Measurement and Control of a Wet-Peening Process

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ABSTRACT

An instrumentation system has been developed which is capable of measuring and controlling slurry flow rates in both conducting and non-conducting fluids. The system uses two separate transducers based on different principles to cover the two types of fluids. The correct transducer is automatically selected by a computer which controls the measurement system. The equipment has been successfully applied to a wet blast machine used for the controlled glass bead peening of aero engine fan blades.

INTRODUCTION

Glass bead peening is widely used to improve the fatigue life of aero engine components. A typical wet blast peening machine is shown diagrammatically in Figure 1. Water and the glass bead peening media are circulated by a pump (A) through the process guns (B) at which compressed air is injected to accelerate the media. A bypass (C) is taken from the media feed line to agitate the slurry in the sump and to allow the guns to be turned off without stopping the pump when loading and unloading the workpiece. During the peening process the glass beads break down and the broken and undersized beads are removed by hydrocyclones (D). Fresh media is fed from a hopper by screw feeder (E) to maintain the concentration of the slurry.

To obtain consistent peening it is vital that the glass bead slurry concentration is maintained within close limits. It is common practice for the operator to sample the slurry from time to time from a tapping point in the media feed line and to add fresh media as necessary. The disadvantages of this method are that it relies on the diligence of the operator and because it tends to disrupt the steady-state conditions it causes the hydrocyclones to dump media which is still within specification.
The slurry concentration can, however, be monitored continuously by introducing a suitable measuring instrument (F) in the media line. By linking this instrument to the screw feeder, the slurry concentration can be held within close limits. Not only does this give consistent process performance, but because the hydro-cyclones are working under more steady state conditions minimises the media consumption.

**Figure 1** Flow diagram of Wet Blast Machine.

**INSTRUMENTATION SYSTEM**

The measurement system developed uses three transducers linked to a micro computer which co-ordinates them and controls the media feeder. When there is little or no dissolved ionic matter in the fluid, a "Capacitance Noise Transducer" is used. When there is a significant quantity present, as when sodium nitrite is added as a rust inhibitor, a "Conductivity Noise Transducer" and a "Temperature Transducer" are used.
It has been shown by Green et al. (1) that variations in the permittivity of an essentially non-conducting fluid, when conveying a discontinuous solid are directly proportional to the mass being conveyed. The Capacitance Noise Transducer quantifies these variations and produces a signal proportional to the level of mass present.

The Capacitance Noise Transducer, shown in block diagram in Figure 2, has non-invasive electrodes implanted to the sides of the media flow pipe and the capacitance so formed becomes part of a tuned circuit. Changes in capacitance alter the frequency of this circuit and the changes in this frequency are converted into a voltage. Over a small frequency range the relationship between frequency and voltage is linear. A voltage controlled capacitor device in the feed-back loop keeps the frequency within this working range. A signal from the frequency to voltage converter is AC coupled time averaged and then converted to current giving a signal proportional to the changes in capacitance.

Figure 2 Block diagram of Capacitance Transducer
It has been shown by Lee et al. (2) that if a fluid carrying a non-conducting phase is itself conducting then the instantaneous variations in the conductivity over a measured section can be related to the mass flow over that section. The Conductivity Noise Transducer measures these variations and other factors such as temperature and nitrite concentration which affect this noise.

The Conductivity Transducer shown in block diagram Figure 3 consists of five distinct parts: an oscillator, a bilateral current source, two sensing electrodes, a signal processing section and a separate temperature sensor.

![Figure 3 Block diagram of Conductivity Transducer](image-url)
The oscillator operates at a frequency chosen to be well above the expected signal range and high enough to prevent the polarisation of the terminals and subsequent electrolysis of the sensing electrodes. Two non-invasive stainless steel electrodes insulated from the pipe are placed diametrically opposed. The oscillator drives the bilateral current source which forces alternately positive and negative currents of the same amplitude through the measurement section. As the resistance of the liquid depends on the concentration of the dissolved ionic salts, the bead concentration and the temperature of the water, the voltage across the electrodes reflects these three variables. This alternating voltage is passed through a detector and a band pass filter giving a fluctuating voltage which represents the varying modulation of the oscillator signal due to the presence of the beads. This signal is rectified again and time averaged to produce a signal of the conductivity noise. For a given size of bead at a constant temperature and salt concentration there is a linear relationship between this signal and the bead concentration. The alternating voltage across the electrodes is also fed into an RMS to DC converter with a long time constant giving a signal which is directly related to the salt concentration and water temperature.

A small semi-conductor temperature sensor is plugged directly into the metal boss welded into the measurement section of the pipe ensuring a good thermal contact with the fluid. The sensor is insulated from the surrounding air by a foam muffler. The sensor is a constant current device and its output is passed into a resistor to give a potential difference. This is compared with a reference voltage by an amplifier and the signal converted to a current. Signals from the transducers are accepted by the microcomputer and converted to analogue voltages. These voltages are fed into a combined multiplexer and analogue to digital converter. Two additional lines are provided. One comes from a manually operated switch which is used to tell the microcomputer which size of bead is being used. The other line is connected to a sensor in the compressed air line. During loading and unloading of the workpiece the compressed air supply to the guns is removed when they are being bypassed. As this leads to a radically different flow regime it has to be taken into account by the microcomputer when calculating the media concentration.

Within the normal operating range of 0-30% concentration by volume, the output of the capacitance transducer is directly proportional to the mass of beads being conveyed. The addition of ionic salt such as Sodium Nitrite to the conveying fluid has the effect at low concentrations of increasing the capacitance noise signal and at higher concentrations reducing it. As a result it becomes impractical to use the capacitance transducer when concentrations of salt greater than 1.5 g/l are present.
The signal from the conductivity transducer is dependent on the mass of beads present, the water temperature and salt concentration. Small variations in temperature and salt concentrations do not have any significant effect, but as the working temperature of a wet blasting machine may vary from 10°C at start-up to 70°C after prolonged use and the salt concentration may vary from 0.5 g/l to 7.5 g/l compensating corrections are necessary.

Rather than mathematically simulating the operating system, correction tables are automatically generated by computerised numerical analysis from empirical plots. These tables, together with the control program, are stored in an EPROM in the micro-computer.

All processing is done by the micro-computer and the output can be used to operate display lights for bead and nitrite concentration and through a digital to analogue converter to drive both an analogue bead concentration percentage meter and a screw feeder for the addition of new media.

APPLICATIONS

The instrumentation system as described above was installed on a wet blast machine designed for peening Pratt & Whitney JT9 fan blades. In addition to the media monitoring instrumentation the machine was fitted with hydro cyclones for extracting fines and broken media and with a screw feeder for adding fresh media. The machine had twelve guns mounted in two banks of six set in opposition at 45° to the blade stacking line. The blade was mounted vertically and rotated about the stacking line while the guns were traversed vertically. The Pratt & Whitney specification reference (3) calls for twelve Almen strips to be placed on a test blade as shown in Figure 4 and peened to 15N in accordance with AMS 2430J using GB50 while keeping broken beads in the system below 10%.

During run-off trials test blades were consistently peened to the specified Almen intensity with the broken media being kept below 10%. The concentration was set at a nominal 8.5% by volume and was checked by taking samples from a tapping point every ten minutes over a six hour period. The mean value of the concentration was 8.3% with a standard deviation of 8.7%.

The monitoring instrumentation through increased process control improved the stability of the blasting process so that the hydro cyclones operated in reasonably steady state conditions. As a result, the media consumption during the trials was only 5kg per blade as compared with 11kg per blade which was the best that had previously been achieved on the machine when maintaining concentration by the conventional method of taking samples from a tapping point. This reduction in consumption is worth noting as the main running cost of a wet glass bead peening machine is the glass beads.
CONCLUSIONS

The instrumentation system described is an example of a difficult measuring problem being simplified by the use of a microcomputer.

The instrumentation has been designed for an industrial environment and is robust. The electrodes for the conductivity transducer are invasive but non-intrusive and those for the capacitance transducer are non-invasive and non-intrusive which is important because of the abrasive nature of the glass bead water slurry.

The instrumentation enabled the performance of the blasting machine to be improved through increased in-process control and also resulted in a significant reduction in running costs through reduced bead consumption.

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REFERENCES


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