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IN THIS ISSUE

PARTICULATE SOLIDS FLOW

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Professor Maurice Beck of UMIST England, once said, with typical English reserve, "Measuring the flow of particulate solids is notoriously difficult". He wasn't saying half of it; it's HELLISH DIFFICULT.

The flow of particles in a pipe or duct will change its flow regime for very many reasons, and all of the variables are interactive. The conveying system is in continuous flux; and a major contributor to this is the system used to introduce the media into the air flow on most 'conventional' shot peening machines. A full-throat metering system, such as that employed in the MagnaValve, can eliminate the feed variations due to air pressure changes.

FLOW REGIME

Once the media gets into the air stream its flow regime will change as the duct or pipe bends and varies its aspect. Imagine a rigid pipe configured to follow the contours of a cube in the sense of passing over it. To further complicate the system, imagine the first and last bends, which are at ground level, are slow gentle bends and the middle two are standard elbows. As the air/media flow approaches the first bend let us assume that the media is relatively evenly distributed in the air flow, although the flow will concentrate toward the bottom of the pipe, and the media velocity is less than that of the air by the slip factor. When the flow passes through the first bend the inertia of the media causes it to hug the outer curve and changes the flow regime from well disbursed to a concentrated stream against one wall of the pipe. In the vertical upward section this stream is less evenly affected by the conveying air flow and the flow regime can be a bubbling flow with some particles in reverse flow, until they are re-entrained. As the vertical length increases, the flow regime changes to a much more evenly distributed media concentration with a much lower relative velocity because of gravitational effects. When the pipe passes over the top of the cube the flow regime changes to a heavily concentrated bottom flowing stream because of the much less media entry velocity. The impact of the media at the elbow further reduces its velocity. If the media concentration is high this could lead to 'dune' flow, where the media piles up in the bottom of the pipe until it restricts the air passage, which then produces an increase in air velocity to above the critical entrainment velocity. The velocity then decays as more media is entrained until saturation is reached and some media precipitates thus starting the cycle again. This produces the rolling dune form. As the pipe passes over the top and starts down the other side gravity provides a helping hand, and the media velocity at the bottom of the line can be greater than the air velocity. The media entry at the last bend will again be a concentrated stream against the outer curve and this concentration against the bottom of the pipe will continue for some distance.

It is evident that the distribution of media, that is the flow regime of the media, changes throughout the system. Also the concentration of the media varies from bottom flowing dense phase, through evenly distributed to turbulent and reverse flow, and therein lies the problem.

MEDIA FLOW MEASUREMENT

To measure the mass flow rate one has to accurately determine the phase density of media flow and relate that to the chemistry of the media, then determine the particle velocity. The flow rate is then computed from mass x velocity.

The method used to determine the concentration of media within the sensing field is very dependent upon the material being monitored and the natural attribute being used. The most reliable is the inductive type of sensor used with steel shot and grit. The ferrous content of such media can be accurately monitored over a wide range of flow regimes. The more difficult materials are the non-ferrous, i.e., glass beads, aluminium oxide, ceramic beads, and plastic media. The flow regime has a distinct affect on the signal generated by the media. The most suitable location for the sensor is near the top of a vertical lift. At this position the flow regime is relatively stable and the media is evenly disbursed in the air flow. This is important because changes in a concentrated flow are much more difficult to detect.

PHASE DENSITY

The concentration or phase density determines the type of instrument used to detect the flow. There is no 'one-method' of quantifying the phase density. If one takes an infinitesimally thin cross-section slice through the flow, and determines the percentage area occupied by the media and air, this is the 'void fraction'. This is important, if only to provide a label for the phase densities at which different techniques may be used to detect the flow.

Phase densities of < 1% do not usually occur on shot peening machines. The technique used is usually optical

continued on page 2...

peening machines. The technique used is usually optical where light-scatter provides the flow inference.

From about 1% to 5% an 'electro-dynamic' device is used. A small amount of media conveyed in air will generate an electrostatic charge, a passive sensor then detects this charge and a charge-amplifier type of device is used to provide usable signals. Above about 5% concentration much of the charge is lost by particle impact and changes in the flow are more difficult to determine. For phase densities of about 3% to 20% a 'capacitance-noise' device is used. The sensor in the flow path acts as a capacitor, and the associated electronics filters the standing capacitance of the sensor and any changes that are less than 1Hz. What is left is the small and fast capacitive disturbance (flow noise) that is produced by the media flow. This signal is then used to indicate media flow.

Dense phase flow, that is from about 15% to a full pipe, the phase density at which a hose will block for the same air flow, will depend upon the media. This usually requires a ratio-arm transformer device, that is, a capacitance bridge transducer. A capacitor, equal to the capacitance of the empty sensor, is part of an electronic bridge; the capacitance of the sensor with media is another part of the bridge. The difference between the two measurements is interpreted as media flow.

CALCULATIONS

One usually knows the air flow and media feed rate. A relatively simple method of determining the phase density from this information is to convert the air and media flow into volumetric flow from which a ratio may be determined (time can be ignored).

The air flow has to be converted from the 'free-air' volume to the compressed volume. For isothermal expansion, $P_1V_1 = P_2V_2$. The calculations are coarse; it is not necessary to be precise.

The calculation for 50scfm compressed to 60 psig is: 14.7 (atmospheric pressure) x 50 = 60 x V. Therefore, the equivalent compressed air volume V = 735/60 = 12.25 ft^3.

The media feed rate should also be converted to volume. Take a box of one cubic foot, pour in the media but do not shake down, scrape the top flat, and weigh the contents. This will give the poured bulk density (PBD) in lb/ft^3 for the media. If we assume the PBD is 80 lb/ft^3 (glass beads), and the proposed feed rate is 50 lb/min, therefore the equivalent volume is 0.625 (50/80) ft^3. The volumetric ratio is therefore: (0.625/12.25)100% = 5%. This falls within the range of the capacitance noise type. However, the ratio is near the low end so one should consider the media size. The bottom limit for most of the devices is higher if the media particle size is small. For example, if these calculations were made for 400-600 micron glass beads the recommendation would be acceptable; however, if the media was 75-100 micron beads the recommendation should be switched to the electro-dynamic type.

FAULT IDENTIFICATION

No display, but you do have flow. The system is not properly connected. If you have read the handbook call the supplier.

Low display level and little change for large change in flow. If the system has been set up correctly and you are using an inductive type sensor, then look to the feed valve. If you are using the electrodynamic or capacitance types, then there are two possibilities: the sensor is located in the wrong position or you are using the wrong type.

High display and little/no change for change in flow. You are outside the range of the instrument in use. For inductive, go up a size in sensor. For others, examine the location. A sensor that is OK at the top of the vertical lift shown in the sketch will go into saturation near the bottom. This is because of the extremely turbulent nature of the flow at that point.

Reasonable display but little/no change for change in flow. This should only happen on non-ferrous sensors. The problem is most certainly because the sensor is located where the flow is concentrated and not disbursed. Try and re-locate it. Such conditions could occur in any of the horizontal sections shown in the sketch.

SUMMARY

All in-line sensors should be mounted so that media will clear the sensor on shut-off; this usually means vertically.

Non-ferrous sensors should always be placed where the media will be evenly disbursed in the air stream; this usually means near the top of a vertical lift.

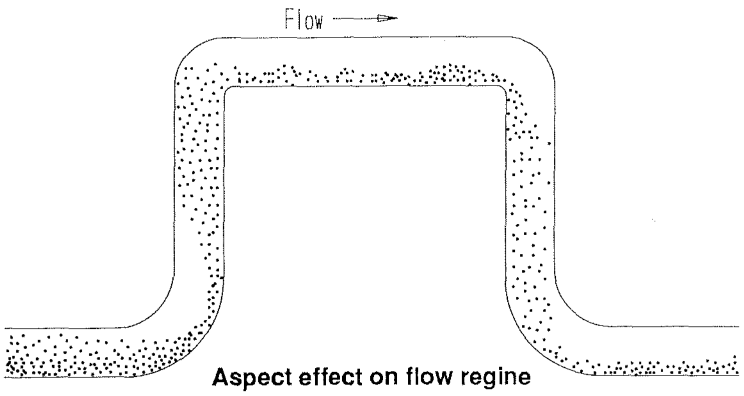
Select the most suitable system for the media and flow rate. If using ferrous media, always use the inductive sensor.

For dilute phase flows and below 100 micron particles, use the electrodynamic type.

Dilute phase flows, below 5%, use the electrodynamic type transducer.

Volumetric ratios between 3% and 20% with medium size media, use the capacitance noise transducer.

Dense phase (above 15%) use the capacitance bridge device.



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