ON THE OPTIMIZATION OF A NPK FERTILIZER PLANT

C. Herce, A. Gil, M. Gil, C. Cortés
CIRCE Foundation – University of Zaragoza
10th European Congress of Chemical Engineering - ECCE 10 + ECAB 3 + EPIC 5

circe RESEARCH CENTRE FOR ENERGY RESOURCES AND CONSUMPTION

ABSTRACT

World nutrient industry produces 190 million tons by year, of which 63% are granular fertilizers [1]. The fertilizer granulation circuit presents a relative simple layout, however the operation of this type of plants is difficult. The main reasons are a) the size of products is usually very restrictive (thus the recycle ratio commonly arrives to 6:1) and b) the cyclic surging and drifting of particles and long residence times makes difficult the steady-state control of the process [2].

The aim of this work is the optimization of an industrial fertilizer plant which produces 0,5 ton/h of NPK Fertilizer. In order to achieve this objective a two-level modeling strategy has been adopted:

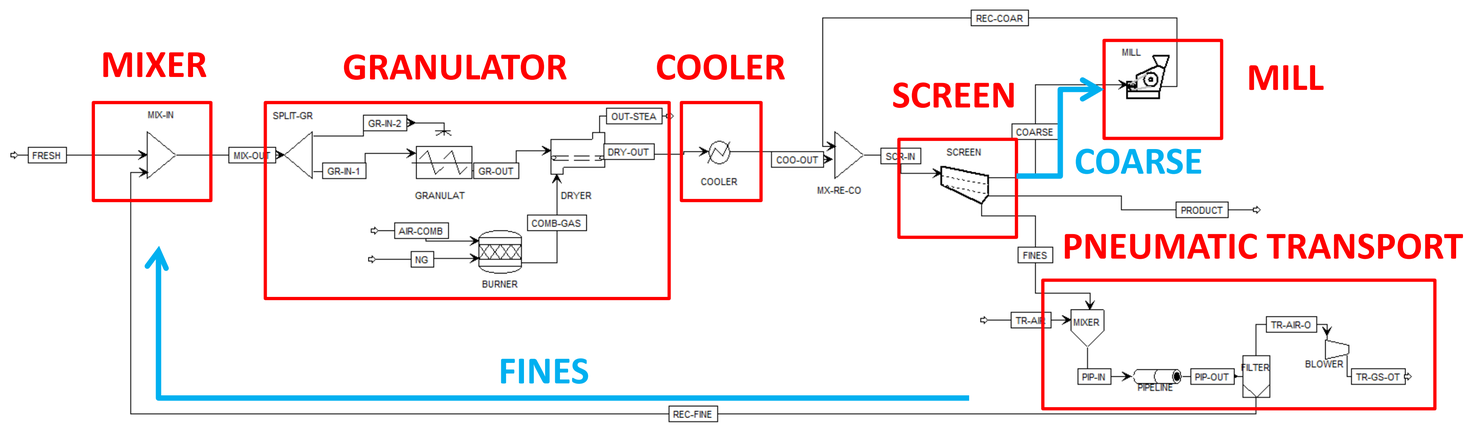
1.- Plant Modeling: By means of AspenPlus Software

2.- Reactor modeling. Each device was also modeled in detail and implemented in MATLAB.

GLOBAL PLANT MODEL

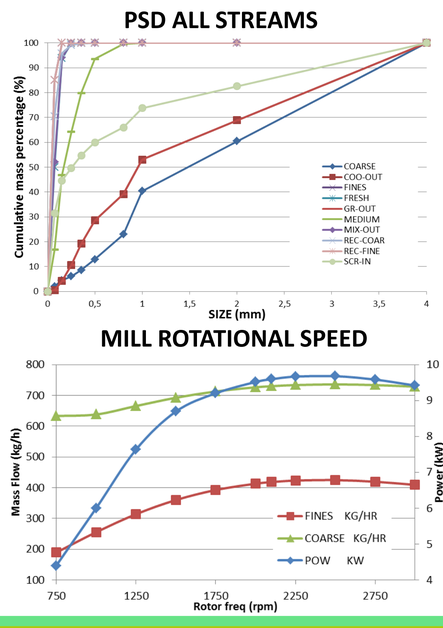
Six main reactors in the plant have been modeled with AspenPlus 8.6 (with SolidSIM embedded code[3-4]) :

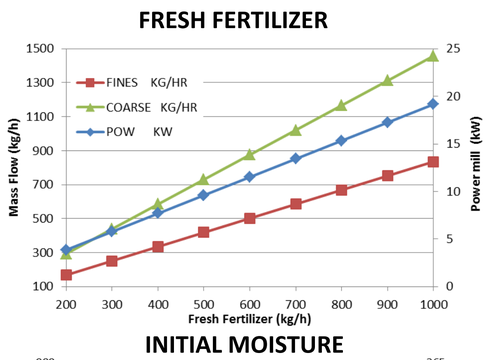
1. Mixer - double-shaft paddle mixer – Ideal mixer
2. Granulator/dryer – divided in three zones:
   Burner Zone (CSTR), Rotary drum granulator (CSTR Vol. Prop. Cons.), Dryer (Rotary Drum)
3. Cooler – Ideal Heat Exchanger – No Particle Size Distribution (PSD) changes
4. Sieve – 2-Screen separator – Roger's model
5. Mill – Hammer mill – Bond's law (Energy Consumption) and Vogel and Peukert Model for PSD
6. Pneumatic transport – Dilute transport model (Muschelknautz Model)

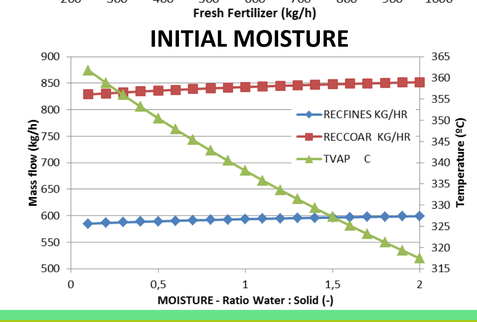


GLOBAL MODEL RESULTS

- Global model presents a **good accuracy** compared with plant data
- The critical parameter in recycling ratio is hammer mill **rotational speed**
- **Particle size distribution** mainly depends on initial moisture and recycling ratio





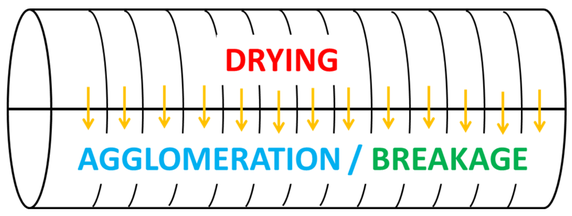


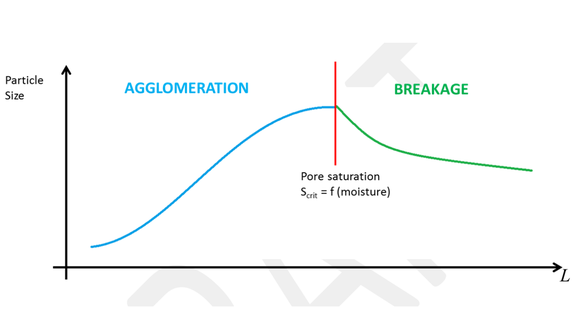
- **Mixer, mill, screen and pneumatic transport** models available in AspenPlus by default present good accuracy and control
- Granulator and cooler ratio models are very limited – Uncoupling PSD changes and heat transfer → A **Comprehensive model granulation/drying has been developed**

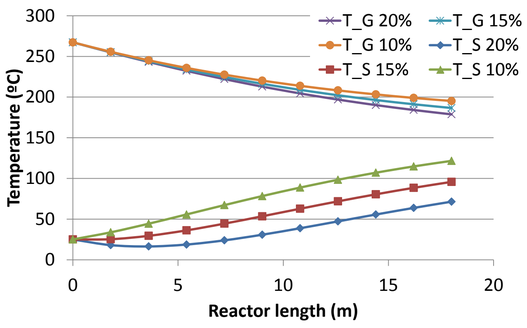
		SIMULATION	PLANT
FERTILIZER FRESH INLET MASS FLOW	kg/h	500	500
WATER INLET MASS FLOW	kg/h	200	200
RECYCLED FINES MASS FLOW	kg/h	588.7	900
RECYCLED COARSE (MILL) MASS FLOW	kg/h	836.8	
PRODUCT MASS FLOW	kg/h	501.2	500
GAS TEMPERATURE INLET GRANULATOR	ºC	316.9	220
GAS TEMPERATURE OUTLET GRANULATOR	ºC	188.4	90
SOLIDS TEMPERATURE OUTLET GRANULATOR	ºC	188.4	60
SOLIDS TEMPERATURE OUTLET COOLER	ºC	25	25
MOISTURE SOLIDS OUT MIXER	% mass	18.5	18
MOISTURE SOLIDS OUT GRANULATOR	% mass	0.25	0.25
AIR MASS FLOW BURNER	kg/h	23276.6	
NATURAL GAS MASS FLOW BURNER	kg/h	142.4	145
POWER MILL	kW	9.6	9.2
POWER BLOWER	kW	93.2	
PRESSURE DROP TRANSPORT	mbar	7.6	
PRESURE DROP FILTER BAG	mbar	23.75	

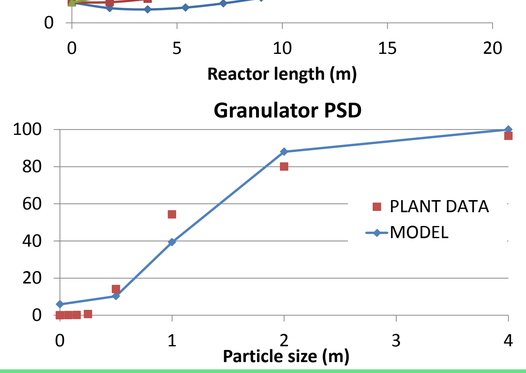
GRANULATION MODEL

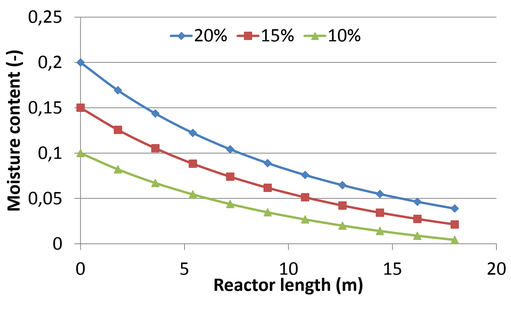
- One-way coupling PSD evolution and heat transfer
- **Mechanistic** approach of agglomeration/breakage balance population models [5-10]
- **Flexible and comprehensive** model – Calibration with few plant data
- The model includes reactor design, operating conditions, material properties and basic hydrodynamics
- Good **agreement** with plant data
- Future **integration** with global model

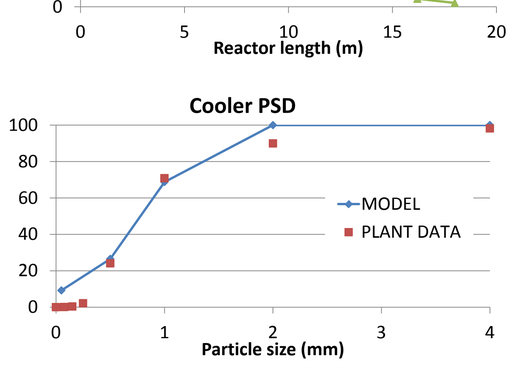


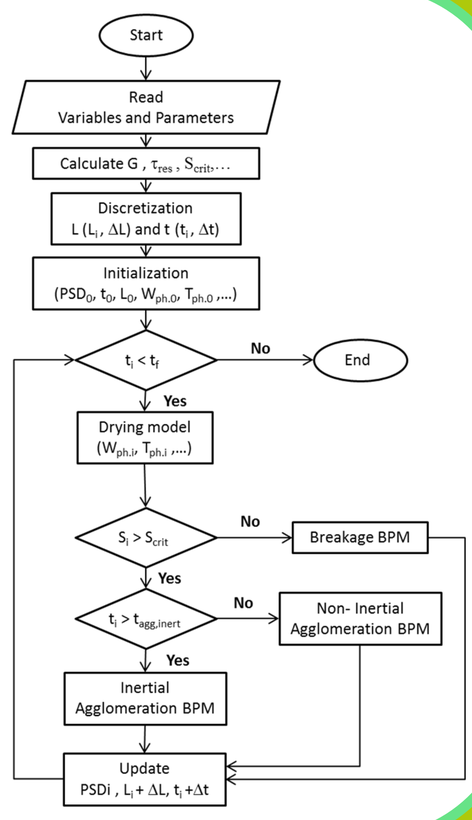












CONCLUSIONS

A NPK Fertilizer plant has been modeled with AspenPlus. Results present good agreement with plant data. Embedded solid handling tools are very powerful and robust; however some limitations in the granulator have been detected. A mechanistic granulator/dryer model (based in Population Balance Models) has been developed. The model correctly predicts plant data, but some refinements must be done. In further developments, the granulator model will be integrated with the global model of the plant.

Acknowledgements

This work has been partially supported by the research project TOP-REF funded from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 604140. C. Herce is supported by the Torres Quevedo Grant No PTQ-13-06393 (Ministry of Economy and Competitiveness). The authors gratefully acknowledge Fertinagro Nutrientes S.L. and Utrillas (Teruel) plant personnel for their support and collaboration.

TOP REF toprefproject.eu

Contact

Carlos Herce – cherce@fcirce.es Antonia Gil – gil.antonia@fcirce.es
Miguel Gil – miguelgc@fcirce.es Cristóbal Cortés - tdyfqdb@unizar.es
Research Centre for Energy Resources and Consumption (CIRCE)-Universidad de Zaragoza
CIRCE Building – Campus Río Ebro, C/Mariano Esquillor Gómez, 15, 50018 Zaragoza (Spain)

REFERENCES

1. Heinrich, D. "Fertilizers, 4. Granulation". Ullmann's Encyclopedia of Industrial Chemistry. 2000. Wiley-VCH Verlag
2. Adetayo, A.A., et al. 1995, Computers & Chem. Engineering, 19 (4), 383-393
3. Hartge, E. U. et al. 2006, Kona, 24, 146-158
4. AspenPlus, "Aspen Plus v.8.7 user guide," Aspen Technology Ltd, 2014
5. Cameron, I.T., et al. 2005, Chemical Engineering Science, 60 (14), 3723-3750
6. Verkoeijen, D. et al. 2002, Chemical Engineering Science, 57 (12), 2287–2303
7. Walker, G.M. Handbook of Powder Technology 2007, 11, 219–254
8. Ramachandran, R. C. et al. 2009, Chemical Engineering Research and Design, 87 (4), 598–614
9. Gil, M. et al. 2015 Powder Technology, 276, 34–44
10. Castaño, F. et al. 2012, Drying Technology, 30 (8), 839–849