The probable parameters evaluation of shot flow and the its indentation field at the shot treatment
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The necessity of the accounting reciprocal impact of the incident and rebounding shot from the finished surface is presented, it limits the efficiency of the shot-casting or pneumatic grit blasting treatment. The offered model of random pellets distribution in the shot flows and in the field of the indentations that are inflicted by these pellets, has permitted to give the parameters evaluation of shot treatment and the probabilities of the pellets reciprocal impact.

The experience and the researches in the shot treatment field show that the increasing productivity and efficiency is limited for a variety of reasons, including the partial shielding of the incident shot flows by a rebounding one. Under such conditions the part of shot energy are expended on the reciprocal impact, the abrasion and the split of the shot before it gets to the finished surface. The higher the density of the shot flow the stronger the effect is, especially at little angle counting from normal to the surface (barrier).

Accepted Poisson distribution of the shot, for example, in the incident flow can be characterized by (1):

\[
\lambda_0 = \frac{q_0}{mU_0},
\]

where \(q_0\) - is the specific shot consumption; \(m\) - is the mass of pellets; \(U_0\) - is their velocity:

- the average probability of pellets number \(a_0 = \lambda_0 V\) in the volume \(V\):
- the location probability of even one pellet in the specified sphere with radius \(r\):\n
\[
P_0 = 1 - \exp\left(-\frac{4}{3} \pi r^3 \lambda_0 \right);
\]

- the probability of distance between nearest pellets \(r_\theta = \left(\frac{2\pi \lambda_0}{3}\right)^{\frac{1}{3}}\).

The indent distribution on the processable surface we also considering as Poisson distribution with parameters:

- the surface density \(\lambda_s = \frac{q_0 \cos \alpha}{m} t\)
where \( t \) is processing time;
- the average probability of indents number \( a_s = s\lambda_s \) in the surface square \( S \);
- the hit probability of even one indent in the specified circle with radius \( r \).

\[
P_1 = 1 - \exp\left( -\frac{4}{3}\pi r^2 \lambda_s \right);
\]

(2)

- the probability distance between nearest pellets \( r_a = \left(2\pi \lambda_s \right)^{-\frac{1}{2}} \).

Choosing the indent square \( \pi r_{ind}^2 \) as the aim of hit we will get the probabilities (or degrees) of single covering

\[
\psi_1 \approx P_1 \approx 1 - \exp(-a_{s\,ind}),
\]

(3)

probabilities of twofold covering

\[
\psi_2 \approx P_2 \approx 1 - (1 + a_{s\,ind})\exp(-a_{s\,ind}),
\]

(4)

probabilities of threefold covering

\[
\psi_3 \approx P_3 \approx 1 - (1 - a_{s\,ind} - \frac{a_{s\,ind}^2}{2})\exp(-a_{s\,ind}),
\]

(5)

probabilities of multifold covering

\[
\psi_n \approx P_n = 1 - \sum_{k=0}^{n-1} \frac{a_{s\,ind}^k}{k!} \exp(-a_{s\,ind}),
\]

(6)

including the early equation for covering degrees that was obtained by M. Saverin.

\[
\psi_1 = 1 - \exp\left( -b_1 \frac{a_{s\,ind}^2 N\cos\alpha}{L} \right),
\]

(7)

where \( b_1 \) - the coefficient of proportionality equal to \( \pi/(4B\mu) \) - for the shot casting treatment and equal to \( \pi/(4\Omega) \) for the pneumatic grit blasting treatment.

\( \mu \) is the dispersal shot angle in the rotor rotation plane of the shot blast unit with width of the window \( B \);

\( \Omega \) is the solid angle of the active cone-shaped part of the shot front edge under pneumatic grit blasting treatment.
On the fig. 1 are the diagrams (3)-(6) that demonstrate quite definite dependencies between covering degrees of different repetition factor (or between one-fold, twofold, threefold and more one) under average specified probable number of the shot hit of its own indent square.

Fig.1 shows that the appropriation of the single covering degree $\psi_1$, which is near to one (for example 0.999) obtaining under $a_{s\text{ind}} \approx 7$, as a matter of fact means that the twofold covering degree ($\psi_2 = 0.998$), the threefold covering degree ($\psi_3 = 0.974$) and even the fourfold covering degree ($\psi_4 = 0.919$) are also near to one. Also the appropriation of the twofold covering degree $\psi_2 = 0.8$, obtaining under $a_{s\text{omn}} \approx 3$, as a matter of fact means that $\psi_1 = 0.995$; $\psi_3 = 0.58$; $\psi_4 = 0.35$ etc.

On the base of the previous data the equations for any multifold covering degrees in dependence from the common shot consumption $G = a_0Stcosa$ for the treatment of square $S$; the equation for the single covering degree was obtained in particular (fig.2)
\[ \psi_t \approx 1 - \exp\left( -\frac{\pi r_{ind}^2}{S} \cdot \frac{G}{m} \right). \] (8)

The probability equation of the fact that the incident pellets will be misled though once by the pellets of the reflected shot flow was obtained under consideration between the incident and reflected shot flows interaction

\[ P' \approx \exp\left( -\pi D^2 \alpha_0 \frac{\cos \alpha}{\sin(\alpha + \beta)} x \right) \cdot \frac{\cos \beta}{\sin(\alpha + \beta)} x \leq L, \] (9)

where

- \( D \) is the diameter of the pellet,
- \( \beta \) is the reflection degree of the shot /2/,
- \( x \) is the depth of the treatment front.

![Fig.2](image)

Fig.2. The dependence of the single covering degree \( \psi_t \) in dependence from the common shot consumption with different indent radius \( m = 0.014 \, g; S = 0.01m^2; q_0 = 10 \, kg \cdot m^{-2} \cdot c^{-1}; \alpha = 15^\circ \): 1- \( r_{ind} = 1 \) mm; 2- \( r_{ind} = 0.6 \, mm \); 3- \( r_{ind} = 0.4 \, mm \); 4- \( r_{ind} = 0.2 \, mm \); 5- \( r_{ind} = 0.1 \, mm \).

Calculating in the practice parameters on the equation (9) shows that the probability of the shot impact is great enough that is why it has to be allowed as a factor that limits the efficiency of the shot treatment.
The received equations are validated by authors and other researchers experiments and allow to clear out the relationship between the shot flow parameters and the indents distribution parameters along the processable surface and also to allowance the rational value to the settled shot treatment efficiency.

Summary
1. The increasing of the productivity and the efficiency of the shot treatment is limited by the partial shielding of incident shot flows by rebounding one, especially at the little incident angle and at the high density of the shot flow.
2. Setting the aim to evaluate that effect, the distribution in the incident and reflex shot flows is laid in account as the Poisson distribution. That allowed to obtain the quantitative evaluations of the shot flow parameters and the shot indents field. It is - the volume density, the surface density, the average probability of pellets number in the volume or the average probability of indents number in the surface square, the hit pellets probability in the specified volume or the hit indents probability in the specified square, the shot consumption, the treatment time.
3. The analytical equations were obtained to give an opportunity to define and to compare the quantities of the one-fold covering degrees between the multifold covering degrees by indents of the treatment surface under specified flow density, treatment time, indent square and est.
4. Calculating the impact probability of incident and reflex shot verify that it is the factor that has an important influence on the limitation of the shot casting (blasting) efficiency growth.
5. The results of the account by presented equations are validated by the authors and other researchers experiments and allow to clear out the relationship between the shot casting (blasting) parameters to define the way of increasing that treatment efficiency.

Key words: the pneumatic shot blasting, the shot casting, the shot indent probability, probable distribution of the shot ant its indents, the one-fold covering degree, the multifold covering degree, shot consumption, time of treatment.

References