AGGLOMERATION OF ZEOLITE IN THE FLUIDIZED BED[#]

Sergej Knez,[a] Janez Stražišar,[a] Janvit Golob,[b] Andrej Horvat[c]
[a]*Faculty of Natural Science, Department of Geotechnology and Mining, University of Ljubljana,*
Aškerčeva 12, 1000 Ljubljana, Slovenia; Sergej.knez@ntfgam.uni-lj.si
[b]*Faculty for Chemistry and Chemical Engineering, Aškerčeva 2, 1000 Ljubljana, Slovenia*
[c]*Silkem d.o.o., Tovarniška cesta 10, 2325 Kidričevo, Slovenia*

[#]This paper is dedicated to Professor Dr. Roman Modic

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Abstract

Zeolites are crystalline materials most widely used as molecular sieves and ion exchangers. The production process yields the base zeolite material with average particle size of about 5 μm. These particles are later mixed with binder and agglomerated during drying in spray-dryers to produce larger particles with upper size range of about 300 μm, depending predominately on the geometry of the atomizer and it's speed of rotation. However, some applications require even larger particles that cannot be produced by spray-drying technique. An important technique for producing large granulates is agglomeration in the fluidized bed. The intensive mixing of solid particles in the fluidized bed facilitates high heat and mass transfer rates and consecutively almost isothermal conditions throughout the bed, resulting in high process yields and effective control. The absence of moving mechanical parts also lowers the maintenance costs. However, there is still a lack of understanding concerning the mechanisms of particle formation and growth in the fluidized bed that leads to difficulties in planning and operating such processes, hence the experiments on semi-industrial scale equipment are needed to obtain the necessary process parameters.

The present work is concerned with the determination of the process parameters for producing granulated zeolite with demanded product characteristics in a semi-industrial scale fluidized bed dryer. The theoretical (and sometimes empirical) knowledge of the operations involved – fluidization, agglomeration, drying – was used to construct the model of the process, which enabled us to identify the relevant process parameters, i.e. those controlling the process and those affecting the product characteristics, and predict their values. Next, the demanded product characteristics were set and then used as a measure of adequacy of the chosen process parameters and their optimization.

The results of our experimental program confirmed the validity of the model and the possibility of using fluidized bed agglomeration for producing large zeolite particles.

Introduction

Agglomeration

Agglomeration is a process of combining small particles into larger structures through some sort of binding mechanism. *Figure 1.* shows the basic binding mechanisms between two solid particles.

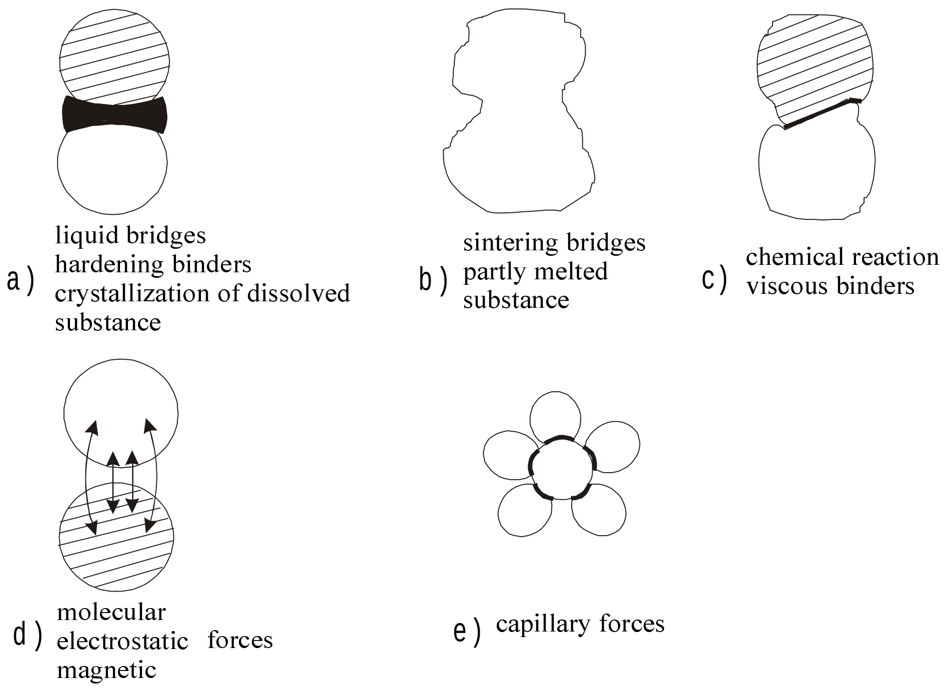

Figure 1.: Basic binding mechanisms between two solid particles

With the exception of sintering all other binding mechanisms can be classified in two agglomerating techniques:

- agglomeration without binder and
- agglomeration with binder.

Agglomeration of Zeolite

Figure 2. shows schematically the mechanism of zeolite agglomeration.

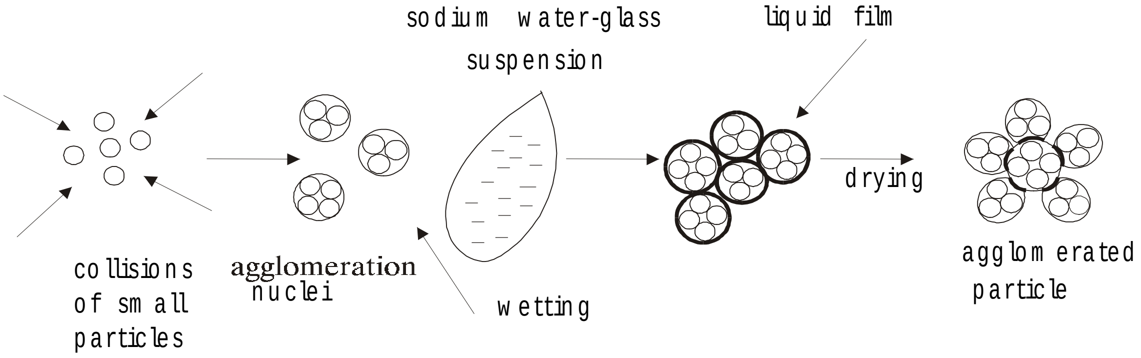

Figure 2.: The mechanism of zeolite agglomeration

The small solid particles – i.e. smaller than 10μm, are small enough to spontaneously form small agglomerates when intensely mixed. For further growth a binder suspension is sprayed on the bed. As the particle are wetted, a liquid surface film forms on their surface, which facilitates deposition of the sodium water glass component on the surface of particles and provides the binding mechanism. When two wetted particles collide, a liquid bridge forms between them on the point of contact. As the agglomerating particles are dried by the fluidizing air, the water evaporates from their surface and the water glass hardens into a solid, glass-like substance – "the silicon polymer" – that firmly binds the smaller particles into larger agglomerates without altering their basic crystal structure.

Fluidization

Fluidization is an operation by which fine solid particles are transformed into a fluid-like state through the contact with a flowing fluid. The advantages of fluidization for industrial operations are[1]:

- the smooth, liquid-like flow of particles allows continuous automatically controlled operations;
- the rapid mixing of solids leads to nearly isothermal conditions throughout the apparatus, so the operation can be controlled simply and reliably;
- it is suited for large scale operations;
- heat and mass transfer rates between gas and particles are high compared to other modes of contacting.

There are, however also several disadvantages to this technique:

- the rapid mixing of solids in the bed leads to nonuniform residence times of solids in the reactor. For continuous treatment of solids this gives a nonuniform product and lower conversions. For batch treatment of solids however, this mixing is helpful since it gives a uniform solid product:
- erosion of pipes and vessels from abrasion by particles can be serious;
- for operations at high temperature the sintering of fine particles can necessitate a lowering of temperature of operation.

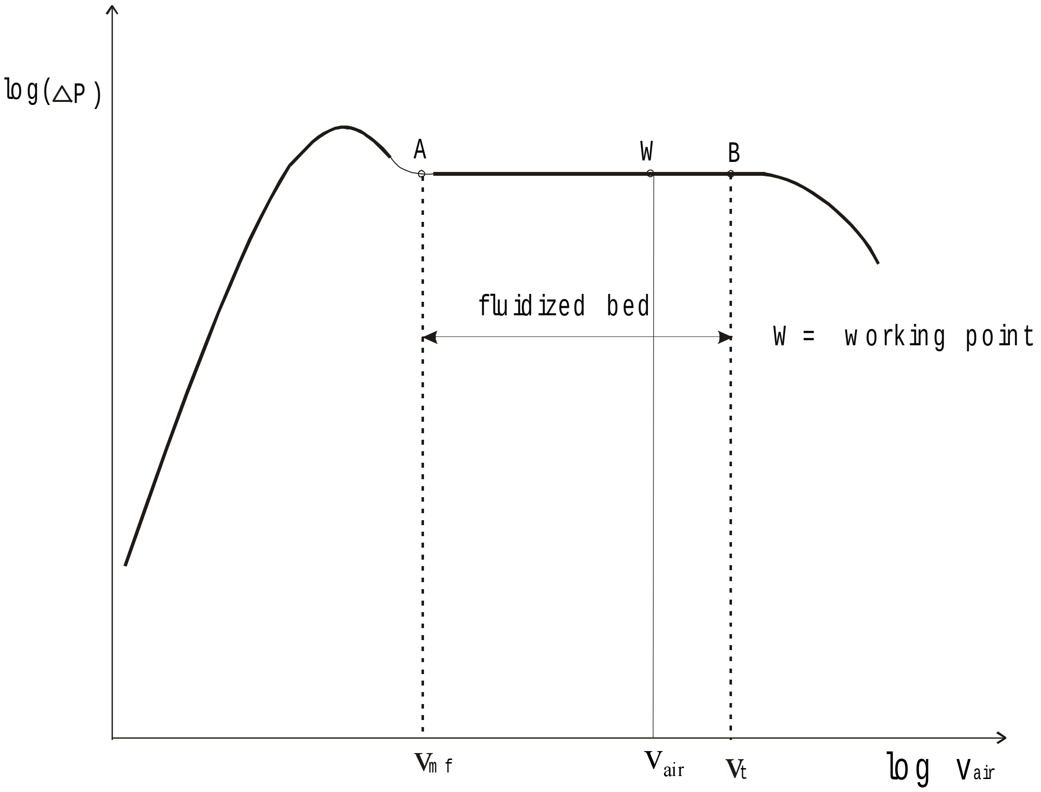

Figure 3.: Pressure drop through a bed of solids

Figure 3. shows the pressure drop through a bed of solids in dependency of the superficial velocity of the fluidizing gas. When the gas passes through the bed at a low flow rate, it merely percolates through the void spaces between the stationary particles – *fixed bed*. As the flow rate is increased, a point is reached when the frictional force between a particle and gas counterbalances the weight of the particle and the pressure drop through any section of the bed about equals the weight of gas and particles in that section – *bed at minimum fluidization.* As the flow rate is increased still further, the bed does not expand much further beyond its volume at minimal fluidization (when the fluidizing medium is gas), but agitation and movement of solids become more vigorous. At a sufficiently high flow rate the terminal velocity of the particles is exceeded, entrainment of solids within the gas flow becomes appreciable and they are carried out of the bed – *pneumatic transport.*

As can be seen from the *Figure 3.* the "usable" range of velocities lies between :

a) the *minimal fluidizing velocity (v_{mf})* – lower boundary;

b) the *terminal velocity (v_t)* – upper boundary.

Basic Equations for Describing the Fluidized State

Minimal Fluidizing Velocity

As stated above, the beginning of fluidization occurs when the drag force by upward moving gas equals the weight of the particles or

$$\begin{bmatrix}\text{pressure drop}\\ \text{across the bed}\end{bmatrix}\cdot\begin{bmatrix}\text{cross-sectional}\\ \text{area of the tube}\end{bmatrix}=\begin{bmatrix}\text{volume of}\\ \text{the bed}\end{bmatrix}\cdot\begin{bmatrix}\text{fraction of}\\ \text{solids}\end{bmatrix}\cdot\begin{bmatrix}\text{specific weight}\\ \text{of solids}\end{bmatrix} \qquad (1.)$$

The pressure drop across the bed is correlated by the Ergun equation[1], and the voidage at minimum fluidization (ε_{mf}) can either be estimated from the random packing data, or better still measured experimentally. This derivation results in a quadratic expression for v_{mf}. However, for small particles and low Reynolds numbers the viscous energy losses predominate and the equation simplifies to:

$$v_{mf}=\frac{(\Phi_S\cdot d_p)^2}{150}\cdot\frac{\rho_S-\rho_G}{\mu_G}\cdot g\cdot\frac{\varepsilon_{mf}^3}{(1-\varepsilon_{mf})}, \qquad \text{for} \quad Re_p<20 \qquad (2.)$$

And for large particles, when only the kinetic energy losses need be considered:

$$v_{mf}=\left[\frac{\Phi_S\cdot d_p}{1.75}\cdot\frac{(\rho_S-\rho_G)}{\rho_G}\cdot g\cdot\varepsilon_{mf}^3\right]^{1/2}, \qquad \text{for} \quad Re_p>1000 \qquad (3.)$$

If Φ_S and/or ε_{mf} are unknown, the following modifications suggested by *Wen* and *Yu* [1.] are used:

$$\frac{1-\varepsilon_{mf}}{\Phi_S^2\cdot\varepsilon_{mf}^3}\cong 11 \qquad \text{and} \qquad \frac{1}{\Phi_S\cdot\varepsilon_{mf}^3}\cong 14 \qquad (4.)$$

and equations (2.) and (3.) simplify to:

$$v_{mf}=\frac{d_p^2\cdot(\rho_S-\rho_G)\cdot g}{1650\cdot\mu_G}; \qquad \text{for} \quad Re_p<20 \qquad (5.)$$

$$v_{mf}=\left[\frac{d_p\cdot(\rho_S-\rho_G)\cdot g}{24.5\cdot\rho_G}\right]^{1/2}; \qquad \text{for} \quad Re_p>1000 \qquad (6.)$$

Terminal Velocity

The upper limit to gas flow rate is approximated by the terminal or free-fall velocity of the particles, which can be estimated from the fluid mechanics:

$$v_t = \left[\frac{4 \cdot g \cdot d_p \cdot (\rho_S - \rho_G)}{3 \cdot \rho_G \cdot C_d}\right]^{1/2} \tag{7.}$$

Where C_d is the experimentally determined drag coefficient. Unfortunately no simple expression can represent the experimental findings for the entire range of Reynolds numbers, so for particular Re we have:

$$C_d = \frac{24}{\mathrm{Re}_p} \quad \text{and} \quad v_t = \frac{(\rho_S - \rho_G) \cdot g \cdot d_p^2}{18 \cdot \mu_G}; \qquad Re_p < 0.4 \tag{8.}$$

$$C_d = \frac{10}{\mathrm{Re}_p^{0.5}} \quad \text{and} \quad v_t = \left[\frac{4}{225} \cdot \frac{(\rho_S - \rho_G)^2 \cdot g^2}{\mu_G \cdot \rho_G}\right]^{1/3} \cdot d_p; \qquad 0.4 < Re_p < 500 \tag{9.}$$

$$C_d = 0.43 \quad \text{and} \quad v_t = \left[\frac{3.1 \cdot (\rho_S - \rho_G) \cdot g \cdot d_p}{\rho_G}\right]^{1/2}; \qquad Re_p > 500 \tag{10.}$$

The Model of the Process

As can be seen from the mechanism of agglomeration, the zeolite particles must first be sufficiently wetted to form a surface liquid film, which facilitates the forming of liquid bridges on the points of contact between colliding particles in the bed and at the same time deposits the sodium water glass on the surface. If that is to happen, the wetness of particles must exceed the critical wetness (X_{cr}) of zeolite (*Figure 4.*).

The optimal wetness of material for agglomeration can be defined as the *agglomeration wetness* (X_{Agg}). X_{Agg} is an operating parameter which must be maintained a constant throughout the agglomeration process. If the wetness of particles is lower than X_{Agg} , the liquid bridges may not form upon particle collisions and/or the sodium water glass may not get deposited on the surface in a manner that ensures the final binding of particles when the agglomerated material is dried and the agglomerates quickly break down. If X_{Agg} is exceeded, the sprayed binder and fluidized particles in the bed may start forming a slurry that can not be fluidized and accumulates on the bottom of the loading chamber, blocking the air flow.

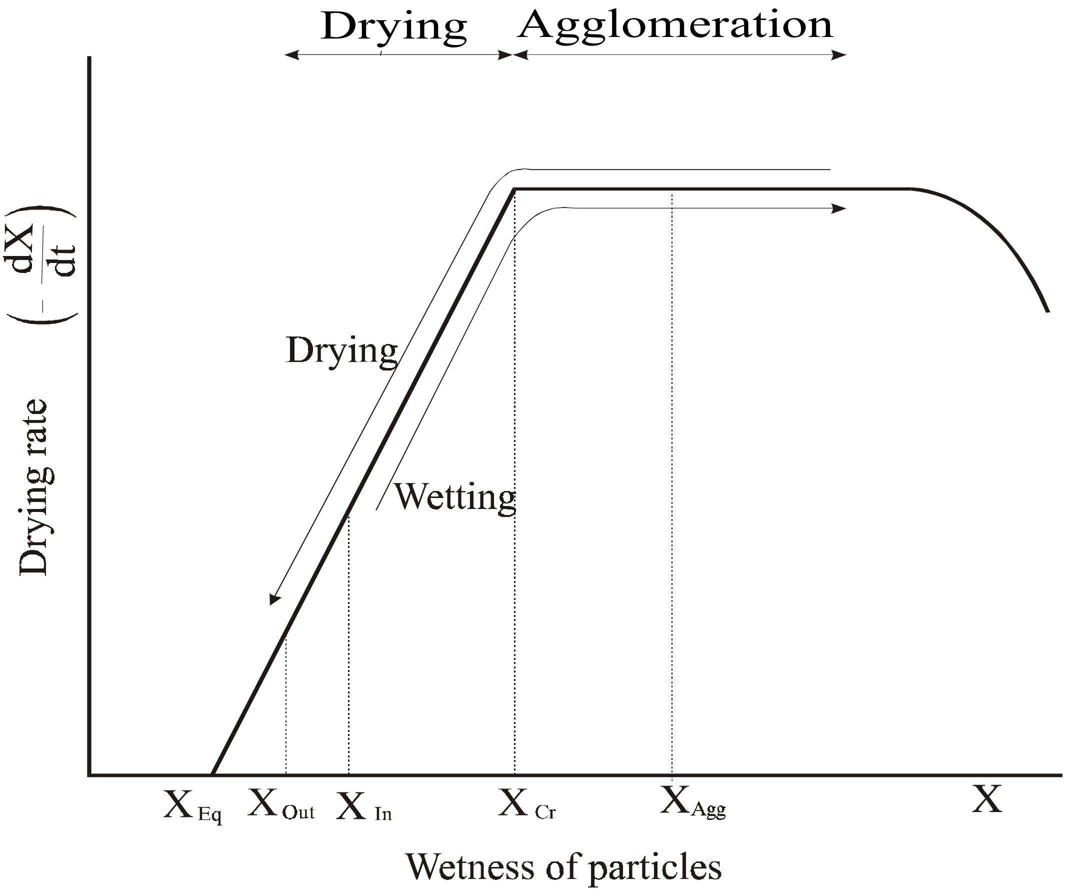

Figure 4.: Kinetic diagram of wetting/drying of zeolite

The wetness of particles in the bed depends on the balance between the two opposite processes – wetting (spraying the binder solution) and drying (removing of moisture by the fluidizing air). A careful manipulation of parameters affecting these processes is therefore needed for successful agglomeration.

The mass balance of water for agglomeration:

$$m_0^{d.m.} \cdot X_{Agg} = m_{bin}(1-\omega_s) - G \cdot \tau \cdot (Y_{out} - Y_{in}) \tag{11.}$$

where $m_0^{d.m.} = m_0 \cdot (1 - x_0)$ and $G = v_{air} \cdot S = v_{air} \cdot \frac{\pi \cdot D^2}{4}$ (12.)

Therefore, the operating wetness of particles in the bed depends on the fluidizing air velocity (v_{air}), the inlet air conditions (temperature – T_{air} and humidity - Y_{in}) and the rate of binder spraying ($\dot{m}_{bin} = \rho_B \cdot \dot{V}_B$).

Air Velocity – Boundary Conditions

As explained previously, the working range of air velocities is between the minimal fluidizing velocity of particles in the bed and their terminal velocity. That, however is only true in case of a homogenous bed – i.e. all particles in the bed are of the same size. In the case of a heterogeneous bed, the velocity boundaries are the minimal fluidizing velocity of the largest particle in the bed and the terminal velocity of the smallest one.

In the case of agglomeration in the fluid bed the situation is further complicated by the fact, that particles grow during the process so the boundary conditions change with time. The boundary conditions in this case are:

a) *lower boundary* – the minimal fluidizing velocity of the largest particle in the agglomerated product ($v_{mf}[d_1^{max}]$);

b) *upper boundary* – the terminal velocity of the smallest particle in the base material ($v_t[d_0^{min}]$).

The values of these velocities can be calculated using the equations (5.) to (10.). Material data needed for calculations are:

density of zeolite - $\rho_S = 1990$ kg/m^3; air density - ρ_G (25^{0}C) = 1.2 kg/m^3; air viscosity μ_G = 1.8 10^{-5} Pa s.

Lower Boundary

As stated, is the minimal fluidizing velocity of the largest particle in the bed. Since we can not predict the size distribution of the product, the demanded median particle size (d_{50}) will be used – 600 μm.

Using the equation (6.), we get a value for velocity of **2 m/s** and a Reynolds number (Re_p) 1.3 10^4 ($Re_p > 1000$). Since this is the median particle size, a somewhat higher velocity will have to be used to ensure, that even the largest particles of the agglomerated product remain fluidized till the end of the agglomeration process.

Upper Boundary

Represents the terminal velocity of the smallest particle in the bed at the start of agglomeration. If this value is below that of the upper boundary, a portion of the base material will be entrained in the air flow and carried out of the working chamber. The consequence is the need to construct a recycling system that will reload these particles in the bed.

Once again, it is more practical to calculate this boundary velocity using the median particle size of the base material. Since the operating velocity of the process will be somewhat lower than the boundary value, the level of entrainment is expected to remain small even for smaller particles.

As the base material for agglomeration, zeolite with three different median particle sizes can be used: 5 µm, 60 µm and 300 µm.

a) d_{50}^{0} = 5 µm: using the equation (9.) we get a value $v_t = 0.03$ m/s at $Re_p = 18$.
b) d_{50}^{0} = 60 µm: using the equation (10.) we get a value $v_t = 1.75$ m/s at $Re_p = 11500$.
c) d_{50}^{0} = 300 µm: using the equation (10.) we get a value $v_t = 3.90$ m/s at $Re_p = 1.3\ 10^5$.

A review of the calculated values shows, that the suitable base material for producing particles of 600 µm with the fluidized bed agglomeration is that with the median particle size of 300 µm. Agglomerating the 60 µm particles will include a noticeable degree of entrainment of the base material, while the material with the median size of 5 µm will be entirely entrained in the air flow and pneumatically transported out of the chamber – i.e. a practically 100 % recycle would be needed.

With thus selected base material with median particle size of 300 µm, the working range of air velocities is:

$$\mathbf{2\ m/s \le \mathit{v}_{\mathit{air}} \le 3.9\ m/s}$$

Inlet Air Temperature, the Rate of Binder Spraying

The equation (11.) represents the mass balance of water during the agglomeration process. Inlet air temperature affects the capacity of air for accepting moisture – drying the material. Higher inlet air temperature means a higher drying rate. That, however is not desirable, since it is of vital importance that the agglomerating particles remain wetted above their critical wetness throughout the agglomeration process. A higher inlet air temperature therefore means that binder will have to be sprayed at a faster rate, to maintain the agglomeration wetness of material, while it is doubtful that the residence time will be shortened in a significant measure.

To validate this suppositions, experiments will be conducted at two different air temperatures – 40°C (“low temperature agglomeration”) and 80°C (“high temperature agglomeration”) respectively.

During the agglomeration process the binder – a suspension of sodium water-glass – is sprayed on the bed by a way of a two-phase spray nozzle. The rate of spraying must be sufficiently high to ensure, that particles will remain wetted above their critical wetness throughout the process. On the other hand, too high a rate can cause the forming of a slurry, which cannot remain fluidized. The slurry accumulates on the bottom of the chamber thereby hindering the air flow. In short, the rate of binder spraying must be such, that a balance between wetting and drying processes is established at the agglomeration wetness of the material.

Experimental

Product Criteria

Are the demanded values of the product parameters – the relevant product characteristics (the actual goals of agglomeration). By comparing the resultant product parameters to these values, the suitability of the chosen values of the process parameters is evaluated.

The product criteria are:

- the median particle size of agglomerated product: $\boldsymbol{d_{50} \geq 600\ \mu m}$
- the wideness of the product particle size distribution: $d_{90}/d_{10} \leq \mathbf{5}$

If the agglomeration process is to be considered successful, the product characteristics must conform to these criteria!

Equipment

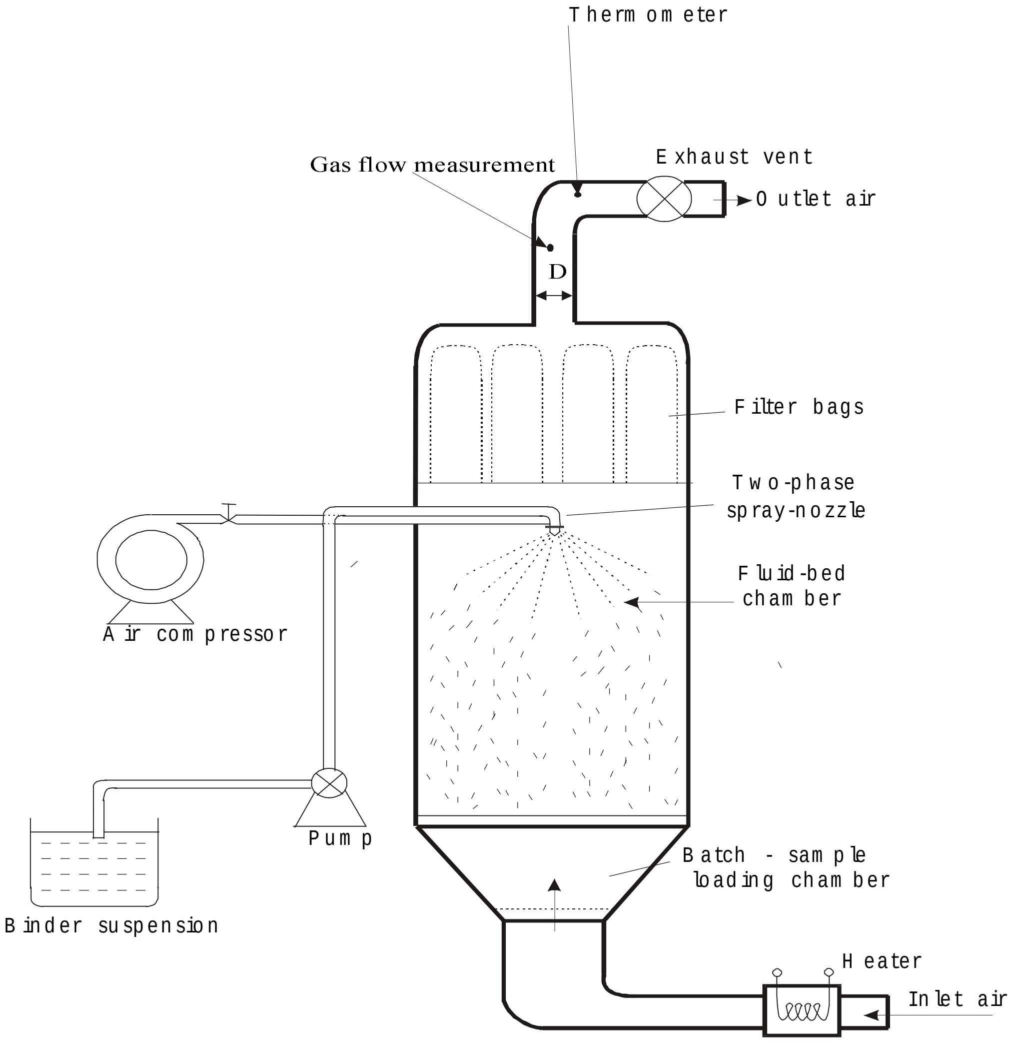

Figure 5.: The schematic presentation of the experimental set-up

Figure 5. shows schematically the experimental set-up used. Experiments were performed in a Glatt WSG5 semi-industrial batch fluidized bed dryer. The binder liquid is sprayed on the agglomerating particles by means of a two-phase spray nozzle, operating at the air pressure of 1.2 Bar.

Measurement Methods and Equipment

The product parameters were determined by the sieve analysis. Five different sieves were used in the particle size distribution measurements, namely 125 μm, 250 μm, 500 μm, 1000 μm and 1600 μm.

d_{50}, d_{10} and d_{90} were determined by plotting the cumulative mass percentages oversize (ΣR) against the size of the sieve.

Raw Material Data

Zeolite

Zeolites are the hydrated alumosilicates of elements from the I. and II. Group of the periodic system. When dehydrated, these materials keep their basic crystal structure. Water molecules are replaced by voids in the structure, which facilitates the use of zeolites as the molecular sieves. They are also used as ion exchangers, detergent additives, etc.

As a base material for the agglomeration, zeolite particles, previously agglomerated by the spray-drying method to a median particle size (d_{50}) of 300 μm were used.

Equilibrium Data

By measuring the equilibrium wetness of zeolite at different relative atmosphere moistures, the sorption isotherm was plotted. The maximum wetness of the zeolite was determined to be : $\mathbf{X_{max} = 0.33}$**.**

Kinetics of Drying, the Critical Wetness

To determine the equilibrium and the critical moisture contents of zeolite, a standard drying test was performed. The respective values are:

- the equilibrium wetness: $\mathbf{X_{Eq} = 0.03}$
- the critical wetness: $\mathbf{X_{Cr} = 0.35}$

Sodium Water Glass

Water glass is a silicate material with empirical formula: $M_2O\ SiO_2$, where M = Na, K or Li. The ratio between the silicate and the alkaline components is called the module of the water glass: $$M_{molar} = \frac{n_{SiO_2}}{n_{M_2O}}$$

(13.)

When the water glass is dried, a highly entangled, amorphous undercooled melt, similar to the glass – hence its name – is formed. Because the entanglement is carried out through the $[SiO_4]^{4-}$ tetrahedrons, the degree of entanglement increases with increasing silicate content – i.e. with increasing water glass module.

As the binder liquid, a sodium water glass, with the following properties was used: *module* - $M_{molar} = 2.5$; *density* - $\rho_B = 1.072$ kg/m^3; *dry matter content* - $\omega_S = 8.72$ %.

Experimental Program

Air Velocity

As previously determined, the “useful” range of air velocities is between 2 m/s and 3.9 m/s. In order to produce large particles, it is desirable, that the operating velocity is as close to the upper boundary as possible, so that the large particles can remain fluidized.

The experiments were performed at two different air velocities:

$v_{air}(1) = 3$ m/s and $v_{air}(2) = 3.5$ m/s.

Inlet Air Temperature

Affects the rate of moisture removal – i.e. drying of agglomerating material – by the fluidizing air. Too high a temperature can prevent the wetting of material above its critical wetness and so prevent the formation of the liquid bridges between the colliding particles and the deposition of the water glass on their surface. Too low a temperature, on the other hand, can cause the formation of slurry and therefore disrupt the ability of wetted particles to fluidize.

The experiments were performed at two different inlet air temperatures:

- $T_{air}(1) = 40$ °C - *low temperature agglomeration,*
- $T_{air}(2) = 80$ °C - *high temperature agglomeration.*

The Rate of Binder Spraying

Provides the balancing process to the drying of agglomerating material. Different rates of binder spraying therefore affect the agglomeration process in the opposite way than the inlet air temperature and the air velocity – the parameters affecting the drying.

However, choosing a suitable rate also depends on the characteristics of the two-phase spray nozzle. The binder liquid must be sprayed on the fluidized particles in form of a jet consisting of very small droplets. Furthermore, the jet must be wide enough, so that the entire fluidized bed is captured, or the particles are not wetted equally and a nonuniform product results.

The suitable spraying rate was determined experimentally, at the previously mentioned air pressure on the spray nozzle of 1.2 Bar. This rate – 110 ml/s was – used in all series of experiments.

The Residence Time

The experiments were performed in series. All the process parameters within a series – i.e. v_{air}, T_{air} and $\dot{V}_B$ had the same values, and the samples were agglomerated for progressively longer times. By comparing the product parameters of the samples to the criteria, the optimal residence time was chosen.

Results and Discussion

The Process Parameters

The experiments were performed in series. The series have different combinations of v_{air} and T_{air}, while the samples within a series have progressively longer residence times. All the experiments were performed with the same rate of binder spraying - $\dot{V}_B =$ 110 ml/min, and with a standard batch load of 1000 g (m_0).

The comparison of the product parameters of different samples to the criteria shows, that the optimal conditions for agglomeration were achieved under low temperature, high velocity conditions.

The process parameters for the fluidized bed agglomeration of zeolite are:

1. the fluidizing air velocity – v_{air} = 3.5 m/s;
2. inlet air temperature – T_{air} = 40 °C;
3. the rate of binder spraying – $\dot{V}_B$ = 110 ml/min
4. the residence time - τ = 6 min.

Table 1. shows the results of our experimental program.

Table 1.: The results of experiments for different sets of process parameters

Series	**Consecutive number Of the sample in the series**	**Residence Time - τ [min]**	d_{50} **[μm]**	d_{90}/d_{10}
High temperature Agglomeration: T_{air} = 80 °C v_{air} = 3.5 m/s $\dot{V}_B$ = 110 ml/min	1	2	340	4,2
	2	8	525	4,3
Low temperature Agglomeration : T_{air} = 40 °C V_{air} = 3 m/s $\dot{V}_B$ = 110 ml/min	1	2	431	4,7
	2	3	483	4,8
	3	4	558	5,4
	4	5	602	5,3
	5	6	683	6,5
	6	7	754	6,2
Low temperature Agglomeration : T_{air} = 40 °C v_{air} = 3,5 m/s $\dot{V}_B$ = 110 ml/min	1	2	436	5,3
	2	3	483	6,5
	3	4	532	4,6
	4	5	563	4,2
	5	**6**	**658**	**4,2**
	5 (2)	**6**	**669**	**4,1**
	6	7	727	5,2
Criteria	/	/	**≥ 600**	**≤ 5**

The agglomeration wetness – the wetness of material at which the agglomerating process was conducted – is calculated from the equation (11.):

$$m_0^{d.m.} \cdot X_{Agg} = m_{bin}(1-\omega_s) - G \cdot \tau \cdot (Y_1 - Y_0)$$

$$X_{Agg} = \frac{\dot{V}_B \cdot \rho_B \cdot \tau \cdot (1-\omega_S) - v_{air} \cdot S \cdot \rho_{air} \cdot \tau \cdot (Y_1 - Y_0)}{m_0 \cdot (1-x_0)} \tag{14.}$$

The data for the calculation:

$\dot{V}_B = 110$ ml/min	$\rho_B = 1072$ kg/m^3	$\omega_S = 8.7$ %
$v_{air} = 3.5$ m/s	$\rho_{air}(40$ °C$) = 1.09$ kg/m^3	$S = 0.1$ m^2
Y_0 (T_0= 40 °C) = 0.005	Y_1 (T_1= 36 °C) = 0.007	$x_0 = 0.07$
$m_0 = 1000$ g	$\tau = 6$ min	

The agglomeration wetness is $X_{Agg} = 0.38$.

Conclusions

A successful implementation of an agglomeration process in the fluidized bed requires a combination of knowledges concerning all the operations involved – agglomeration, fluidization and drying.

Furthermore, the determination and optimization of the process parameters requires an experimental program performed on pilot scale plants before approaching the planning of an industrial scale continuous process.

A careful manipulation of the process parameters allows for a relatively easy transition from a batch operation to the continuous one.

The model of the agglomeration process that was used for the determination and optimization of the process parameters on the particular case of zeolite agglomeration, can also be used for other materials and binding mechanisms that require the wetting of the agglomerating particles.

Symbols and Abbreviations

Symbols

v_{mf}	minimal fluidizing velocity of particles	[m/s]
v_t	terminal velocity of particles	[m/s]
Φ_s	sphericity of particles	[/]
ε_{mf}	bed voidage at minimum fluidization	[/]
ρ	density of material	[kg/m^3]
μ	viscosity of material	[Pa s]
d_p	particle diameter	[m]
Re_p	Reynolds number of particles	[/]
C_d	drag coefficient	[/]
X_{cr}	critical moisture content	[g/g$_{\text{dry matter}}$]
X_{Agg}	agglomeration wetness of particles	[g/g$_{\text{dry matter}}$]
X_{Eq}	equilibrium moisture content	[g/g$_{\text{dry matter}}$]
X_{max}	maximum moisture content	[g/g$_{\text{dry matter}}$]
$-{}^{dX}\!/_{dt}$	drying rate of material	[s^{-1}]
Y	air wetness	[/]
G	air mass flow rate	[kg/s]
τ	residence time	[s]
S	cross-sectional area	[m^2]
ω	mass share of a component	[%]
d_{50}	median particle size	[m]
d_{90}	particle size at 90 % oversize	[m]
d_{10}	particle size at 10 % oversize	[m]
M_{molar}	molar module of the water glass	[/]
T	temperature	[K, °C]
$\dot{V}$	volume flow rate	[m^3/s]
ΔP	pressure drop	[Pa]

Subscripts

in … inlet; out … outlet; 1 … starting; 0 … ending; G … gas; S … solid;
B … binder.

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Povzetek

Zeoliti so kristalinični materiali, ki se največ uporabljajo kot molekularna sita in ionski izmenjevalci. Produkt proizvodnega procesa so delci zeolita s povprečno velikostjo okoli 5μm. Te delce se nato zmeša z vezivom in aglomerira med sušenjem v razpršilnih sušilnikih do zgornje meje velikosti nekako 300μm, odvisno predvsem od geometrije in vrtilne hitrosti atomizerja. Nekateri načini uporabe pa zahtevajo večje delce, ki jih z razpršilnimi sušilniki ni mogoče pridobivati.

Pomembna tehnika za pridobivanje velikih aglomeratov je aglomeracija v fluidiziranem sloju. Intenzivno mešanje delcev v fluidiziranem sloju omogoča visoke hitrosti prenosa toplote in snovi in s tem skoraj izotermne pogoje v celotnem sloju. Zaradi pomanjkljivosti pri poznavanju mehanizmov nastanka in rasti delcev je načrtovanje in izvajanje the procesov težavno in potrebni so eksperimenti na pilotnih sistemih za določitev ustreznih procesnih parametrov.

V pričujočem delu je predstavljeno določanje procesnih parametrov za pridobivanje aglomeriranega zeolita zahtevanih lastnosti na polindustrijskem šaržnem sušilniku s fluidiziranim slojem. Teoretična (in včasih empirična) znanja o posameznih operacijah procesa – aglomeracija, fluidizacija, sušenje – smo uporabili za razvoj modela procesa, ki je omogočil identifikacijo relevantnih procesnih parametrov – tistih, ki nadzorujejo potek procesa in tistih, ki vplivajo na lastnosti produkta – ter napoved njihovih vrednosti. Zahtevane lastnosti aglomeriranega produkta pri tem služijo kot merilo ustreznosti izbranih vrednosti procesnih parametrov in njihovo optimizacijo.

Rezultati eksperimentalnega dela so potrdili ustreznost postavljenega modela in možnost uporabe aglomeracije v fluidiziranem sloju za proizvodnjo velikih delcev zeolita.