Pulverised Fuel Measurement with Split Control

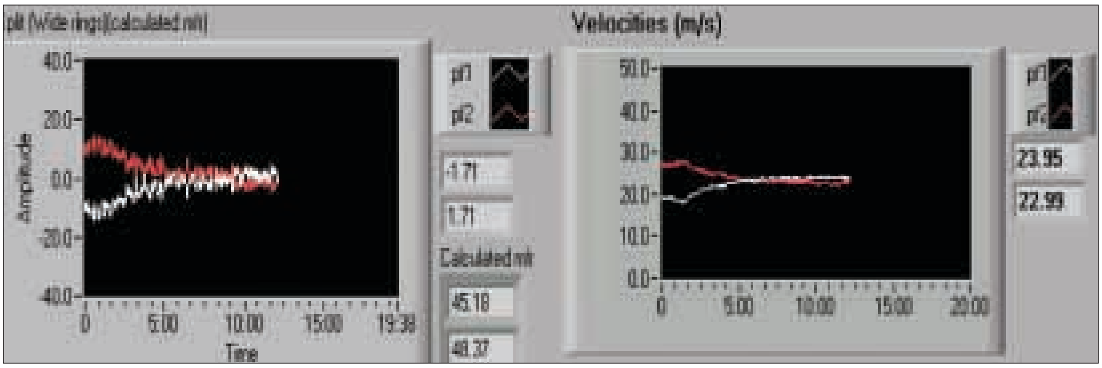

Figure 1. Computer display showing variation in Pulverised Fuel Distribution between two pipes after closing a control loop. Initial Conditions +/- 10% Split. Final Conditions +/- 0% Split. Horizontal time scale is in seconds

OBJECTIVES

- To investigate the performance of pulverised fuel meters to measure the relative mass flow rate in two parallel pneumatic conveyors.
- To demonstrate, on a small-scale, control of the distribution (split) of pulverised coal between two parallel pneumatic conveyors, fed from a source via a bifurcator, using pulverised fuel meters to measure the mass flow rate The meters providing signals used to actuate a flow control device.

SUMMARY

To improve the combustion efficiency of pulverised fuel (p.f.)-fired furnaces in electrical power generation, it is desirable to measure, optimise and then, ideally, control the p.f. flow velocity and the solids distribution (split) between pneumatic conveyors leading to burners in the furnace.

On leaving the pulverising mill, the solids-air mixture is split into several different pipes each feeding an individual burner. One mill can feed as many as eight burners. Usually the fuel and air are metered before the mill where the ratio can be accurately set. Differences in routing of the lines injecting p.f. into the furnaces, and phase maldistribution at the splitting points, results in an uneven feed to the burners. Consequently, the combustion stoichiometry at the burners is disturbed. This leads to increased fuel costs, higher levels of carbon in the ash and excessive specific emissions in the flue gas. If the mass flow rate of the fuel can be measured, and the flow splitter controlled, then, in principle, the air-fuel ratio can be accurately set and the combustion stoichiometry optimised.

There are several possible ways in which the split can be varied. One proposal has been to use an active riffle box, another is the use of compressed air to deflect the solids at the pipe junctions. The ideal is to have a perfectly dispersed solids phase in the approach to the flow splitter. In small diameter pipes, the simplest method, used in these experiments, is to restrict one or both pipes using a variable orifice or valve so that the back pressure deflects the solids from one pipe to the other. This method will also affect the velocity and total mass flow rate but these can now be measured on-line using instruments developed by ABB Ltd. Automatic control was demonstrated, balancing pf mass flowrates and velocities from initial open loop conditions, where significant maldistributions were present.

COST

The total cost of the project was £131 673, with the Department of Trade and Industry contributing £65 155. ABB Ltd provided the balance of the project funding.

DURATION

24 months from Jan 1999 to Jan 2002

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Project Summary 330

JULY 2002

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TEST SECTION

The full report describes experiments carried out at the laboratories of EMC Environment Engineering Ltd. at Cheltenham. The aim was to measure and control the fuel distribution or split between two parallel 40mm diameter pneumatic conveyors. These were supplied with pulverised coal from the output of a bifurcating valve whose input was supplied from a hopper via a 63mm diameter pneumatic conveyor. Feedback signals were obtained by metering the mass flow through each 40mm conveyor. The arrangement is shown in Figure 2. The instrument mass flow rate readings were confirmed by data logging signals from the meters and comparing these data with those derived from load cells fitted to the receiving hoppers.

The solids split could be preset using a modified solids diverter valve and the split could then be varied by a controlled butterfly valve in one of the conveyors. The valves were used to demonstrate a principle rather than suggesting a practical method for controlling the fuel split.

An actuator controlled by the PC drove the flow splitting valve. The actual valve position, which could be logged, was displayed on the computer screen and was used to preset the split to any desired value.

Figure 2. Flow Test Section

Partially constricting one conveyor with a controlled butterfly valve resulted in a variation in line back-pressure that had the effect of diverting solids along the adjacent pipe, thereby affecting the split. An actuator controlled by the 'ABB Commander 355 Advanced Process Controller, drove the butterfly valve. The actual position of the valve was displayed on the screen and could be logged to a file if necessary.

Pinch valves were considered as viable industrial alternatives to the butterfly valve used in the project to demonstrate the principle.

ABB PF METER

Two 40mm diameter P.F. meters known as PfMaster as shown in Figure 3, were fitted, one in each branch to give a direct measure of the solids mass flow rate, the meter mass flow rate outputs were used to calculate the actual split.

Figure 3. Photograph of DN40 PfMaster Sensor

The flow sensor comprises a non-restrictive, robust electrode arrangement, which detects electrical charges present on moving solids particles. The phenomenon is well known and documented in the literature dealing with pneumatic conveying. The primary sources of electrification are due to the following effects;

1 frictional contact charging,

2 charge transfer from one particle to another,

3 charging of a conductor by inducement due to the presence of a nearby charge.

Electrical charges on the electrodes can be considered to originate from two effects;

1 Charging due to the particles impacting with the electrodes in the sensor,

2 Charging due to inducement, when charged particles pass within the vicinity of the electrodes requiring no physical contact between the particle and the electrodes.

During the passage of charged particles, variations in level of the charge signal on the sensor can be used as an indication of the solids concentration. It is obvious that this is not an absolute measure of solids concentration since the charge level is dependent on many properties. However, it was confirmed at EMC that, over the range solids:air 0:1 : 1:1 mass of solids : mass of air, the meter's output signals were directly proportional to the solids mass flow rate.

The sensor contains concentration electrodes and two velocity electrodes. An absolute measure of solids velocity is achieved using two narrow ring-shaped electrodes placed a known distance apart. These electrodes induce signals proportional to the instantaneous quantity of solids passing through the sensor which are cross correlated to measure the solids transit time between the two rings.

The accuracy to which the sensor can measure the velocity of a moving surface is at least 1% over the entire velocity range.

The mass flow rate of the solids is measured using a novel electrode arrangement combined with specialised signal processing techniques. The PC based digital signal processor contains a multiple cross-correlation facility capable of measuring the solids velocity in real time from many pairs of sensors. The computer display can be in the form of bar charts to show the instantaneous solids velocities in any or all pipes and the solids split (solids distribution) between the pipes is indicated by bar-charts. Alternatively, the display can be in the form of scrolling charts showing the flow history over the last 60 minutes or other user-selected period. The air mass flow rate, the solids mass flow rate and the solids split in each of the two parallel sections can be continuously displayed. The gas temperature within the pipe was also given as standard from temperature sensors fitted into the pipe walls.

CONTROL SYSTEM

The controller used was the ABB Commander 355 [12] 'Advanced Process Controller' which offers a wide choice of control strategies. The split was the control target. The 'target split' value was the local set point on the controller, which is equal to the control set point. Here the process variable was the split based on 'calculated solids mass flow rate' determined in the PC. The data was then sent to the output channel via a specially designed module. The split variable was converted to a 4-20mA signal and fed to the controller. In the controller, the process variable was compared to the control set point and the deviation was used as the input to the controller. The output controlled the actuator that drove the butterfly valve to maintain the split at the set level. Figure 4 shows the general arrangement.

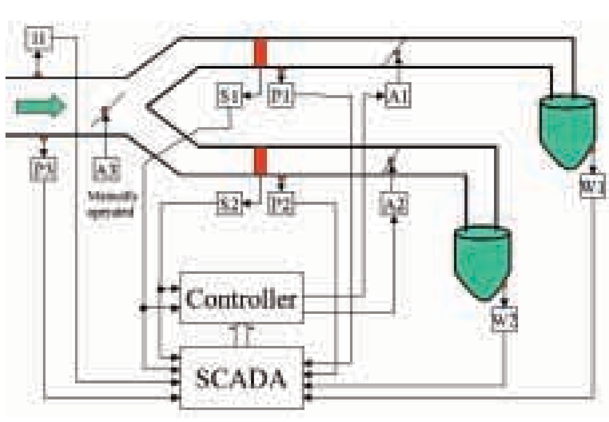

Figure 4. Control Loop Diagram

The split could be set remotely as it would be on a large plant or if used as part of another control system.

In the complete report there are a number of examples showing the mass flow rate in each pneumatic conveyor after closing the control loop. Figure 1 is the computer display showing the split adjusted to be equal from initial conditions of ±10%. The changes observed of the solids velocity in each conveyor are also shown. Signal 'spikes' were a characteristic of the flow rig since, under certain conditions, irregular flows caused a sudden rapid increase in loading as a 'lump' of solids entered the flow stream. The system response was very fast maintaining control of the split.

The full range of the test rig was used at velocities from 15 to 30m/s. Control was possible over the full range of solids loading and the velocities could also be maintained to ensure balanced conveying conditions.

CONCLUSIONS

This experimental project has confirmed that the use of mass pf flowmeters combined with mechanical actuators can be used to control the solids split between two conveyors fed from a bifurcator. It is appreciated that this project was restricted to using 40mm diameter pipes and conditions in 375mm diameter pneumatic conveyors found on large boilers can be expected to be more challenging. However, as a first attempt, the exercise can be judged to have been very successful. Refinements to the flow test rig are planned so that the operation is aligned with industry practice.

FUTURE WORK

The whole subject of controlling the solids split now requires in-depth theoretical and experimental investigation using the new technology to confirm the theory. The next phase is to implement the principle on to plant of various scales from 25mm diameter upwards. New areas of complexity are likely to emerge since any non-uniform distribution of solids in the approach to the split is likely to present many challenging problems to be overcome, particularly at the larger pipe diameters and where trifurcation is used. The solids velocity must also be monitored as a critical combustion and conveying parameter. In particular, it must not be permitted to fall below certain limits to ensure efficient conveying. There are many possibilities since split control can detect the presence of solids roping and could then actuate mechanisms to disperse the flow.

At EMC Environment Engineering Ltd, the plan is to replace the butterfly with two controlled pinch valves one in each conveyor. These comprise a valve body lined with a flexible cylindrical sleeve. By applying pressure to the sleeve deformation occurs closing the valve.

Locating the p.f. meters downstream of the constricting controllers requires investigation. In general, a detailed and more comprehensive study of the subject is now required but the tools are now available. The interacting effects of pressure, non-uniform solids distribution and the larger pipe diameters require further study. Whilst riffle boxes are intended to minimise the effects of non uniform solids distribution, the possibility of some control on the riffle box itself could be an attractive alternative to using constricting valves.

Whilst this project was limited to two pipes, it demonstrates an important advance in measurement and control, opening up a host of new research into different control strategies as the number of splits increase from two pipes, to three, etc. up to eight. The project has also laid the foundations for more detailed research on larger-scale plant to investigate the subjects touched upon in the full report.

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