THE 7th INTERNATIONAL CONFERENCE ON SHOT PEENING
ICSP 7
INSTITUTE OF PRECISION MECHANICS WARSAW, POLAND

A NEW METHOD OF MEASUREMENT OF THE VELOCITY OF SOLID PARTICLES AND THEIR MASS FOR AIR BLASTING

J. ANDZIAK
Institute of Precision Mechanics, Warsaw, Poland

Abstract

The results of air blasting are presented. The methods of measurement of velocity of solid particles are characterized. The new, original threefold - disk method of measurement of the velocity and mass of solid particles is described as well as construction of the measuring instrument.

KEY WORDS

air blasting, velocity, solid particles, measurement of velocity of solid particles

INTRODUCTION

The principle of air blasting relies upon the fact that in the air stream there are carried abrasive grains which form the abrasive stream, and the result of materiel removing is obtained through conferring the sufficiently high velocity to that stream. Such velocity is obtained through decompression of compressed air in the nozzle. The kinetic energy of abrasive grains, is sufficiently high as to exert the significant effect on the results of air blasting, despite their low unit mass.

The results of air blasting are as follows:

- the removal of solid impurities from the substrate with possible loss of substrate material;
- changes of the geometric microstructure of the surface;
- changes in the material of surface layer.

Thus the air blasting can be used e.g. as

- blast cleaning - the basic method of mechanical steel substrate pretreatment before application of protective coating. The aim of such treatment is to remove from the substrate the solid impurities bounded with the surface (e.g. mill scale, products of iron corrosion, degraded paint coating etc.) and at the same time to obtain the desired roughens and roughness profile,
- finishing treatment resulting in the surface of the defined roughness and appearance,
- shot peening resulting in the change of properties of the material of surface layer.

The process of air blasting and its results depend mainly on the kinetic energy of particles stream ($E=m \bullet v^2/2$), and those properties that affect the velocity of solid particles. The knowledge of the velocity of solid particles allows the quantitative assessment of the results of air blasting.

Thus in the case of removing the hard and brittle mill scale from the substrate there the following dependence between the amount of the removed material (w) and the particle velocity is valid

$$w = c \cdot v^n$$

where: c - coefficient characterizing the properties of the removed material and particle
n - velocity exponent

The above equation confirms the important influence of the velocity of particles on the results of air blasting.

METHODICS OF MEASUREMENTS OF PARTICLE VELOCITY

In air blasting, in the case of stationary surface the determination of mathematical relations enabling to define the particle velocity is very complicated. The exception is the application of the instrument (so called "acceleration centrifuge") imitating the process of air blasting [1-4]. In such instrument the treated samples are fastened on the arm rotating with the variable velocity. Similarly, in the airless shot blasting the velocity of particles is approximately equal to the peripheral speed of the ends of blades of the throwing wheel.

In the research practice the velocity of individual particles, which are pneumatically accelerated is frequently measured by photographic method using the "fast shot" camera [5,6]. There are also used electronic [7-10] and, recently, laser [11-13] methods of measurements.

However the most frequently used is double disk method [14]. Its advantage is that the results of measurements of the velocity or particles are well correlated with the velocities determined on the basis of the theory of two phase flow [15]. Similar to the double disk method is the method of "paddle wheel" [16]. Both methods permit the mean velocity of the random particles of abrasive stream to be determined.

NEW THREE-WHEEL METHOD OF MEASURING THE PARTICLE VELOCITY

The new method of the measurement of the particle velocity, called "three-wheel" method permits a determination the mean velocity of the specified number of particles included in the string freely selected from the stream.

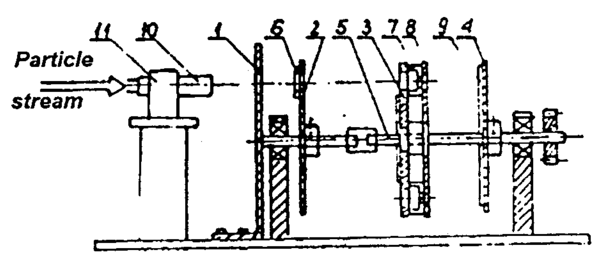

Fig. 1. Construction of the instrument for measurements of the velocity and mass of particles by "three-disk" method. 1 - diaphragm, 2,3,4 - disks, 5 - shaft, 6 - panel, 7 - container for abrasive, 8 - aluminum foil, 10- nozzle, 11 - nozzle holder

Fig. 1 schematically shows the construction of the measuring instrument consisting of the motionless diaphragm (1) and three disks (2,3,4). There are rectangular slots in disks (2) and (3), but in measurements only the slot in disk (2) is used. Disk (3) serves for the measurement of particles velocity and their mass. Behind the disk (3) with slots there are vessels (7), in which abrasive is collected, falling through slots. Disks (2) and (3) are fastened on the shaft in such a manner that in position "zero" the center of one ("zero") slot in disk (2) and the center of one ("zero") slot in disk (3) lay on a line parallel to axes of both disks. Disk (4) serves only to measure the velocity of particles. The construction of instrument permit the distances between disks to be changed.

Nozzle (10) is fastened in a holder (11), which allows movement of the nozzle along its axis as well as the rotation in a plane parallel to the basement of an instrument.

The important part of instrument forms the diaphragm (1). It has a slot with an axis in line with the axis formed by the center of the nozzle and the center of the slot in disk (2), as well parallel to axes of both disks. Changing the angular position of the nozzle in relation to the plane formed by these axes, permits the selection of the particle stream in the range of η angle from 0° to 90° (fig. 2).

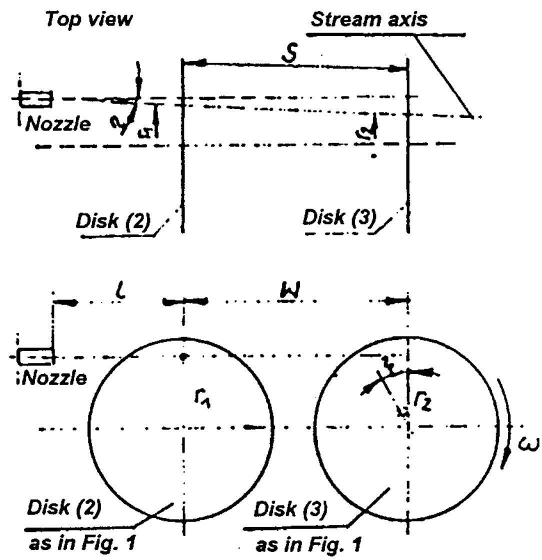

Fig. 2. Calculation the velocity of particles by "three-disk" method

Symbols on fig. 2 have the following meaning

r_1 and r_2 - radii of circles, on which there are positioned centers of slots in disks (2) and (3) — mm

w - distance between disks (2) and (3) — mm

s_0 - path of particles between disks (2) and (3), when $\eta > 0$ — mm

ω - angular velocity of disks — rad/min

n - rotational velocity of disk — rpm

ξ - angular displacement of disk (3) in relation to initial position — (degree)

η - deflection of the axis of slot diaphragm from the vertical or the angle of deflection of the axis of abrasive stream from axes of both disks — (degree

Assuming the change of velocity of particles in the instrument is negligible, the measured velocity v equals the velocity of particles at the point set by the slot of diaphragm and the track or slots of disk (2). Thus one can write (Fig. 2), that

$$S_0 = \left[w^2 + (r_1 + r_2)^2\right]^{1/2} \qquad (1)$$

and it is obvious that if $r_1 = r_2$, then S0 = w. Angular displacement ξ of disk (3) in relation to initial position at the time t is

$$\xi = w \cdot t \qquad (2)$$

Taking into account that $\omega = \pi \bullet n$, and using equations (1) and (2) one can write the velocity of particles is

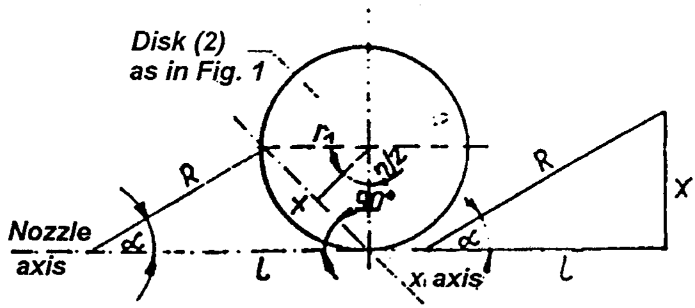

Fig. 3. Method of determining the coordinates of the point of stream of particles, in which the velocity of particles is calculated

$$v = \frac{\pi \cdot n \cdot S_0}{\xi} \qquad (3)$$

The coordinates of point, in which the velocity of particles is calculated, can be determined (in accordance with symbols used in Fig. 3) in a following manner

$$x = 2 \cdot r_1 \cdot \sin\frac{\eta}{2} \qquad (4)$$

$$\alpha = \left(\frac{2r_1}{l} \cdot \sin\frac{\eta}{2}\right) \qquad (5)$$

$$R = \left(l^2 + 4 \cdot r_1^2 \cdot \sin^2\frac{\eta}{2}\right)^{1/2} \qquad (6)$$

Therefore it is possible to calculate both spherical coordinates (α, β, R) and the cylindrical coordinates (l, β, x) of the point of stream of particles, in which the velocity of particles is measured.

The mass of particles in the string selected from the stream of particles, collected in individual containers (7) of the disk (3) is measured by weighting.

The presented original three-disk method of measurement of the velocity of particles was used to elaborate the mathematical model of particle velocity distribution in the stream ejected from the convergent-divergent nozzle.

REFERENCES

1. Kleis J.R.: Wear, 13 (1969), p. 188-215.
2. Goodwin J.E., Sage W., Tilly G.P.: Proc. Instn. Mech. Engrs., 184 (1969-70), p. 279-292

3. Rickerby D.G., Macmillan N.H.: Wear, 60 (1980), p. 369-382.
4. IidoK., The Fifth International Conference on Shot Peening, Oxford, 1993
5. Christman T., Shewmon P.G.: Wear, 52 (1979), p. 57-70.
6. Jennings W.H., Head W.J., Manning Jr. C.R.: Wear, 40 (1976), p. 93-112.
7. Ives L.K., Ruff A.W.: Wear, 46 (1978), p. 149-162.
8. Green R.G., Gregory I.A., Henry R.M., Hill E.K.: Impact Surface Treatment. Second Int. Conf. on Impact Processes, Cranfield Institute of Technology, Bedford, UK, 22-26 September 1986.
9. Lecoffre Y., Jouet F., The Fifth International Conference on Shot Peening, Oxford, 1993
10. Linnemann W., Kopp R., Kittel S., Wũsterfeld F., The Sixth International Conference on Shot Peening, San Francisco, 1996
11. Eaton H.E., Novak R.C.: Surface and Coating Technology, 36 (1988), p. 75-85.
12. Ruff A.W.: Wear, 108 (1986), p. 323-325.
13. Blatt W., Kohley T., Lots U., Heitz E.: Corrosion, 4 (1989), 10, p. 793-804.
14. Ruff A., Ives L.K.: Wear, 35 (1979), p. 195-199.
15. Gulden M.E.: Wear, 69 (1981), p. 115-129.
16. Hovis S.K., Anand K., Conrad H., Scattergood R.O.: Wear, 101 (1985), p. 69-76.