Modelling of a Sinter Plant in gPROMS with Selective Waste Gas Recirculation

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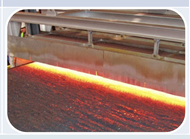
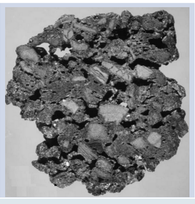
Introduction

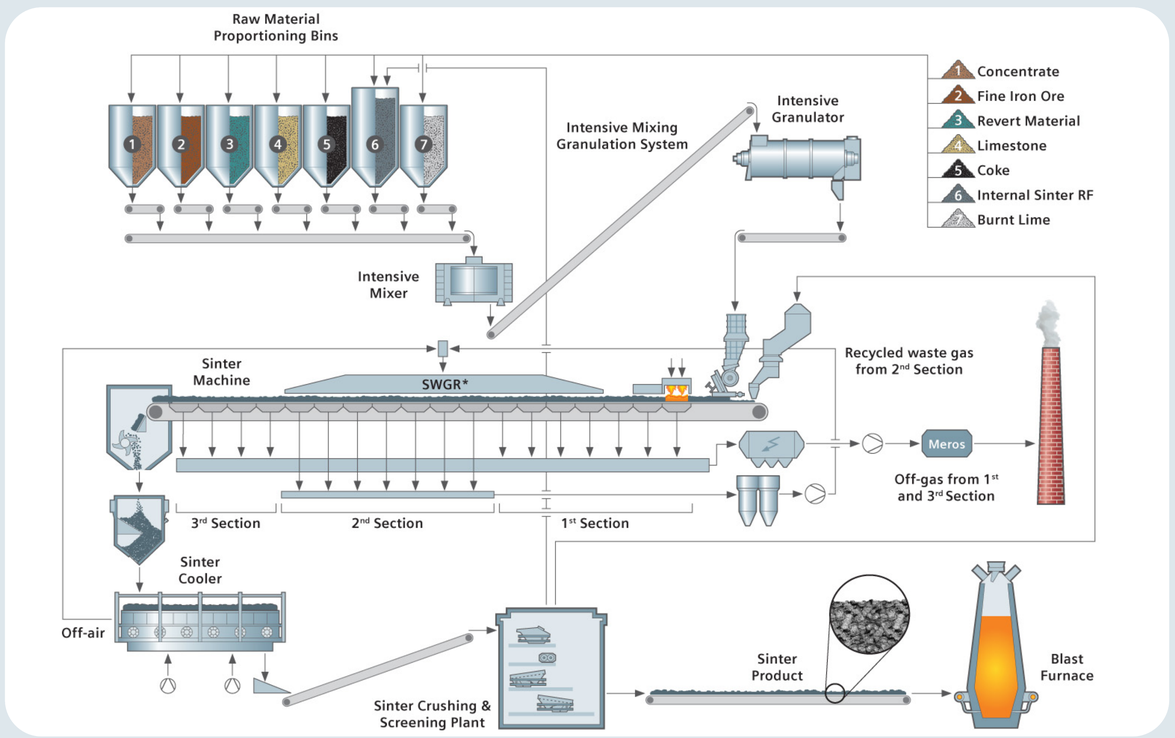
In the field of iron-making, sintering is the main technology responsible for the preparation of iron oxides prior to their use in the blast furnace. About 70% of the world's primary production originates from the use of the sinter plant – blast furnace combination. The target of this work is the development and validation of a sinter plant model with selective waste gas recirculation (SWGR). Additionally, an algorithm for detecting feasible SWGR scenarios is presented.

Process

The sinter is an agglomerate of mineral particles into a porous mass by incipient fusion caused by heat. The raw materials used for its production are ores (e.g. iron oxides), additives (e.g. dolomite, limestone) and fuel (e.g. coke breeze). Among other quality criteria, the sinter product must encompass high resistance against mechanical stress, good reducibility, uniformity in the size distribution and high iron content. There is a series of process steps taking place in a sinter plant that make sure that these requirements are met.

Sinter Plant Basic Process Steps

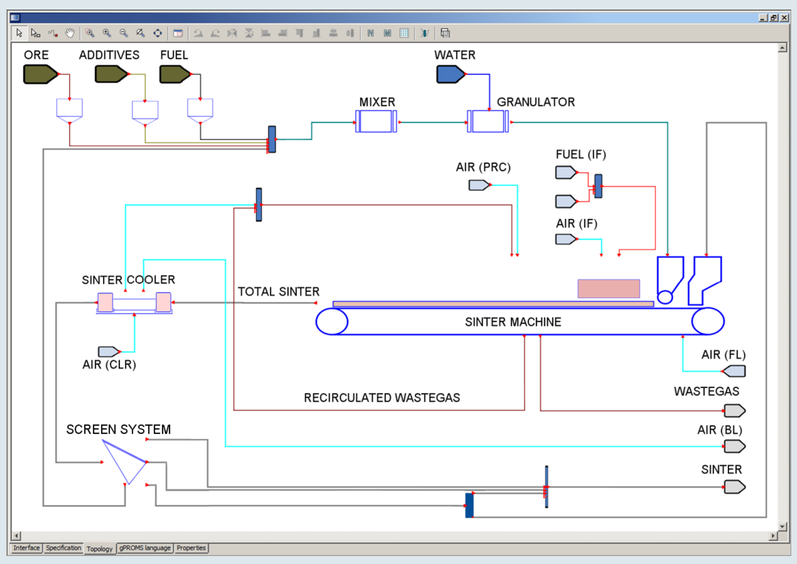
1. Mixing	2. Granulation	3. Sintering	4. Cooling	5. Crushing & Screening	
					



Below the whole length of the sinter machine there are windboxes collecting the produced waste gas. Siemens VAI has developed the SWGR technology for the partial recirculation of this gas. For this reason, a recirculation hood is positioned over the sinter strand. The advantage of this solution is the reduction of the fuel consumption due to the integration of generated heat back into the process. Additionally, this is an environmentally friendly process, due to the reduction of waste gas volume and SOx/NOx emissions.

Model

The models and the flowsheet of the sinter plant were created within the environment of the gPROMS ModelBuilder. Each unit operation is a different model developed in the gPROMS language.



inputs
ore
additives
fuel (solid, fluid)
water
air (process, ignition furnace, false, cooling)

outputs
sinter
waste gas
air

unit operations
mixer
granulator
sinter machine
sinter cooler
screen system

The main unit operation of the plant is the sinter machine. In this device the mass and energy balances are applied for the involved reactions.

Basic Model Equations

mass balance	$\sum_{in}\left(m_{in}\cdot c_{in,k}\cdot si_{k,i}\cdot\frac{MW_i}{MW_k}\right)=\sum_{out}\left(m_{out}\cdot c_{out,k}\cdot si_{k,i}\cdot\frac{MW_i}{MW_k}\right)$
energy balance	$\sum_{in}\left(m_{in}\cdot c_{in,k}\cdot h_k(T)\right)=\sum_{out}\left(m_{out}\cdot c_{out,k}\cdot h_k(T)\right)+H_{losses}$
reaction stoichiometry	$\sum_{in}\left(m_{in}\cdot\frac{c_{in,k}}{MW_k}\cdot RD\right)=\sum_{out}\left(m_{out}\cdot\frac{c_{out,j}}{MW_j}\right)$

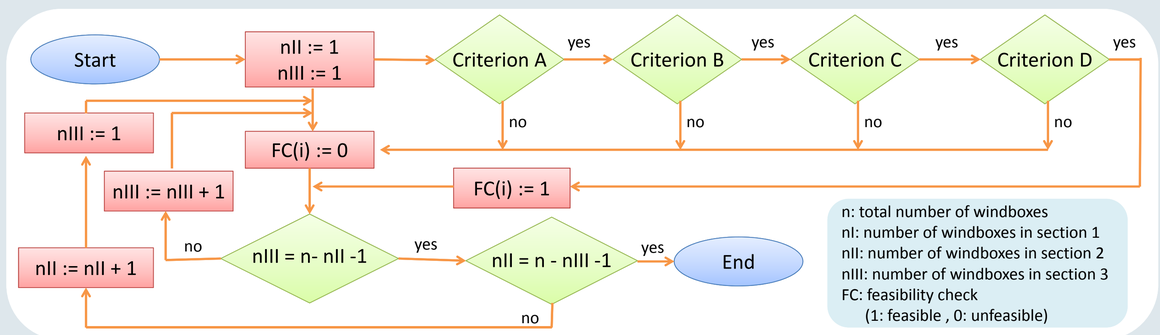
Sinter Machine Model Reactions

C gasification	$C + O_2 \rightarrow CO_2$ $C + ½O_2 \rightarrow CO$
drying	$H2O_{(l)} \rightarrow H2O_{(g)}$
LOI removal	$MgCO_3 \rightarrow MgO + CO_2$ $CaCO_3 \rightarrow CaO + CO_2$ $Fe_2O_3{*}H_2O \rightarrow Fe_2O_3 + H2O_{(g)}$ $FeCO_3 \rightarrow FeO + CO_2$
Fe oxidation	$Fe + ½O_2 \rightarrow FeO$ $3Fe + 2O_2 \rightarrow Fe_3O_4$
S combustion	$S + O_2 \rightarrow SO_2$
CO combustion	$CO + ½O_2 \rightarrow CO_2$

Due to technical restrictions the whole amount of waste gas can not be recycled. In practice the total range of winboxes is divided in different parts and a defined number of windboxes are returned in the recirculation hood. There are criteria that define the feasible/optimal amount of windboxes that should be included in each section. These are:

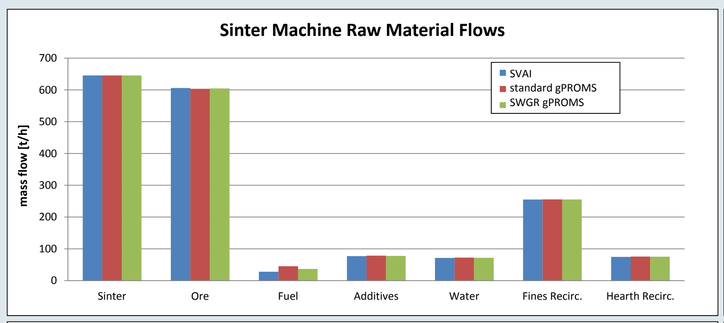
A: temperature limits in sections of the process
B: temperature difference between waste gas and recirculation gas
C: volume flow ratio on a Nm³/h basis between recirculation gas and total waste gas
D: volume flow ratio on a Bm³/h basis between recirculation gas and total waste gas

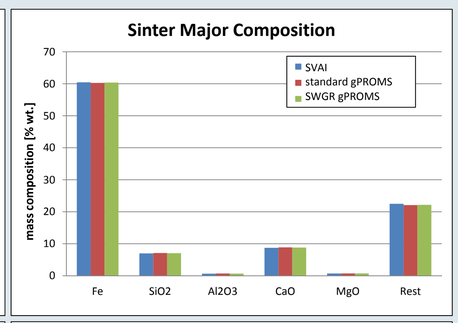
An algorithm in the form of a task was developed for finding the cases that meet the above criteria.

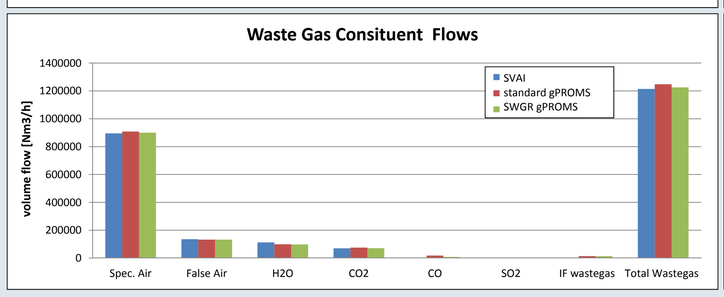


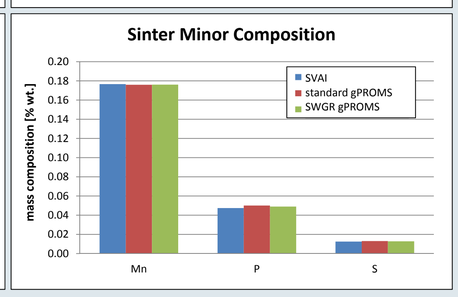
Simulation Results

For the validation of the model, the standard (without SWGR) model is cross-referenced against plant data provided by Siemens VAI. Additionally, the SWGR model is calculated for observing the differences compared to the standard mode.









Conclusions & Outlook

- the simulation results are in good accordance with the plant data for both gas and solids
- the SWGR decreases the fuel consumption and the waste gas volume
- a discretised model of the sinter machine should be developed for more detailed results

References

H. Ahn et. al., Process simulation of iron ore sintering bed with flue gas recirculation, Institute of Materials, Minerals and Mining, Daejeon, Korea, 2013
A. Babich et. al., Ironmaking – Textbook, RWTH Aachen University, Aachen, Germany, 2008
R.W. Lewis et. al., Numerical Methods in Heat Transfer, Volume II, John Wiley & Sons, New York, USA, 1983
J. Reidetschläger et. al., Selective Wastegas Recirculation for Sintering Plants, Linz, Austria, 2012

Acknowledgements

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