiments on break up of nanoscale silica particles using the Microfluidics M-110P

Dominik Kubicki

Executive Summary

This report details the preliminary results on the breakage of nanoscale silica particle clusters in a microfluidizer, Microfluidics M-110P.

The objectives of this work have been to:

- determine the range of operating conditions
- identify any difficulties that may be encountered during equipment operation and
- make an initial assessment of the performance of this device.

DOM11 June 2009

Results of a preliminary study on particle incorporation using the Ytron Y Jet Mixer

N. Gül Özcan

Executive Summary

Findings from a preliminary study on the incorporation of nanoscale silica particles using the Ytron Y Jet mixer are presented in this report. The study was carried out within the work package C1 of DOMINO 2008-09 programme at a low solids concentration of 1% (w:w) and within B.2- Effect of solids concentration for higher concentrations of up to 10%.

Ytron Y Jet device consists of an axial flow impeller mounted in a draft tube (or stator) positioned

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off-centre, close to the base of an unbaffled tank. A feed tube connected to a funnel (or hopper as referred to by manufacturers) is intended to introduce the particles into the impeller region.

A small scale vessel of 0.29 m diameter was used for the study. Experimental work included determining:

- power characteristics for different configurations;
- surface aeration conditions;
- drawdown rate over a range of power input values;
- effect of vessel and mixer unit configuration and
- effect of solids concentration.

Results and overall trends are also compared with the published data from another project, PROFORM.

DOM12 December 2009

DOMINO Final Workplans for 2009-2010

N. Gül Özcan

Executive Summary

This document details the work programme of DOMINO for 2009-10.

DOM13 January 2010

Effect of dispersion methods on the delamination of two types of nanoclay (Cloisite 30B in Daltocel and Cloisite Na+ in water)

Neil J Alderman, Ainee Cheah, N. Gül Özcan, Gustavo Padron

Executive Summary

In this report, findings from a study on the importance of different dispersion technologies are presented for two types of nanoclay dispersions.

The dispersion devices used were:

1. Hielscher UP200S 24kHz ultrasound disperser in a tank fitted with a PBT covering a specific power input range of about 40-80 Wkg⁻¹;
2. Lightnin A310 impeller in a tank at a specific power input of about 0.1 Wkg⁻¹;

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3. saw tooth high shear impeller in a tank at a specific power input of about 5 Wkg^{-1} ;
4. Hielscher UP200S 24kHz ultrasound disperser within a flow cell in the circulation loop of a stirred tank equipped with the large ICI impeller covering a specific power input range of about $40\text{-}80 \text{ Wkg}^{-1}$.

Samples taken at regular intervals under different operating conditions have been analysed through particle size measurements, X-Ray diffraction, rheology measurements and electron microscopy to monitor the dispersion process.

DOM14 March 2010

Literature review on break up of nanoparticle clusters with high pressure jets and valve Homogenisers

N. Gül Özcan

This report provides a review of literature on the break up of nanoparticle clusters using high pressure jets and valve homogenisers.

DOM15 February 2010

Literature review on break up of nanoparticle clusters using stirred bead mills

Emmanuela Gavi

This report is prepared for DOMINO members to provide background on stirred bead mills and on their application for efficient nanoparticle dispersion. Following on from a description of the equipment, its working principles and operating conditions, some recent advances on nanomilling and modelling of the grinding process in the bead mill are discussed. Information on the different types of equipment widely used in industry is also given.

DOM16 April 2010

Effect of residence time in an in-line rotor-stator on break up of silica nanoparticle clusters

Gustavo Padron

In-line rotor-stator mixers are used in a wide range of energy intensive applications in the chemicals, food, personal, health care applications and numerous other applications for example, foam generation, chemical reactions, break up of liquid droplets or particle clusters. However, there is limited published work on their performance and often process design and equipment selection

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must be done on a trial-and-error basis.

This report evaluates the effect of residence time within the rotor-stator on the de-agglomeration of fumed silica clusters. The rotor-stator used was a Silverson 150/250MS with a dual EMSC stator. Residence time was varied by either changing the batch size or flow rate.

DOM17 May 2010

Preliminary experiments with hydrophilic and hydrophobic zinc oxides

Gustavo Padron

Executive Summary

Zinc oxide has many industrial applications such as cosmetic UV protection and the production of UV-protected coatings and polymers. It has also potential uses in areas such as cross-linking, chemical catalysis and corrosion protection. It is therefore of interest to determine the best ways to finely disperse ZnO particles in order to take full advantage of their potential.

This document reports the findings from the studies undertaken within DOMINO in 2007-08 and 2008-09 using different types of zinc oxide.

Work has been carried out with three zinc oxides: two naturally hydrophilic manufactured by different processes and one whose surface has been treated to become hydrophobic (VP AdNano Z 805). Also, three different dispersing agents have been tested. The dispersions were produced using an ultrasound disperser. Results for particle size, viscosity, zeta potential and SEM imaging will be shown.

An optimised PSD measurement procedure was developed for ZnO dispersions due to their tendency to dissolve and/or settle during analysis. This was done to ensure the reliability of the results.

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DOM18 May 2010

Population Balance Modelling of the break up of nanoscale silica agglomerates using an in-line rotor-stator: effect of power input, flow rate and particle concentration

Dominik Kubicki

Executive Summary

This report presents the results of numerical modelling of the nanoparticle breakage process. The breakage of Aerosil 200V nanoparticle clusters processed in an in-line rotor-stator device is modelled. The numerical model assumes a simple 1D flow pattern in the system. The evolution of particle size distribution is modelled using the discrete form of population balance equations. The results of numerical simulations are compared with experimental data.

Four different breakage mechanisms are studied: erosion, shattering, rupture and binary breakage. Effects of three parameters are investigated: power input, flow rate and particle concentration.

DOM19 May 2010

Effect of Particle Concentration on the Performance of Microfluidizer for Breaking up Silica Particles

Emmanuela Gavi

Executive Summary

Microfluidics M110-P was used within DOMINO in a preliminary study on the break up of a 1% silica dispersion (DOM10). Those first results raised sufficient interest to investigate further the performance of this device at higher particle concentrations. This has been the motivation of the study documented in this report.

DOM20 May 2010

Effect of Continuous Phase Viscosity on Break Up of Silica Nanoparticles using Microfluidics M-110P

Emmanuela Gavi

Executive Summary

Microfluidics M110-P was used within DOMINO in a preliminary study on the break up of a 1% silica dispersion and this study carried on the investigation and is aimed at testing the effectiveness

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of operation of the Microfluidizer with increasing continuous phase viscosity. The results are compared with previous results from Rotor-Stator and Ultrasonic devices.

DOM21 August 2010

Break up of Zinc Oxide Nanoparticle Clusters Using Surfactants and Microfluidics M-110P

Emmanuela Gavi, Gustavo Padron

Executive Summary

This document reports the findings from the studies on the dispersion of zinc oxide clusters within DOMINO in 2009-10. Work carried out has two strands:

The first set of experiments was aimed at verifying if a polymeric surfactant with a high molecular weight, used in the early work during 2008-09, prevented zinc oxide agglomerates from breaking up by binding particles together. With this objective the stabilising agent Tergitol NP-9, was chosen because of its low molecular weight.

The second set of experiments aimed at verifying if a higher energy intensive device may achieve a higher fines volume fraction than the ultrasonic processor.

DOM22 October 2010

Effect of Solids Concentration on Break Up of Silica Nanoparticle Clusters with an In-Line Rotor-Stator and an Ultrasound Disperser

Neil Alderman, Dominik Kubicki, Gustavo A Padron

Executive Summary

Within DOMINO, in-line rotor-stators and ultrasound processors have been used to investigate the break up of nanoparticle clusters. Many nanoparticle break up applications require the processing of dispersions with high solids loadings. Therefore, it is important to understand how solids concentration affects the performance of the process equipment used.

In this report, results on the effect of solids concentrations up to 15%wt in an in-line rotor-stator mixer (Silverson 150/250MS) and an ultrasound disperser (Hielscher UP200S) on the de-agglomeration rate of fumed silica particle clusters are presented. The effect of solids concentration on dispersion rheology was also investigated and used in the interpretation of the break up results.

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DOM23 September 2010

Particle-Liquid Affinity - DOMINO results from 2008-2010

Ainee Cheah, Gustavo A Padron, Gul Ozcan-Taskin

Executive Summary

Findings from 2008 - 2010 programme of DOMINO on particle-liquid affinity are summarised in this report. These studies have been undertaken with a different continuous phase (Dipropylene glycol dimethylether) and a different type of hydrophobic nanoscale fumed silica (Aerosil® R202) particles.

DOM24 September 2010

CFD model of flow generated by an ultrasonic disperser

Dominik Kubicki

Executive Summary

This report presents the results of numerical modelling using Computational Fluid Dynamics (CFD) of the flow field generated using an ultrasonic disperser.

The model consists of two parts. First, the acoustic pressure distribution is solved using finite element solver Elmer, then acoustic pressure distribution is used to model cavitation in Fluent.

DOM25 December 2010

DOMINO Final Workplans for 2010 – 2011

Dr. N Gul Ozcan, Dr Gustavo Padron, Dr Neil Alderman, Mrs Ainee Cheah, Dr Emmanuela Gavi, Dr Dominik Kubicki

Executive Summary

In this report the workprogramme of DOMINO for 2010 – 2011 is presented. For completeness, first a description of the project is given in Sections 2 and 3, proposed workpackages are presented in Section 4 and Section 5 contains the WorkPackages that will be undertaken in this period based on the votes received from members.

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DOM26 January 2011

Effect of Continuous Phase Viscosity on Break Up of Silica Nanoparticle Clusters with an In-Line Rotor-Stator

Gustavo A Padron

Executive Summary

Within DOMINO, in-line rotor-stators have been used to investigate the break up of nanoparticle clusters. In this report, results on the effect of continuous phase viscosity on the mechanisms and rate of de-agglomeration of fumed silica particle clusters in an in-line rotor-stator mixer are presented. The viscosity of the continuous phase was varied from 1 to 100 mPa·s by using aqueous glycerol solutions of different concentrations. The rotor-stator evaluated was the Silverson 150/250MS equipped with a dual Emulsor screen (EMSC). Results are compared to those previously obtained using the same particle/fluid systems with a batch ultrasound disperser and a high pressure microfluidiser.

DOM27 January 2011

Particle incorporation using the large scale Ytron Y Jet (T= 0.61 m)

Gul N. Ozcan

Executive Summary

Ytron Y Jet, is a commercially available mixing unit, designed for the incorporation of fine powders into liquids. It consists of an axial flow impeller (operated in down pumping mode) placed in a short draft tube (or stator) and is recommended to be used in an unbaffled tank at an off-centre position as close to the vessel base/corner as practicably possible. A feed tube, which is part of the unit, allows the addition to be made into the impeller region from a funnel (or hopper at industrial scale).

Following on from the preliminary studies carried out within DOMINO in 2008-09 using a small tank (T= 0.29 m), further work with Ytron Y Jet has been undertaken in a T= 0.61 m diameter vessel to assess the performance of this device. Findings from this large scale vessel are presented in this report.

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DOM28 February 2011

Particle incorporation using an in-line rotor-stator Ytron ZC1

Gul N. Ozcan

Executive Summary

Ytron ZC1 is a commercially available in-line rotor-stator, designed for the incorporation of fine powders into liquids.

Exploratory work has been undertaken with this unit within DOMINO for an initial assessment of its performance with a view to undertake more detailed work in the future.

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