A SURVEY ON MODERN (1995) MASS FLOW EQUIPMENT

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ABSTRACT

A condensed description of commonly known and popular mass flow measuring systems and also flow metering systems involved. It refers to the field of industrial and scientific peening and blasting engineering working with air operated machinery.

KEYWORDS

Flow monitoring, Flow measuring, Flow control.

1. INTRODUCTION

The interest in having peening/blasting machines equipped with precious mass flow equipment has primarily arisen due to the knowledge gained in high-tech shotpeening. In the field of such flow equipment, some literature exists, but normally it is an internal specialty of the peening machine manufacturers.

Information about media flow-rates in peening machinery is required in compliance with various specifications such as in MIL, SAE, GE, BAC, etc. Also for fully automated processes, including abrasive blasting, flow measuring can be advisable for quality control reasons or to improve productivity. Also for other specialized peening and blasting, eg. in research work, such processes will always ask for mass flow information; this again connected with appropriate flow metering equipment.

This paper does not enter into more scientific details discussing the importance and finally necessitates accuracy of media flow monitoring. Just to mention this one sample: "It is commonly known, that in air-operated shot peening processes, the media flow has somehow a self-compensating effect. When the media flow gets increased, this results in an air-pressure drop at the nozzle, equivalent to a shot speed drop due to higher friction inside the hose and a higher acceleration work in the media inlet area." (and vice-versa), but eg. it does not affect the coverage very much. Such effects create a certain complexity in the field of media flow technology. Also the scope of this paper will not include supplementary equipment such as shot:velocity:measuring devices eg. by Helispire F-Saint-Ismir with TRAVEL.

2. FLOW MEASUREMENT

2.1 History

At least for Europe, it is believed, that in 1972 a Swiss company has first
introduced mass flow measuring in the field of shot peening. This company has started development, right from zero, to finally be able to present complete systems in various configurations.

In 1978, in the United States, a new line of shot control equipment has been developed, for both wheel and air operated machines. Commercialised in 1981 with an improved device³ in 1983, it was developed to a standard that will cover most of today's requirements.

In 1990, a Swiss company has started advertising a high precision measuring device, believed to be the only one that also allows to monitor non magnetic and non ferrous shot.

Also various OEM's have tried to use standard industrial products⁴ common eg. in powder / granulate processing. This with little success, as such equipment is not really suitable to cover all the specific needs necessary in shot peening.

2.2 Flow Sensor Principles

The chapter 2 "Media Flow Measurements and Phase density" in "Particulate Solids Flow" clearly describes some problems and mentions possible solutions on this subject.

A first question "where to measure" is simple to answer. The velocity of particles should be the same at all times and the particles evenly dispersed over preferably circular strapped duct area. So this will be eg. just after the funnel shaped outlet of a pot, the pressure pot normally, where gravity fall gives a constant average speed

\[ v = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 0.05} = 0.99 \text{ m/s} \]

![Fig. 1. Inductive Sensor](image-url)
if the actual point of measuring is active after eg. a 0.05 m distance from gravity effective starting point. So in this point, the actual mass flow has to be measured, depending on mechanical proportions and loaded with a dense phase flow from less than 10% up to nearly full pipe.

This can be done by clever arrangements of capacitive or inductive electrical devices. A combination of two coils with the shot flow as a variable "core" may be a good solution to start experiments. [Fig. 1] under different shot flow values, the electrical transformation efficiency will be different and the secondary coil will show a flow depending voltage. For eg. 5 kg/min flow could be equivalent to a 1 mm dia steel wire placed through the center of the mentioned coil arrangement. But to create a high standard industrial measuring device is a fairly tricky job and has been already performed by competent manufacturers.

A completely different and more common measuring technique is based on various kinds of weighing either with a bell or flap arrangement. But all these systems are not really suited to be used on peening machinery. Here a rugged, compact simple to attach unit is required.

![Diagram](image_url)

**Fig. 2. Mech. / Electronic type**
Specially for shotpeening / blasting application a device has been developed which exists out of a spring suspended cone with the point upside and a displacement sensor mounted beneath. [Fig. 2]: Depending on the amount of media falling on to the cone, the cone will be forced down due to friction and pulse reaction of the particles. Accordingly the displacement sensor will vary its signal level. As the cone is spring suspended and oscillates with a mass typical frequency, the overall accuracy is extremely high. Contrary to the direct electronical working devices, this hybrid unit can measure any kind of media such as glass, ceramic, nutshell, ice pellets etc.

2.3 Instrumentation and readout

Flow measurement systems normally have a rugged sensor device to be mounted in the shot generating area and a panel mount gauge that includes all signal conditioning, amplification, interface and eventual means of configuration in the operators area. A 3-digit display and a volt, amp or other output interface is standard.

3. METERING

To measure media flow could be of great importance - but to control media flow comes even first. In the past 50 or more years, numerous inventions have been announced and various devices have been tested and produced. Basically two different systems exists.

3.1 Gravity Feed Principle

Similar to a "sand-glass", the media flow is controlled or restricted by an orifice or any other means of outlet with either a fixed or variable area. The outlet size variation can be performed cock-like, with a "mushroom", by squeezing of an elastic hose (radial or parallel) or many other concepts. Activation can be done manually, pneumatically, electrically, either continuously variable, in steps, on-off on the base of preset, manually controlled or in a closed-loop mode, etc.

In this family, a sophisticated solution has become quite popular. Here in "OFF"-mode, the media gets captured by itself due to local magnetizing by strong permanent magnets. In "ON"-mode, the permanent field gets partly compensated by electric magnets at a certain frequency. Analog to the level of di-magnetization, the media flow is established.

3.2 Forced-Feed Principle

For such equipment, a belt, a rotating arm system [Fig 3], an auger [Fig 4], belt conveyor or similar device will perform the metering. Various types of E-motors such as AC, DC, stepper type just according to individual needs.

These are the only systems that can autonomously provide a constant and accurate media flow, to a certain degree independent from shot quality and size. Basically, one revolution of any part in the drive gear train represents a defined quantity of media, therefore the actual media flow is equivalent just to the number of revs.
Only, such mentioned forced-feed systems are comparably expensive, and in abrasive media application eventually more liable to wear out.

Fig. 3. Auger type Feeder

Fig. 4. Twin arm feed device

4. MEASURING - METERING COMBINATION PHILOSOPHY

A mass flow sensor is always placed after the metering equipment. So a key question is, if, or how to functionally combine this two devices. Mainly it might
be a matter of costs. A very sophisticated solution with all high-tech electronic and mechanical parts integrated, should give better results even better than for the moment required.

4.1 Independent Combination

The metering device must be of such a design, that it can be preset to get a certain flow level. In operation, this level shall remain within a tolerance approximately half the tolerance admitted by the process specs. Here, the gravity feed technique is at its limits. But it is not a problem to all forced-feed machines.

The repeatability for one and the same shot size is given by the actual shot quality such as screen-analysis, cleanliness and static 7 magnetic effects eventually. An additional but very important fact is that many industrial blast vessels have problems with pressure balancing between pressure vessel with a static situation and hose entrance (mixing chamber) where we find a dynamic situation. This may affect flow repeatabilities specially in respect to low-high working pressure ranges, near-median empty vessels and of course under "START-STOP" conditions.

When changing media e.g. from S110 to S170 or 230, the different metering devices respond differently, normally in such a way that a compensation is necessary. With today's technical means this problem can be easily solved. The functional order manual source or from CNC should also animate the corresponding device on the metering side. As for example if media "A" compared to media "B" has a 6% different feed characteristic, a 6% multiplier for the feed technique of media "B" has to be activated.

The addition of a measuring device for the here mentioned unreliable systems mentioned would only be for the purpose of process quality control.

4.2 Partly Dependable Combination

It is only a small step to improve the described independent combination and with little effort, a highly accurate but simple machine can be achieved. Here, PLC features can make it possible. The basical arrangement is still the "independent combination", also the process starting function is equal, but this only for eg. the first 5 seconds. During this time, the media flow should get established and a constant level signal should be obtained from the flow sensor.

The machine should be designed and set, so that the flow is at least within ±10% of actual display reading. Now a ±4% sensitive comparator detects the 10% difference and therefore induces an adjustment of 3%. With repetitive activation of this comparator routine every 5 seconds, the flow will be correct after max. 15 seconds in the worst case, not much later as quite often a peening process effectively starts. Such a control configuration could be realized in many different ways; finally replaced by the help of PID controllers, or even improved characteristics. As the control procedure can be very slow (5
seconds...), a cost reducing multiplexing technique for multi nozzle machines is quite advisable.

4.3 Closed Loop Combination

Such systems can be the most expensive ones and components within a system must be highly compatible. Such a standard solution exists of a monitor, controller and feed-device. A sensor and its separate interface with display normally represent the "monitor". Shot peening suitable OEM-controllers are not common, therefore the sensor interface and a special controller are combined in one unit. This is a quite practical solution.

![Diagram of different feed control systems]

Fig. 5. The 3 different feed control systems

As mass flow measuring itself is delicate and response times must be observed, the mentioned closed loop technique is not too simple. Instability problems may bother development engineers. Also in certain cases, interference problems may occur when running multi nozzle systems with different parameters (caused eg. by facts mentioned under "Independent Combination".. pressure balancing, etc. !)

4.5 Instrument Control Layout

An excellent solution is offered by the magnetic system EI7. Here the flow metering unit is combined with the flow monitor. With two pieces components only, this can be considered as a highly integrated system. Another manufacturer uses a more open technique with three or four pieces components. In the kind of general purpose units (one to four pieces components), systems in various configurations are possible. Either with gauge direct, conditioned signal in addition, with monitor, with feed unit, finally with a controller.

As a result of many years of experience, for high integrated control gear, a kind of standardization in respect of operation has become common to manufacturer

Manual Control

Flow to be set / preset by potentiometer, knob or thumb switches. This can be used for special jobs,
service work, to trace faults, etc.

Local Set Point
Local setting of a desired value, eg. together with a controller.

Remote Set Point
This switches over to an external signal level eg. from a CNC device.

Zero Setting
Either a knob to compensate eventual zero-offsets, can also be an auto system.

Media Definition
Selector switch to adapt device to media-size or type, either just to increase the total accuracy or to adapt principally to a particular media. Can also be remote operated in case of CNC operation.

5. PERFORMANCE AND ACCURACY

The individual providers of mentioned equipment will inform about product related specification with respect to utility-range and accuracy. So far no international recommendations/specifications exist. But accuracy guarantees are very delicate and presently all figures given must be regarded as fairly optimistic as a laboratory calibrated flow control unit may work different under rough production operation. Finally only field tests on process ready machines will give a true picture. Such tests could be performed as described in the contribution "Shot Flow Sampling".

6. ECONOMICS

There is no standard solution neither for metering nor monitoring. Between very simple and highly sophisticated ones is a wide range, additionally complicated by different parametric and other requirements. A sensor without any signal conditioning could cost US$ 500. A complete monitoring unit could come to US$ 2000. A full metering-monitoring "plug & play" outfit can be between US$ 4000 and 8000, a cost factor to be remembered specially for multi-nozzle installations.

7. CONCLUSION

This paper does not go into various details such as micro size systems, different shot propelling systems, uncommon shot, stabilization problems, alarm techniques, calibration procedures. But it shall give an idea of the overall complexity and solution possibilities in this field of modern mass flow equipment for peening / blasting machines.

8. REFERENCES


BIKER AG, CH-Glattbrugg

ELECTRONIC INC. USA-Mishawaka with Magna Valve, etc.
ANVIL DEVELOPMENTS, CH-Volketswil with "Model 501"
E and H.D. Maulburg Popular in Europe : GRANUFLOW,
Magna Valve, note 3.