Labasys® 100 Flex
Monitoring stagnating Bulk Flow

Fig. 2: Labasys® 100 Flex instrument for velocity measurement of bulk solids with 6 m flexible tip.

Alstom is a specialist for energy production as well as for innovative technologies for the protection of the environment. Power transmission and distribution, turbines and generators for nuclear plants, smart grids and much more belong to their activities. Among others the environmental-friendly combustion of coal has always been in their focus. With the urgency to minimize CO_2 exhausts Alstom began to develop CO_2 capture processes, which they integrated lately in a small-scale pilot plant at their Windsor site. Among others Alstom evaluates chemical looping processes, which are a cost effective way to capture CO_2 from new and existing coal fired plants. The main benefit is that the only emissions are water and CO_2, which can be separated and conserved. Another benefit is that NO_x is not exhausted.

Fig. 1: Schematic of the Alstom's Calcium based Chemical Looping Process.

From three possible ways using chemical looping path to convert fuel to energy Alstom pursues the chemical looping combustion in the current experimental tests. Fig. 1 shows a scheme of this limestone-based process. Besides the carbonate and calciner thermal loop the main loop is the oxygen transport loop. Simplified it consists of an air reactor (oxidizer) and a fuel reactor (reducer).

Essential for the exchange of oxygen between the reactors is an oxygen carrier. Developing the process Alstom utilizes calcium. In the air reactor the solid oxygen carrier is oxidized by the O_2 content in the air.
End products of this oxidation are N_2 and O_2. The O_2 is transported by the solid oxygen carrier $CaSO_4$, to the reducer where it is finally converted to CO_2 and H_2O. The CO_2-water mixture is separated by condensing the water so that a steam of almost pure CO_2 is obtained.

Measuring Task

Overview
- Task: **Real-time velocity data of stagnant bulk flow for chemical looping**
- Target Size: **Velocity of stagnant bulk flow**
- Motivation: **reliable and cost effective measuring solution**
- Solids Conc.: **Packed bed of $CaSO_4$?**
- Temperature: **up to 100 °C ?**
- Particle Size: **10 - 100 μm ?**

Three loops, in which large amounts of solids need to be circulated, are used to realize the process (Fig. 1). In order to maintain the solids flow in such a circulation loop, pressure differences between the riser and the downer are necessary. A key component to overcome those pressure differences are seal pots, which are developed and optimized through extensive tests.

Realisation

Key Success Factors
- Powerful algorithms of 'Flow Det' Module
- Existing basis of modular Labasys® 100 and LabaSoft technology
- New solution developed, tested and implemented successfully in short time

With the objective to demonstrate the operation a lab scaled test unit was built. This cold flow model was used for scale-up purposes, solids flow control and solids pressure drop tests. Therefore precise insights in the complex solids loops were fundamental.

Fig. 3: Labasys® 100 Flex instrument at a pilot plant (right) and tip of the instrument (left).

A continuous solids flow was not attained despite all works, but a stable flow regime could be achieved with a *stagnating solids flow*. In order to monitor and control the solids flow rate in the oxygen loop, the solids velocity in the downer should be measured. At this position the stagnating nature of the bulk solids flow in the downer made the measuring task very difficult. Periods of 2-3 seconds with solids flow alternate with periods of halt for the same time.

While the Labasys® 100 instrument itself could be used without modifications, a new module «FlowDet» for the Software LabaSoft had to be developed to differentiate moving and non-moving flow regimes.

State of the art is the correlative velocity determination, in which the time of flight between the two sensor tips is calculated and thus with the known gap between the two sensor heads the velocity is derived. Since the time of flight would be infinite, non-moving flows could not be determined with this method.

Products and Services used

- **Labasys® 100 Flex instrument** with a 6 m flexible probe tip
- **Labasoft** – with 'Flow-Det' module Windows™ based (98/NT/2000/XP) data acquisition and analysis Software for analysis and reporting
- **Services:** instrument rental, commissioning, customer training, maintenance and analysis services; software engineering services (flow detection module)

«The Labasys® 100 Flex system with the in short time developed 'FlowDet' module was an essential step for the successful operation of our chemical looping unit. The good cooperation with MSE Meili together with the high-standing technology was a very convincing package.»

Dr. Herbert Andrus, Project Leader, Alstom Power, USA

A new, advanced algorithm was evaluated and developed that could reliably distinguish whether the flow is moving or not. If the state «non-moving» was detected the velocity values were set to '0', in the state 'moving' the ordinary correlative velocity determination was carried out.

The challenge was to keep up with the high dynamics of the flow that is irregular, stagnates and halts for a few seconds. The real time measurement requires fine tuning and numerically optimized algorithms.

Labasys® 100 Flex measures a challenging key quantity, namely the in-situ measurement of the solid flow recirculation rate in the oxygen transport chemical loop. This quantity is calculated as product of measured solids velocity, the cross sectional area and the assumed time «constant» bulk density.

In the tests a standard Labasys® 100 with 6 m flexible tip was used as measuring instrument. The body of the instrument is placed on a table, while the tip can easily be moved to the desired measuring position. The flexible stainless steel wrapped metal tube with silicon caoutchouc casing warrants that the minimum bending radius is kept.

As shown in Fig. 3 Labasys® 100 Flex was positioned outside the Plexiglas tube and measured through it. As the sensor head can hold temperatures up to 300 degrees Celsius without cooling, hot process measurements, for instance through a quartz window are feasible. This elegant setup is handy since the probe tip can be positioned freely anywhere desired.
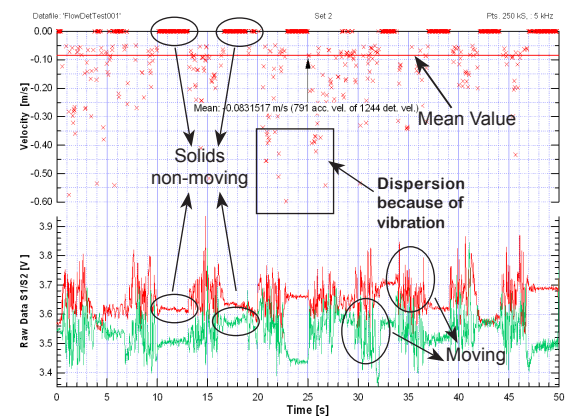

Fig. 4: Exemplary chemical looping data: Both graphs show the stagnating flow of the running process

Typical results of the measurement are shown in Fig. 4: The data shows a 50 second cycle duration with 9 alternating flow and non-flow periods.

The lower graph shows the raw signals of channel 1 and channel 2 both with the same characteristics. In the upper graph the velocity is shown. As there are vibrations in the tube when the particles fall down and stop, the dispersion of values is high. Thanks to the high number of velocity data, robust mean values can be derived using proper statistics. The FlowDet algorithms are efficient enough to keep up with this fast changes of the solids flow.

The periods of halt and movement can be reliably monitored. So the Labasys instrument allows for intelligent control of the internals of the chemical looping process.