

Agglomeration in detection

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Unwanted particle agglomeration in fluidized beds is a major problem in industrial practice. A monitoring method for the early detection of agglomeration has been developed at Delft University of Technology. This method was successfully applied in fluidized bed combustion and gasification to timely detect agglomeration and subsequently take counteractions to avoid defluidization of the bed.

Gas-solid fluidized beds are used in processes such as catalytic reactions, drying, coating and energy conversion. In energy conversion processes, typically combustion or gasification, agglomeration often happens when alkali components from the fuel react with silica from the bed material and/or fuel. Together they can form alkali silicates which melt below the typical operating temperatures of about 850 °C. The presence of such a liquid phase results in increased particle stickiness and formation of agglomerates (Figure 1). If this effect is not counteracted it can eventually result in defluidiza-

tion of the bed and a subsequent costly shut-down of the installation. Average pressure drop measurements are generally not suited for the detection of this phenomenon since they indicate this problem too late. Therefore, an *early* warning tool to reliably detect agglomeration and to enable timely counteraction is of added value for process operation.

Monitoring Method and Measurements

Pressure fluctuation measurements taken in the dense bed are the basis for the analysis method. Traditional pressure measurements in a fluid bed ignore rapid fluctuations by averaging them out. In the new method, however, these fluctuations are the subject of the analysis. The pressure is measured a few hundred times each second to ensure sufficient time resolution of the fluctuations. The attractor comparison method [1], previously developed at Delft University of Technology, has been applied to detect changes in the pressure signal. It is based on a relative comparison of the state-space projections of pressure fluctuation measurements, so-called attractors. The method compares a reference attractor

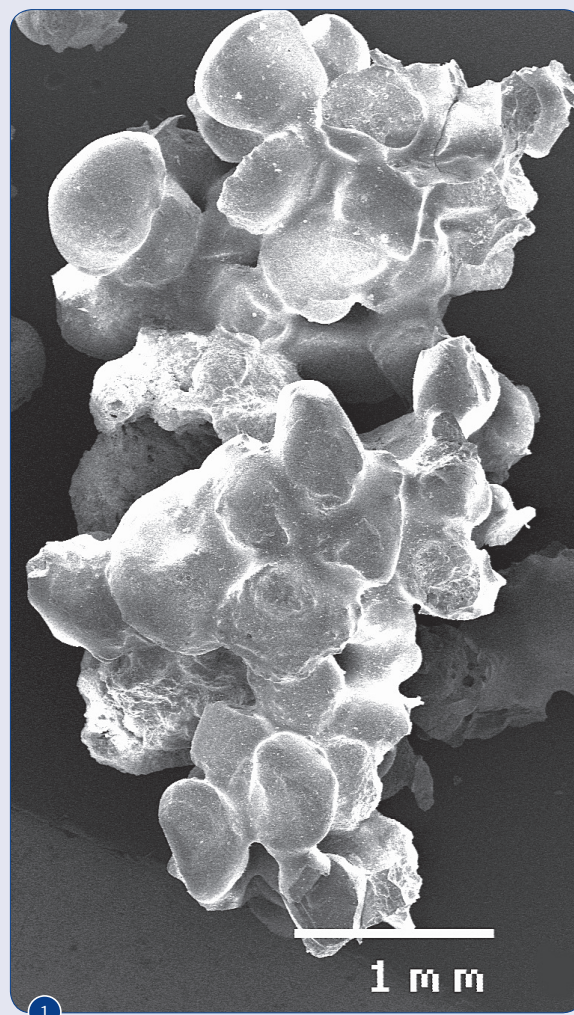


Fig. 1 Agglomerate of sand grains covered with alkali-silicate layer: particle coverage and neck formation is clearly visible (courtesy Energy Technology Group (3mE), Delft University of Technology)

from an earlier well-fluidized situation with the attractor from the current situation by means of the dimensionless distance S between both. S has an expectation

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of 0 for the same hydrodynamics, while an S-value of 3 and higher indicates changes in the hydrodynamics with a 95 % confidence level. Attractor comparison therefore indicates *statistically significant* changes in the hydrodynamics. For details of the method, see [1]. Besides fluidized beds, the method also has potential for application in other multiphase systems.

Detecting Agglomeration

Attractor comparison has been applied on small-scale circulating fluidized beds, both in cold-flow and during combustion/gasification conditions. The method is sensitive to even small changes in the particle size, as has been shown in cold-flow tests. During gasification of straw, agglomeration with subsequent defluidization has been observed. The monitoring method has shown to correctly indicate the onset of defluidization with an early warning time of about 30 minutes. In contrast, pressure drop does not indicate any significant change until actual defluidization (Figure 2).

Attractor comparison has also been used to initiate counteractions to demonstrate the suitability of the method for avoiding defluidization. Agglomeration tests have been carried out in a 1 MW_{th} bubbling fluidized bed boiler during combustion of biomass. With the method it was possible to prevent defluidization of the bed using a temporary temperature decrease controlled by the fuel feed ("emergency measure") or by replacement of bed material.

Counteracting Agglomeration

Typical agglomeration counteraction measures can be divided into operational strategies and the use of additives and alternative bed materials. For a recent review, see [2]. Operational strategies can involve drastic measures to avoid shutdowns in urgent cases, such as temperature decrease by stopping or reducing the fuel feed. More gradual methods that are already industrial practice apply increased bed recycle via a sieving installation or by changing the ratio between two fuels. Additives can avoid formation of a sticky layer of liquid-phase alkali silicates by formation of other compounds with higher melting points. For alternative bed materials the crucial idea is to avoid molten silicates by avoiding silica itself. Both additives and alternative bed materials have been shown to successfully postpone or even avoid agglomeration. The most suitable additives and bed materials contain Ca, Al, Mg, Fe or mixtures thereof.

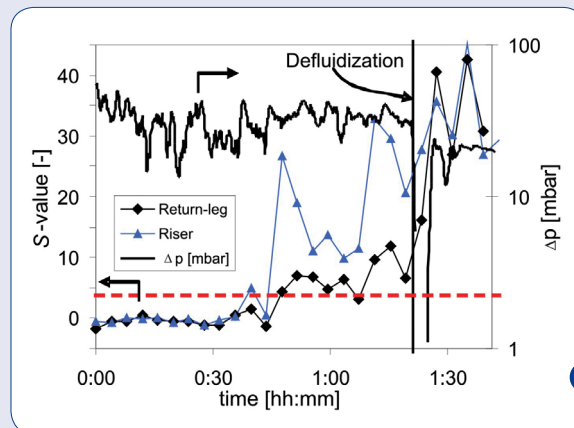


Fig. 2 Successful agglomeration detection: Defluidization is not anticipated using average pressure drop measurements, but correctly indicated by the S-value exceeding the critical value of 3. The early warning time is about 30 minutes, based on measurements from the lower riser (dense bed) and horizontal return-leg (moving bed)

Industrial Application

Several requirements and recommendations are made based on tests in lab-scale and industrial environments. The pressure probes need to be capable of resolving the pressure fluctuations with sampling frequencies of a few hundred Hz. Existing pressure (drop) sensors are normally not suitable for this purpose. Continuous or regular pulsed purging of the sensor is required to prevent clogging of the probe. The effective monitored volume of each pressure probe mounted at a reactor wall is limited to about 0.5-1 m into the dense bed. Since agglomeration can develop somewhat localized in the bed, e.g. in a corner, several measurement probes are needed when going to larger fluidized beds. This has already been tested on industrial scale with six probes.

Conclusion & Outlook

Unwanted agglomeration is a major problem in industrial fluidized bed processes. Making use of pressure fluctuation measurements, the attractor comparison method has been developed and applied for the early detection of agglomeration. The method has shown to successfully indicate agglomeration in an early stage of the process in bubbling and circulating fluidized beds. The application in circulating fluidized beds is especially important in view of the wide-spread application of circulating beds in the energy sector. As a result, this technology can have added operational value for energy producers and therefore play a prominent role in the process of further promoting the acceptance of biomass as a renewable energy source. ●

For references see www.npt.nl at Inhoudsopgaven.