B66: Direct On-Line Measurement of Wall Friction of Coal as an Indicator of Handleability

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Objective

- To develop an on-line measuring instrument to give a continuous readout of wall friction of coal, to assess its ‘handleability’
- To Prove or disprove whether there is a:
  - consistent link between changes in wall failure and internal failure properties based on moisture content,
  - correlation between on-line and off-line wall friction measurements.
Why?

Variation in Flow properties
  - Blockages in bunkers & chutes
    - Unscheduled downtime
      - Process stoppages

Off-line measurement
  - Time
  - Money
  - Training
Wall friction tester - Setup

Jenike type wall friction tester

Driving unit  Sliding unit

Load Cell
Shear Pin
Shear cell
'Skid' Plate
Parallel support blocks

'Skid' plate (SS 304 2b) finish
On-line test rig

- Continuous & rapid status monitoring
- No sampling
- No manual operation
- Simple and rugged sensors
- Cost effective

Schematic of linkage & skid plate assembly
Test conducted

On-line Trials

Crushed Glass

Coal EC2101 (RuM3)

Load
0.42 kg, 2.7 kg, 4.7 kg

Speed
0.01 m/sec, 0.1 m/sec, 1 m/sec

Jenike wall friction

Crushed Glass

Clean Plate
Unclean Plate

Coal EC2101

Clean Plate
Unclean Plate

From each batch
Angle of wall friction as a function of shear displacement on crushed glass

![Graph showing the angle of wall friction as a function of shear displacement on crushed glass. The graph has a series of curves for different speeds, with each curve indicating the friction angle in degrees as a function of distance in meters. The speeds represented are 0.1 m/sec, 1 m/sec, and 0.01 m/sec. The graph shows that higher speeds result in a higher friction angle.](image-url)
Crushed glass

- Starting with a clean plate the trend measured on crushed glass can be broken down into 3 stages
  - An initial lead-in region, where the measured angle of wall friction was approximately constant (0 – 50m)
  - A transient condition, where the measured wall friction increases, at a rate dependent on speed
  - A final steady state wall friction value, obtained after relatively large shear displacement (~150m)
Unlike crushed glass, the initial lower stable value for coal is not well defined.

Gradual increase towards a higher steady state value at all speed.

Influence of velocity is negligible unlike with crushed glass.

More consistent result compared to crushed glass.
Comparison between failure loci obtained from on-line & Jenike ("clean" & "unclean" Plate) for crushed glass
Comparison between failure loci obtained from on-line & Jenike ("Clean" & "Unclean" Plate) for coal (RuM3)

- **Initial values**
  - "clean":
    - 0.01 m/sec (initial values)
    - unclean - 2.4% moisture

- **Final values**
  - "unclean":
    - 0.01 m/sec (initial values)
  - "clean":
    - clean test3 st - 2.8% moisture

Graph showing the relationship between shear force and normal force for different moisture levels and test conditions.
For both the crushed glass and the coal samples...

- The Jenike wall friction loci obtained from the “clean” plate tests were similar & comparable to the loci obtained from the initial stable values measured on the on-line wall friction tester.

- The Jenike wall friction loci obtained from the “unclean” plate tests showed significantly higher shear force (than the clean plates) but lower values than the final stable value measured on the on-line wall friction tester.
Plausible causes

- Effect of particle size and distribution in the on-line wall friction tester
- In on-line tester ‘Skid’ plate is sheared over a large shear displacement
- Dynamic effect on the on-line wall friction tester with respect to speed and load unlike Jenike type wall friction tester

By comparison in the Jenike wall friction test the powder sample used is very small and may not be representative sample
Results suggest that as the maximum particle size reduces the wall friction increases.
Interim Conclusions

- There is a significant difference in the angle of wall friction of a “clean” and “unclean “ surface
- Surface wear on the “skid” plate does not have a significant effect on the wall friction measurement
- The rate at which the wall friction increases is bulk solid dependent, the glass showing a gradual transition whereas the coal increases rapidly
- From the tests carried out both the Jenike and the online tester shows the same trend, though there are some variation seen quantitatively
Proposed work

- Jenike wall friction tester
  - Test varying the moisture content on coal

- Test on Annular shear cell varying the moisture content

- Existing Online Tester
  - Add moisture to coal to find if it can sense the difference
  - Test by introducing Pre-consolidation plate

- Development of a separate pilot scale rig with trough shape belt

- Other option considered for comparison
  - Hopper flowability tester
Schematic of on-line test unit

- Roller for horizontal movement
- Winch for up & down movement
- Enclosure
- Linkage
- Material flow
- Load cell set-up
- ‘Skid’ Plate
- Plate
- Frame
- Conveyor belt
Thanks ....Any Questions??