1993122 TRAVEL®

A real time particle velocity measuring system for use in shot peening.

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ABSTRACT

This paper presents a new device for measuring shot velocity in air blasting and wheel blasting operations. This device is based on an original concept developed and patented by Helispire[1]. The commercial name of the product is **TRAVEL**. The application of TRAVEL to shot peening has been made under a joint development program between Wheelabrator Allevard[2] and Helispire.

The system is a non-contact optical device where continuous measurements can be made 10cm away from the shot jet. It gives the velocity of individual shots passing through the 4mm^3 measuring volume. Dedicated software has been developed for data processing and for the presentation of the results. Mean velocity and standard deviation, as well as shot velocities histograms, can be instantaneously displayed.

Experiments have been carried out in the Wheelabrator Allevard test center in a true shot peening environment. The corresponding design of experiments includes all the principal parameters, such as type of nozzle, distance, flow rates and shot sizes. The results obtained are briefly described in this paper. This new device will help to solve the everlasting question of an instantaneous measurement of shot kinetic energy in the peening process.

KEYWORDS

Shot peening, Fatigue strength, Velocity, Optics, Data processing, Shot kinetic energy, Blasting booth.

INTRODUCTION: REQUIREMENTS

Shot peening considerably increases the fatigue strength of mechanical parts. However, while treated parts are guaranteed a longer working life in all cases, the results are not absolutely consistent throughout a given batch. This can be a source of problems in quality procedures. The current tendency in the profession is to try to master all the parameters involved in the process, and more particularly to measure the abrasive flow rate and the projection speed. Indeed, the result such obtained is directly related to the energy transmitted to the part, and this, in turn, only depends on the speed and flow of particles at the point of impart. This can be complicated when the distribution of particle sizes d and velocities V present a high deviation. One has to remind that the Kinetic energy of each particle is equal to

$$E_c = 0.5\ \rho\ V^2\ \pi/6\ D^3$$

There are several means of measuring the abrasive flow rate with accuracy. The main problem still to be solved was therefore how to measure the instantaneous speed of abrasives in a blasting booth environment.

The Travel® system developed by Helispire in association with Wheelabrator Allevard provides a simple, reliable and economically attractive solution for this major technical problem.

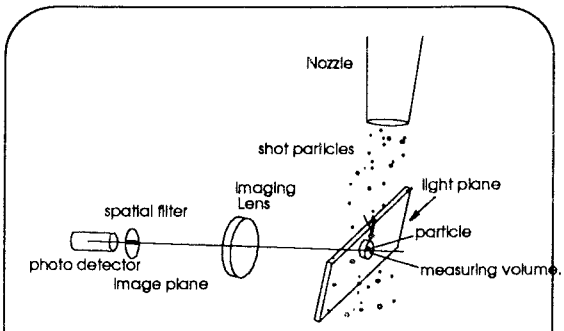
PRINCIPLE

Optical System

Travel is an optical, non-contact method for measuring particle projection speed. A measurement volume is determined by the intersection of a beam of white light and an optical receiving system including a spatial filter in the image plane. White light has been preferred to lasers or laser diodes due to a better light intensity uniformity.

When a particle passes through the measuring volume (which is comprised between 4 and 30 mm^3 for the most commonly used abrasives) it emits light. The modulation of this light through the spatial filter is then measured by means of a high frequency photodetector.

In the basic version of Travel, the measuring unit is placed 10 cm away from the point of measurement. This prevents any interaction with the jet of abrasives which could be due to rebounds or aerodynamic effects. The 50 W light is placed inside the measuring head. A special ventilation system has been developed which prevents overheating. The dusty environment requirements have been taken into account.



TRAVEL: Principles.

The photodetector is also located in the measuring head. Fiberoptics for lightning and detection have also been used in specific applications.

Travel can measure the speed of particles of all sizes, in particular metal and other types of abrasives between 100 µm and 3 mm in diameter. Among other features, one of he very interesting operating principles of Travel is that the measuring volume dimension is adjusted to the particle size.

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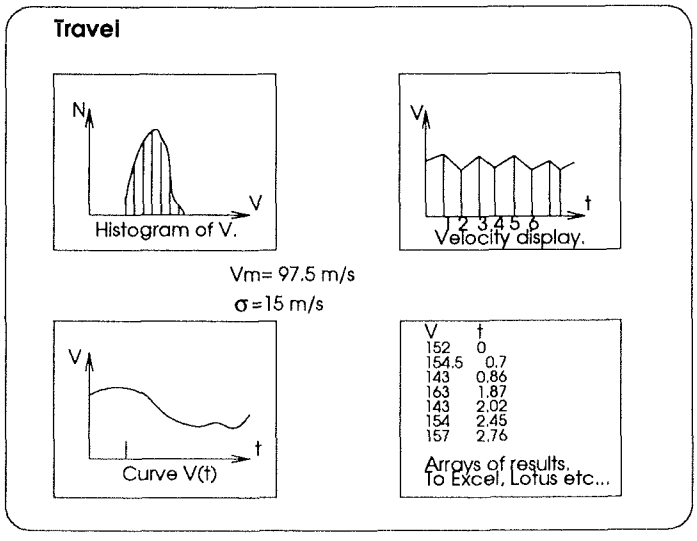
Electronics and Signal Processing

The modulation of light caused by the passage of a particle is processed by a system which comprises the following items:

- A photosensitive cell which can be a photomultiplier, a diode or an avalanche diode, depending on the shot velocities and dimensions. The standard Helispire system uses a photomultiplier.
- A signal conditioner which includes filters and amplifiers.
- A signal acquisition and processing unit. Signal acquisition is made by a 40 MHz acquisition 8bit card. Signal processing uses a dedicated software which eliminates spurious signals that fail to comply with a set of predetermined parameters.
- A personal computer is used for signal display. Information such as discrete particles velocities, average velocity or standard deviation are readily obtained. The software and computer are part of the standard Travel package for abrasive applications. Industrial computers can be supplied on request.

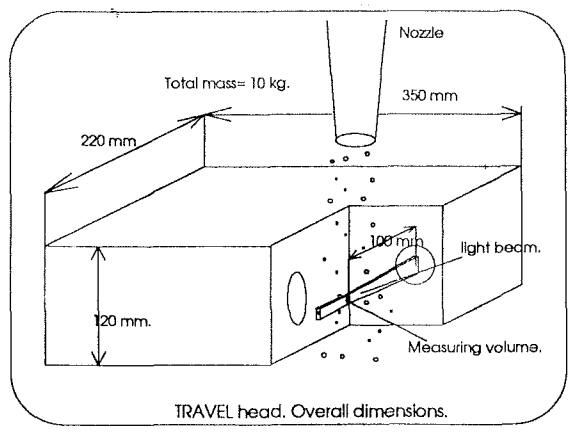
The results can be used for regulation purposes in a real time control system including, for example, nozzle pressure or mass flow rate automatic control.



Typical Display

Mechanical Characteristics

The travel system has been designed to work in the hostile environment of a blasting booth. The measuring head is rather compact. As shown on the figure, its overall dimensions are 350x220x120 mm and its weight is 10 Kg.



TRAVEL head. Overall dimensions.

In order to prevent rapid destruction of the apparatus in blasting conditions, the head is completely plated with an 8mm thick rubber. A special mechanical design prevents direct impact of abrasives on the two saphire optical windows. The cover of the head is interchangeable and standard spare parts are available at Helispire.

Travel Operation

Travel operation is very simple and can be easily done by trained operators. Installation can be made in five minutes. The measuring head is installed in the cabin and is readily linked to the electronics. The standard optics need only two adjustments depending on the shot mean diameter. The other calibrations are made semi-automatically with the help of the data processing computer.

The Travel optical and electronic components are installed in the dedicated head which is put in the booth. The electrical mains and data processing circuits are normally installed outside. The necessary connections are made through a single rubber hose which crosses the cabin walls.

MEASUREMENTS

Installation

The unit was installed in a Wheelabrator Allevard compressed air blasting booth. A complete test program was drawn up, taking into account the following parameters:

- Size of abrasive
- Type of nozzle
- Diameter of nozzle
- Distance from nozzle
- Length of feeder pipe
- Flow rate of abrasive
- Nozzle upstream pressure

The tests programmed provided results for two series of 32 tests. Each test result is the mean of 20 individual particle speed measurements. The programme showed that the mean and standard deviation no longer varies beyond 10 measurements. These preliminary tests have been made with 10, 20, 50 and 100 measurements.

The standard deviation and relative error were calculated, but these results must be treated with caution as the speeds do not have a normal distribution, due to variations in flow rates.

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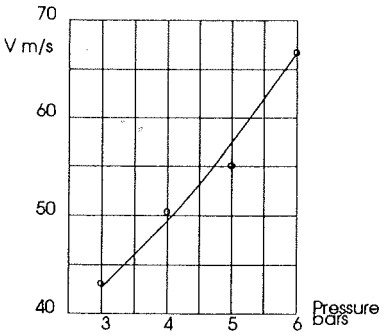
The calculated speed is the mean of a large number of low velocity values corresponding to normal operation conditions and a few high speeds during sudden increases in flow rates. Relative standard deviation ranges from 7% to 30% and its mean value has been found to be 20.5%.

Results

The calibration has been made by Helispire by means of an illuminated rotating disk. The verification of this calibration was done by measuring the speed of water drops and particles falling from a known elevation. The test conditions at Wheelabrator Allevard were carefully controlled and the results obtained provided very interesting information, some of them being unexpected.

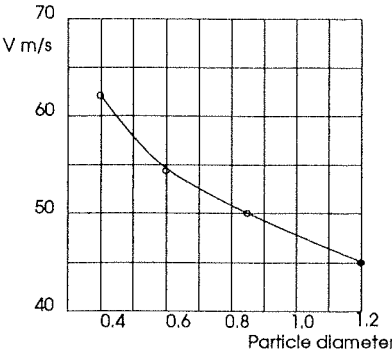
The values of velocities are well below those observed to date. Velocities from 40 to 100 m/s have been recorded. The generally accepted values of 100 to 300 m/s are obviously too high.



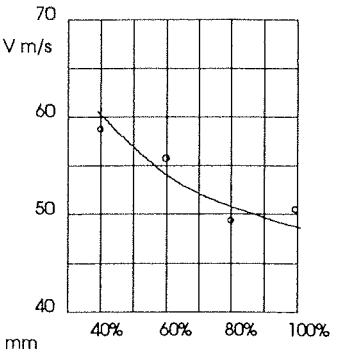
Influence of Pressure

Concerning the effect of the operating parameters, the following trends could be distinguished.:

- The minimum speed measured was 12 m/s and the maximum 150 m/s.
- The mean values from 20 points ranged from 25 to 105 m/s depending on operating conditions.
- Speed varies monotically as a function of pressure and particle size. It increases with pressure and decreases when particle diameter is larger.
- Speed decreases as abrasive flow increases.
- Changing from a straight nozzle to a venturi nozzle produces a net increase in particle speed.
- The effect of the feeder pipe length is greater when fine abrasive is used. As it travels faster, there is a greater braking effect. However, it should be noted that the shape of the pipe and the existence of wrinkles or bends is much more important than length.
- A final interesting result is that the spreading of speed distribution decreases as the nozzle diameter increases. This might be explained by a reduced number of impacts on walls and a lower density of particles in the nozzle.
- Lastly, varying the distance from the nozzle from 100 to 500 mm causes hardly any slowing down of the particle speed.



Effect of particle size.



Effect of flow rate.

PROSPECTS

Qualification of nozzles

As a first step, Wheelabrator Allevard intends to supplement the information obtained during this preliminary series of experiments. More analytical tests are also scheduled, concerning for example, the distribution of projection speeds within the jet, measured axially and radially. This will be compared to the aerodynamic model developed by Helispire, and it is intended to develop a complete simulation giving the velocity and density distribution of abrasives in a jet at the exit of a nozzle. These results will be introduced into mathematical models simulating the operation of shot peening nozzles. These models will constitute part of a data bank for future automatization of shot peening process.

It is, of course, intended to develop a procedure for completely or partly avoid the use of test plates, which is still a fairly laborious operation. Effects of velocities and impact angles will be systematically tested very soon. In this way, it will be possible to optimize the various setting parameters for a blasting booth and to control operations in real time. There will be an obvious gain in productivity and an improvement in quality by taking into account the additional parameter of abrasive projection speed.

CONCLUSION

The Travel method is a major technological breakthrough in the field of shot peening, as it enables real time measurement of local particle projection speed. The tests carried out at Wheelabrator Allevard confirm that it works reliably in the very hostile environment of a blasting booth. The tests performed by Helispire show that the unit also works with other products such as glass beads, plastic media and ceramics. Travel can also be used in fluid velocity measurements.

The Travel unit thus provides the ideal solution for measuring of particles of varying types and shapes. Its reasonable price means that it can be used not only in shot peening, but also in the more usual fields of blasting works.

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