SPIRE 8 – 2015 – Solids handling for intensified process technology	

Title: Intensified by Design© for the intensification of processes involving solids handling

Acronym: IbD

Grant Agreement No: 680565

Deliverable 3.10	Public/publishable outputs from WP3
Associated WP	WP3 PI Modules
Associated Tasks	Tasks 3.1-3.5
Due Date	31/08/2017 (M24)
Date Delivered	18/12/2017
Prepared by (Lead Partner)	UNEW
Partners involved	DRA, ZHAW, OULU, VTT, Teltek, AMT
Authors	Kamelia Boodhoo and Ahmad Mustaffar (UNEW)
Dissemination Level	Public

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1 Introduction

WP3 of the IbD project focused on the characterisation of a number of PI modules for inclusion in the IbD Platform.

The partners involved with WP3 are UNEW, DRA, ZHAW, OULU, VTT, Teltek, AMT, UNIVLEEDS.

2 Objectives of WP3

(1) To prepare Built-in PI modules for a range of existing, well-known PI technologies as well as more novel, less well-studied technologies for incorporation into the IbD® Platform.

(2) To consider fouling mitigation and control strategies in the above PI modules

(3) To develop a PI module designer template for incorporation of new PI designs into the IbD Platform for specific applications as defined by the IbD case studies

3 Key achievements of WP3 at M24

- A review paper describing the state-of-the-art technologies for solids handling applications has been published in August 2017. Technologies for various common processes such as crystallisation, precipitation, mixing, drying are highlighted as well as processes that are more pertinent to the IbD project such as granulation, grinding, milling and particle classification.
- Five well established PI modules, namely the RFB, SDR, MRT, OBR and the Coflore Reactor (also referred to as the Agitated Tube Reactor) and four additional novel modules (Mop-fan deduster, Tube inserts, Heat Pipe Screw Dryer, Taylor-Couette) have been characterised for coding into the IbD Platform. The key characterisation data included for each PI module are: description/geometry of technology; key design and performance models (theoretical/empirical models); areas of application highlighted in terms of gas/liquid/solids handling; fouling and control/instrumentation considerations. In addition, a User Interface Flowchart has been developed for each technology to highlight a detailed design algorithm in order to facilitate coding of the module in the IbD Platform.
- The PI module design template has been designed based on the common information present in each of the existing PI module backlogs highlighted above. There is also a greater focus on inclusion of solids handling data. This template will be used to code an additional six case-study related PI modules (Elbow Jet Classifier, High Shear Mixer Granulator, Flash Floatation unit, Twin Screw Granulator, Torbed, Coflore) as part of WP6.
- Process monitoring and control requirements for the built-in and novel PI modules were evaluated in co-operation with PI experts and control experts. As a result, qualitative information about important variables and their interactions to be considered in preliminary control design, taking place in an integrated manner with the process design, was established.
- Input tables for fouling functionalities in the IbD® platform for built-in PI modules (RTB, SD, MRT and MAT) and novel PI modules (Mop fan, Heat pipe screw dryer, Tube inserts and Taylor-Couette reactor) have been prepared. These input tables provide information on key features of technologies for fouling prevention/reduction, important parameters that affects fouling, possible remedies and relevant references.

4 Public outputs from WP3

4.1 Journal papers

4.1.1 Published papers

H. Wang, A. Mustaffar, A. Phan, V. Zivkovic, D. Reay, R. Law, K.V.K. Boodhoo, 2017, "A review of process intensification applied to solids handling", Chem Eng & Processing: Process Intensification, 118, pp. 78 – 107, https://doi.org/10.1016/j.cep.2017.04.007.

R. Law, C. Ramshaw and D.A. Reay, 2017.Process intensification – Overcoming impediments to heat and mass transfer enhancement when solids are present, via the IbD project. Thermal Science and Engineering Progress, 1, pp. 53-58, https://doi.org/10.1016/j.tsep.2017.02.004

M. Hochstrasser, D. Jussen, P. Riedlberger, 2017, "Towards process intensification: Remediation of fouling in continuous microscale synthesis of phosphated TiO2", Chem Eng & Processing: Process Intensification, 121, pp. 15 – 23, https://doi.org/10.1016/j.cep.2017.07.024.

4.1.2 Papers under review or in preparation

A. Mustaffar, A. Phan and K.V.K. Boodhoo, "Hybrid heat pipe screw dryer: a novel, continuous and highly energy-efficient drying technology", Submitted to Chem Eng Journal (15 December 2017).

M. Ohenoja, D. Reay and K.V.K. Boodhoo, "Process control considerations in intensified continuous solids handling", In preparation (November 2007).

4.2 Conference publications

4.2.1 Conference presentations

A. Mustaffar, A. Phan and K.V.K. Boodhoo, 2017, "Heat pipe screw dryer (HPSD): an energy-efficient drying", 10th World Congress of Chemical Engineering – International Process Intensification Conference (WCCE-IPIC), 01-05 October 2017, Barcelona, Spain. https://submission.wcce10.org/index.php?pool=26506.pdf&site=wcce&lang=en&id=26506

H. Wang, A. Phan and K.V.K. Boodhoo, 2017, "Particle Classification via Taylor-Couette flow: Experimental and Simulation Studies", 10th World Congress of Chemical Engineering – International Process Intensification Conference (WCCE-IPIC), 01-05 October 2017, Barcelona, Spain. https://submission.wcce10.org/index.php?pool=66376.pdf&site=wcce&lang=en&id=66376

P. Livotov, D.A. Reay, R.Law, Mas'udah, A. Prashad, C. Sekaran, 2017. Systematic Innovation in Process Engineering: Linking TRIZ and Process Intensification. TRIZ Future Conference, Finland, October. (To be published by Springer Verlag).

A. Mustaffar, A. Phan and K.V.K. Boodhoo, 2017, “Heat pipe screw dryer: a continuous and highly energy efficient drying technology”, 7th International Symposium of Energy (ENERGY7) Conference, 13-17 August 2017, Manchester, United Kingdom.

D.A. Reay, 2017, Process Intensification: Overcoming impediments to heat and mass transfer enhancement when solids are present. Proc. SC-CST (UK-China Collaboration) Conference, Northumbria University, June.

A. K. Srivastava, I. B. Haugland, C. Ratnayake, 2017, "A Short Review on Fouling/Scaling/Caking during Powder Processing Operations" International Symposium of Reliable Flow of Particulate Solids; “RELPOWFLO V", 13-15 June 2017, Skien, Norway.

R. Law, C. Ramshaw and D.A. Reay. 2016, Process intensification – Overcoming impediments to heat and mass transfer enhancement when solids are present, *via* the IbD project. Proc. International Heat Transfer Conference, Nottingham University, UK.

K.V.K. Boodhoo, A. Phan, V. Zivkovic, V. Eze and A. Mustaffar, 2017, “Intensified-By-Design (IbD): Creating a Platform for Facilitating Process Intensification in Solids Handling Applications”, Abstract submitted for review in AICHE 2018 Spring Meeting and 14th Global Congress on Process Safety, Orlando, United States.

A. Mustaffar, A. Phan and K.V.K. Boodhoo, 2017, “Hybrid Heat Pipe Screw Dryer: A Novel, Continuous and Highly Energy-Efficient Drying Technology”, Abstract submitted for review in AICHE 2018 Spring Meeting and 14th Global Congress on Process Safety, Orlando, United States.

A. Mustaffar, A. Phan and K.V.K. Boodhoo, 2017, “Bi-Directional Thermal Control of Twin Screw Granulation Process Via a Specialised Annular Heat Pipe”, Abstract submitted for review in AICHE 2018 Spring Meeting and 14th Global Congress on Process Safety, Orlando, United States.

V. Zivkovic, R. Law, K. Boodhoo and D.A. Reay 2017, “Process intensification by miniaturization of fluidized beds”, Abstract submitted for review in AICHE 2018 Spring Meeting and 14th Global Congress on Process Safety, Orlando, United States.

4.2.2 Conference posters

M. Ohenoja, 2017, “Control perspective of selected PI technologies in continuous solids handling”, 10th World Congress of Chemical Engineering – International Process Intensification Conference (WCCE-IPIC), 01-05 October 2017, Barcelona, Spain. https://doi.org/10.13140/RG.2.2.27014.47687.

D. Jussen, M. Hochstrasser, P. Riedlberger, 2017, “Fouling remediation during microscale synthesis of a phosphate modified TiO2-catalyst“, 50. Jahrestreffen Deutscher Katalytiker, Weimar, Germany.

R. Law, D.A. Reay, K. Boodhoo, 2017 “Towards Standardisation of Process Intensification in Solids-Handling Processes – the Ibd Platform”, Abstract submitted for review in AICHE 2018 Spring Meeting and 14th Global Congress on Process Safety, Orlando, United States.

4.3 Other technical presentations (e.g seminars, invited talks etc.)

A. K. Srivastava, I. B. Haugland, C. Ratnayake, 2017, "Fouling in Mass Transfer" in 25th Process Intensification Network Meeting, Newcastle, United Kingdom.

A. Mustaffar, 2016, “Heat Pipe Screw Dryer: a novel drying technique”, in 25th Process Intensification Network, Newcastle, United Kingdom. http://www.pinetwork.org/pubs/PIN24/HEAT%20PIPE%20SCREW%20DRYER%20MUSTAFFAR%2022%20JUNE%202016.pdf.

D.A. Reay, 2016. Heat exchanger fouling prevention – learning from the HORIZON 2020 ‘Intensified by Design’ project. David Reay & Associates. HEXAG Meeting Presentation, Newcastle University, 20 June. See www.hexag.org

K.V.K. Boodhoo, 2016, “Process Intensification in Solids Handling Applications: Challenges and Prospects”, in NEPIC Pharmaceutical Event: Continuous Processing, 8th March 2016, Cramlington, United Kingdom.

D.A. Reay, 2016. Intensified by Design – The IbD Project. Process Intensification Group Meeting, School of Chemical Engineering, Newcastle University, 4 March.
H. Wang, 2016, Taylor-Couette reactor for solids processing applications, Process Intensification Group (PIG) Seminar, Newcastle, United Kingdom.

F.L. Muller and D.A. Reay, 2016. ‘Intensified by Design’ – Overview of the IbD project and the Case Studies. Leeds University and David Reay & Associates. Proc. 24th Process Intensification Network Meeting, Newcastle University, 21 June.

-Mixing in microfluidic structures. Daniel Jussen, ZHAW, Switzerland

-Fouling in heat exchangers. Akhilesh Kumar Srivastava, Tel-Tek, Norway

-IbD work with AM Technology. Tim Hunter, Leeds University

-A novel design of granulator/dryer. Ahmad Mustaffar/Anh Phan, Newcastle University

A. K. Srivastava, 2016, "Fouling/Scaling/Caking during Heat and Mass Transfer" in 24th Process Intensification Network Meeting, Newcastle, United Kingdom. http://www.pinetwork.org/pubs/PIN24/IbD%20_PIN%20presentation_Tel-Tek.pdf

D. Jussen, D. Lüthy, P. Riedlberger, 2016, “Mixing in microfluidic structures“, Process Intensification Network, Newcastle, United Kingdom.

D. Jussen, 2016, “Challenges in process-intensified nanoparticle synthesis”, in Biocatalysis and Process Technology Group Seminar, Wädenswil, Switzerland.

4.4 Non-technical presentations

D.A. Reay, 2016. Article on the IbD project. APSOCPIS (Asia-Pacific Society for Process Intensification and Sustainability) Newsletter, Vol. 3, Issue 2 , September.

K.V.K. Boodhoo, A. Phan, V. Zivkovic, D. Reay, 2016, “IbD - Intensified by Design® for the intensification of processes involving solids handling”, in Newcastle University HORIZON

2020 Brochure, pp. 30, http://www.ncl.ac.uk/media/wwwnclacuk/research/files/horizon-2020-brochure1.pdf.

5 Appendices

Relevant websites with links (where available) to abstracts/presentations highlighted above:

www.hexag.org

www.pinetwork.org

http://wcce10.org/index.php/program/st-program

https://www.aiche.org/conferences/aiche-spring-meeting-and-global-congress-on-process-safety/2018