The Analyses of the Shot Velocity Thrown from the Nozzle and the Bladed Wheel

Kisuke Iida

Meiji University, Mechanical Engg. Dept.
Higashimita, Tamaku, Kawasaki, JAPAN-214

ABSTRACT

Shot is thrown from the nozzle by compressed air flow and from the bladed wheel by centrifugal force. Practically, the shot velocity is a important factor of peening intensity.

The following functions of shot velocity have been drawn from the equation of motion of shot in nozzle and on blade.

On air pressure type, shot velocity is the function of air velocity, density of air and shot, nozzle length and diameter of shot.

On centrifugal type, shot velocity is the function of revolutionary speed of wheel and blade length.

KEYWORDS

shot peening, shot velocity, peening intensity, coverage.

NOMENCLATURE

A : geometry of shot: sphere (πr^2)
C : centrifugal force
C_d : drag coefficient
D : nozzle length
F : resistance of flow
f : reverse force of centrifugal force
g : gravity
L : length of blade
m : mass of shot
N : r.p.m. of bladed wheel
R : distance of flight
$2r$: diameter of shot (sphere)
V : velocity
V_a : air velocity
V_d : dropped velocity of shot
V_i : initial velocity of shot
V_r : radial velocity of shot
V_s : shot velocity
V_t : tangential velocity of shot
x : displacement from center
μ : coefficient of friction
ρ : density
ρ_a : density of gas
ρ_s : density of shot
ωt : rotating angle of blade (t sec)

1. INTRODUCTION

Peening intensity consists of velocity of shot, size and hardness of shot, angle of impingement, quantity thrown per second, and shape of pattern.

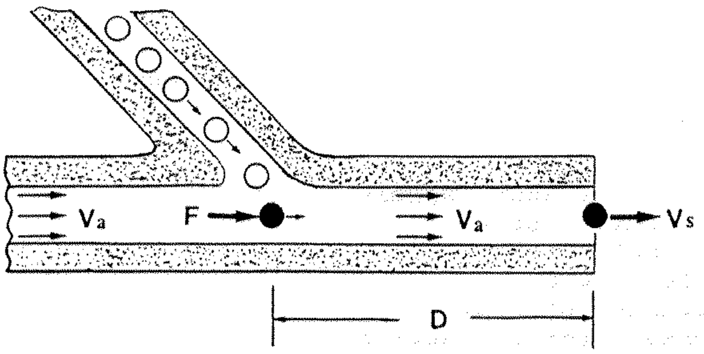
For the comparison of research results from different investigation, it is practically useful to state Almen intensity in addition to velocity and other factors. But it is not so easy to know shot velocity.

In practice, shot velocity is controlled by air pressure or the revolutionary speed of bladed wheel. In the critical aspect, it is useful to know the function of shot velocity. Theoretically, shot velocity can be obtained through the equation of motion of shot in air flow and on blade of wheel.

2. AIR PRESSURE TYPE SOLUTION

Figure 1 shows nozzle section of air pressure type. Shot is accelerated by air flow and get away from nozzle. The equation of motion of shot and force are shown in Fig. 1.

AIR PRESSURE TYPE



$$m\frac{dv}{dt} = F \qquad F = Cd \cdot A \cdot \frac{1}{2} \cdot \rho_a \cdot V_a^2.$$

Fig. 1. Nozzle and the equation of motion of shot.

The force is the resistance of object in high speed gas flow as well known in aerodynamics [1].

Shot velocity can be obtained through the following process as the formula (1).

$$m\int_0^{V_s} V\,dv = C_d \cdot \pi r^2 \cdot \frac{1}{2} \cdot \rho_a \cdot V_a^2 \int_0^D dx$$

$$V_s^2 = \frac{C_d \cdot \pi r^2 \cdot \rho_a \cdot V_a^2 \cdot D}{\frac{4}{3}\pi r^3 \cdot \rho_s}$$

$C_d \fallingdotseq 1.$ ρ_a : air (1.29×10^{-3}),

$$V_s = 0.0311 \left(\frac{D}{r \cdot \rho_s}\right)^{\frac{1}{2}} \cdot V_a \qquad (1)$$

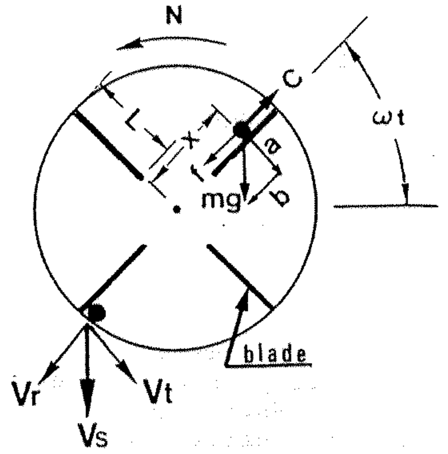
Example: a) steel shot V_s = 39.4 m/s (ρ_s = 7.8)

b) glass shot V_s = 69.5 m/s (ρ_s = 2.5)

3. CENTRIFUGAL TYPE SOLUTION

Figure 2 shows the principle of bladed wheel for centrifugal type. Shot is accelerated on blade by centrifugal force and other forces, then get away from blade. The equation of motion of shot and forces are shown in Fig. 2. The forces on shot are centrifugal force and others from gravity which change with rotation of wheel. Shot velocity can be obtained through the following process as the formula (2).

CENTRIFUGAL TYPE



a: $mg\sin\omega t$

b: $mg\cos\omega t$

C: $mx\omega^2$

f: $\mu a+b$

L: length of blade

N: r.p.m. of wheel

$$m\frac{dv}{dt} = C - f$$
$$= mx\omega^2 - \mu mg\sin\omega t - mg\cos\omega t$$

$\sin\omega t$, $\cos\omega t = \pm 1$ • • • • • max value

Fig. 2. Bladed wheel and the equation of motion of shot.

$$\frac{dv}{dt} = x\omega^2 \pm (1 \pm \mu) g$$

$$\int_0^{V_r} V\,dv = \int_0^{L} [x\omega^2 \pm (1 \pm \mu)]\,dx$$

$$V_r^2 = L^2 \omega^2 \pm (1 \pm \mu) g L$$

$$V_t = L\omega, \quad V_s = (V_r^2 + V_t^2)^{\frac{1}{2}}$$

$$V_s = \sqrt{2}\,V_t \left(1 \pm \frac{1 \pm \mu}{V_t^2} g L\right)^{\frac{1}{2}}$$

$$= 2\sqrt{2}\,\pi L \cdot N \tag{2}$$

$$= 1.48 \times 10^{-4} L \cdot N \ (m/sec)$$

L (mm), N (r. p. m)

Example: $L = 150$ mm, $N = 2000$ r.p.m.

$V = 1.48 \times 10^{-4} \times 150 \times 2000$

$= 44.4$ m/s

4. REAL VELOCITY OF CENTRIFUGAL TYPE

When shot is freely thrown from bladed wheel, shot velocity is V_s as shown in Fig. 3 (a). Practically, bladed wheel is covered by the cage as shown in Fig. 3 (b). When shot reached the cage, radial velocity is vanished and tangential velocity remain but centrifugal force is acting on shot. Before throwing out from wheel, shot is collected at inside of the cage. The velocity of the collected at the end of blade is about tangential, because acting time of centrifugal force on them is too short at the opened zone of cage as shown in Fig. 3(b).

Then the velocities of shot thrown from bladed wheel are not constant from the maximum V_s to the minimum V_t.

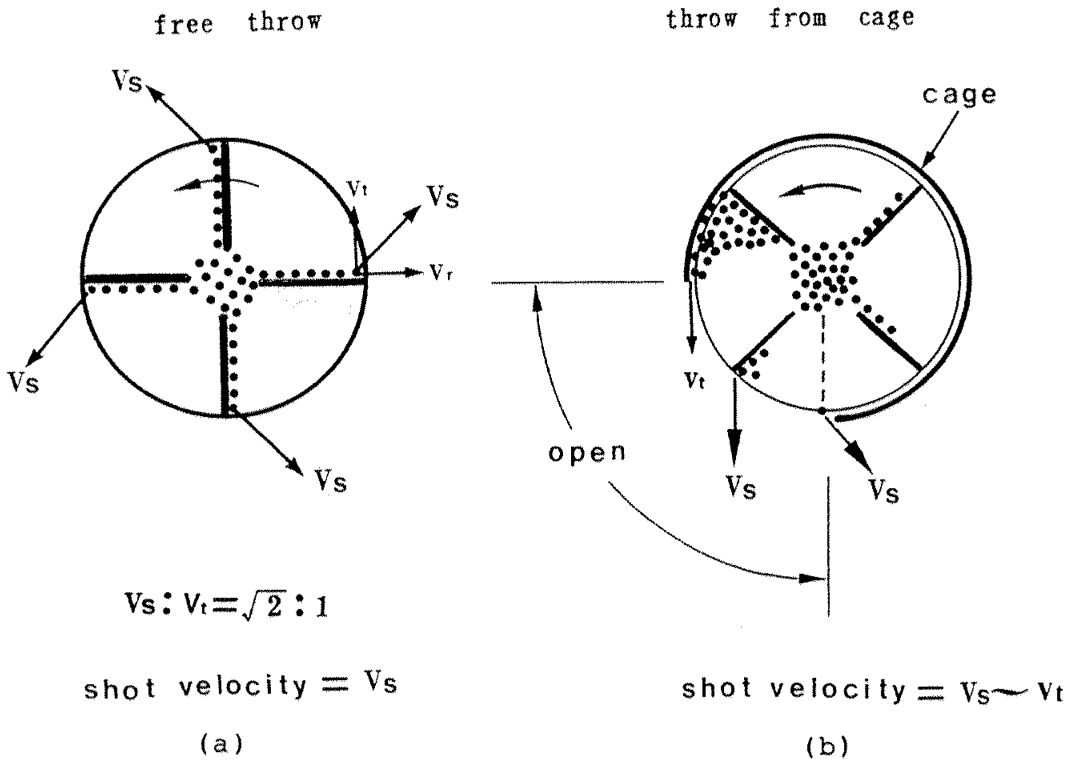
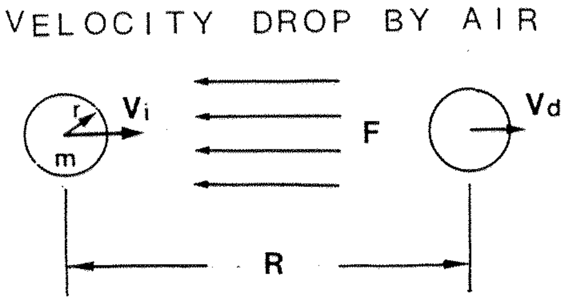


Fig. 3. Shot velocity thrown from bladed wheel
(a) free throw, (b) throw from cage.

5. VELOCITY DROP BY AIR RESISTANCE

Flying pellet or object is received resistance from air, then the relation between the ratio of velocity drop and flying distance obtained as formula (3) from the equation of motion of shot (as sphere) as shown in Fig. 4 and from similar process.



$$m\frac{dv}{dt} = -F \qquad F = Cd \cdot A \cdot \frac{1}{2} \cdot \rho_a \cdot V^2.$$

Fig. 4. Air resistance for flying shot (sphere)

$$\int_{V_i}^{V_d} \frac{m}{V}\, dv = -C_d \cdot \pi r^2 \cdot \frac{1}{2} \int_0^R dx$$

$$\log \frac{V_d}{V_i} = -\frac{3}{8} \cdot C_d \cdot \frac{\rho_a}{\rho_s} \cdot \frac{R}{r}$$

$$R = -\frac{8}{3} \cdot \frac{r}{C_d} \cdot \frac{\rho_s}{\rho_a} \cdot \log \frac{V_d}{V_i} \qquad (3)$$

Example: 10% speed down distance of flight R is

$V_d = 0.9 V_i$, $C_d \fallingdotseq 1$, $r = 0.5\,mm$,

$\rho_s = 7.8$ (steel), $\rho_a = 1.29 \times 10^{-3}$ (air)

$R = \frac{8}{3} \times 0.5 \times 7.8 \div 1.29 \times 10^{-3} \times (-0.046)$

$= 0.371\,m$

6. CONCLUSION

Theoretical shot velocitys were obtained from the equation of motion of shot as sphere. Formula (1) is for air pressure type. Formula (2) is for centrifugal type. Formula (3) is the relation of ratio on velocity drop and flying distance.

REFERENCE

1. Iida K and Miyazaki K, Peening Effect on Flow Resistance of air, Proceedings of ICSP-4, 73 - 82, 1990.