About the Influence of Different Separation Systems on Shot Peening Treatment

H. Kreikenbaum, G. Fischer AG,Branche Strahlmaschinen
Schaffhausen, Switzerland

In the past, the importance of separation in shot peening processes very often has not received the attention that would have been necessary. Regarding the demand to keep constant the main parameters influencing the shot peening process, we recognize that the separation is situated in a chain of parameters and that we have to draw our attention not only to the separation process, but also to the continuous supplying of new shot if we want to keep constant the particle distribution of the shot working mixture. In figure 1 you can see furthermore the well known fact, that in order to keep constant the intensity, you have to control the wearing of shot acceleration elements and guide elements.

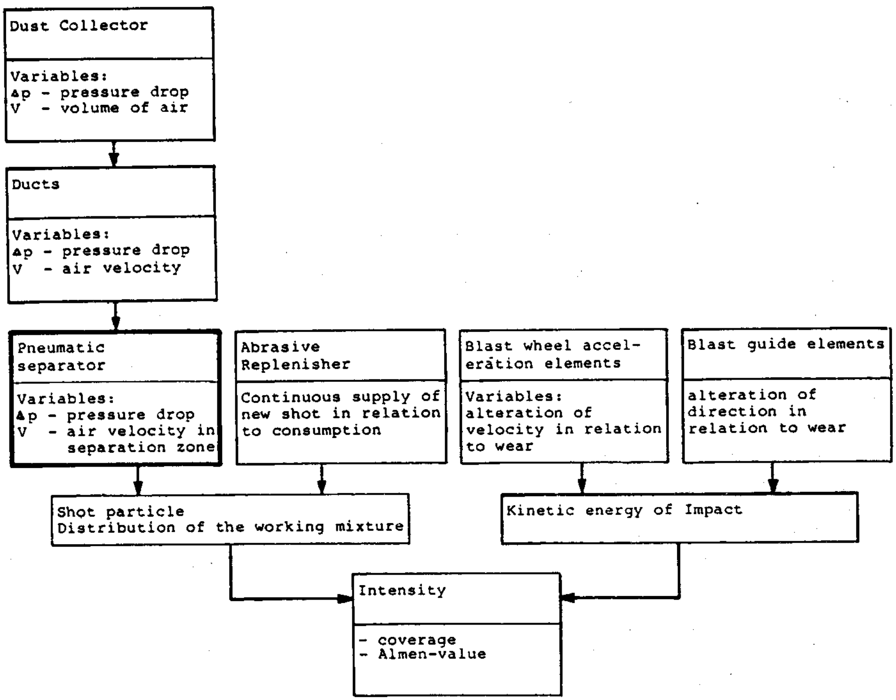

Figure 1: Chain of parameters effecting intensity

In this paper we will draw our attention only to one element of this "Chains of Parameters" affecting the intensity: the pneumatic separator devices. First a short survey on the system: Pneumatic Separators can be divided into two principal groups:

Systems, basing on gravity and those where centrifugal forces are used for separation, figure 2.

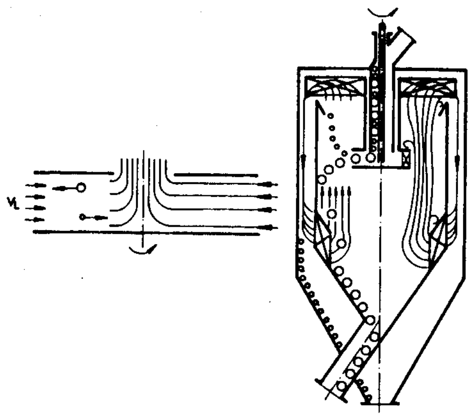

Figure 2a:
Scheme of centrifugal pneumatic separator

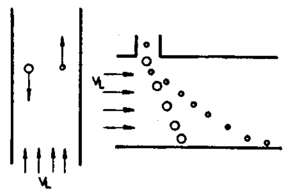

Figure 2b:
Scheme of gravity pneumatic separators

The fact that most of the applications in the shot peening industry are working with gravity puts our interest on this type. Pneumatic separators based on gravity can be divided into two groups, depending on the relation of motion between air flow and shot in the separation zone:
1. cross-flow type separation
2. counter-flow type separation

The working scheme of both types is shown in figure 3.

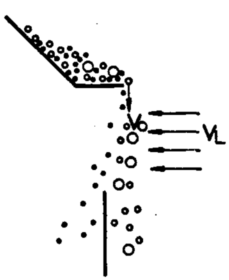

Figure 3a:
Cross-flow type separator, scheme

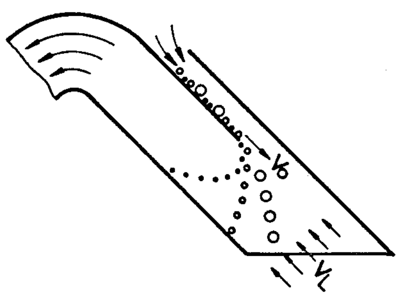

Figure 3b:
Counter-flow type separator, scheme

Cross flow type separators

This type of pneumatic separator is specified by a separation zone where the shot falls through vertically. The gravity causes an acceleration of the shot from zero on the top to the maximum velocity at the bottom of the separation zone. Caused by this acceleration, the porosity of the shot curtain in the separation zone becomes lower inversed proportional to the particle velocity and so the pressure drop over the height of the curtain changes, too. The local volume flow is varying with the third power of the porosity and so we find quite different conditions in the separation zone from the top to the bottom.

The particles are deviated more or less depending on their sedimentation velocity. And this sedimentation velocity depends on parameters as particle size, specific weight of particles, particle form, viscosity of the air, influence of other particles (neighbours in the curtain, porosity of the curtain).

Counter-flow type separator

The particle mixture slides down on a chute with about 40° and is hereby pre-accelerated. On the slide way the smaller particles of the shot mixture are sliding near the ground of the chute. The bigger particles are sliding on the top. This effects a pre-separation on the chute, so that in the separation zone most of the smaller sized particles must not be transported through flight paths of bigger sized particles.

Depending on the length of the slide way, the particle entrance velocity Vo in the separation zone changes and is much higher than of cross flow type separators. In view of the sliding velocity the porosity of the curtain is already lower, particles are disaggregated and the influence of neighbour particles on the sedimentation is lower than in cross-flow type separators especially at the top of the separation zone. Compared with cross-flow type separators, the particle entrance velocity is higher in the separation zone and demands a higher air velocity and consequently a higher pressure drop. Thus a certain technical limitation is given, for in normal cases separators are integrated in the dust collecting system of the complete machine and here the maximum pressure drop often is limited by other circumstances. In counter-flow type separation systems the air stream penetrates the curtain at an angle of approx. 150°. With this angle the fine sized particles are completely deviated from their original path of motion, figure 4.

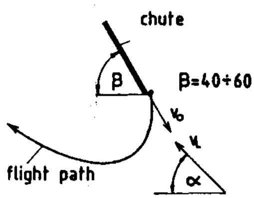

Figure 4a: Counter-flow type, principle

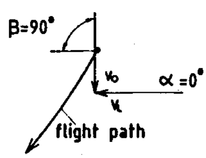

Figure 4b: Cross-flow type, principle

In cross-flow type separation systems the particle deviation is significantly smaller. Caused by the important deviation of the particles the curtain is faned out much wider with counter-flow type separators compared to cross-flow systems. This fact is evident not only for the separation accuracy, but also for the sensitivity to throughput variations and adjustments.

Figure 5 shows the vector diagram of forces and velocities of a particle valid for a counter-flow system. This vector diagram is valid for cross-flow separation, too, but in this case, values and directions of the vectors are modified in accordance with the other physical conditions.

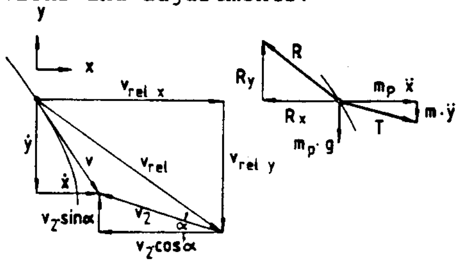

Figure 5: Vector diagram of forces and velocities

With an equation system which can be deducted from the vector diagram, the flight path of the particles in the separation zone can be calculated. If the following idealised boundary conditions are assumed:

1. The flight paths of the particles are situated in a plane in a two-dimensional unlimited stream field
2. The stream is stationary and with unlimited dimensions
3. Air velocity, air temperature, air density and viscosity are constant in the registered field
4. The particles have the form of a mathematical ball
5. No influencing of the particles between each other during the flight
6. The influence of the border of the separator is negligible

then the following equation comes out:

$$T = m_p \cdot \frac{d\vec{v}_p}{dt} = V_p \cdot (\varrho_p - \varrho_L) \cdot \vec{g} + \vec{R}$$

whereby

v_p = flight path velocity
m_p = particle mass
ϱ_p, ϱ_L = particle density, air density
V_p = particle volume
g = gravity acceleration

and

$$|\vec{R}| = \gamma \cdot \frac{\varrho_L}{2} \cdot A_p \cdot \vec{V}_{rel}^{\,2}$$

whereby

$\vec{\psi}$ = air resistance factor
$V_{rel.}$ = relative velocity between particle and air
A_p = projection area of particles

Splitted in the x and y components the equation is:

$$m \cdot \ddot{x} - R_x = 0$$

$$-m \cdot g - m \cdot \ddot{y} + R_y = 0$$

whereby Rx, Ry are components of R

This greminated differential equation of 2nd order is not integrable analytically, but the numerical integration is possible. We made it with the Runge-Kutta-Nyström integration process.

The particle flight paths have been calculated with different parameter combinations, this especially for having an impression of the specific influence of every parameter.

Here we cannot discuss the influences of all these parameters in detail, only some of the main results are shown in figures 6, 7.

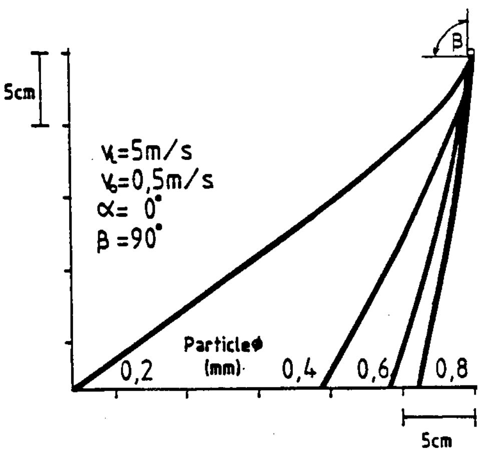

Figure 6: Cross-flow type, principle

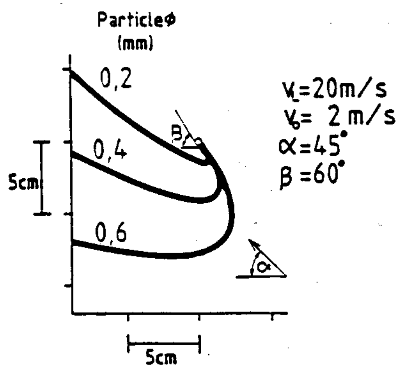

Figure 7: Counter-flow type, principle

For counter-flow type separators we need, in general, twice the air velocity of cross-flow systems.
The counter-flow system is much more independent against varying specific curtain density in the separation zone. This fact is important if you are working with discontinuous machines where the shot flow value changes.

Both types, cross-flow and counter-flow separators have been built in a lot of different models with one or more separation zones. Those types with more than one separation zone can be useful if there are great quantities of fine sized particles in the circuit, but this condition normally is not given in shot peening applications.

The main problem we found investigating this type of separator with more than one lip has been that in every separation zone the curtain density and perhaps even the particle velocity changes. And that demands a separator, enabling you to vary the air velocity from separation zone to separation zone if you do not want to work empirically.

Speaking about separators for shot peening machines, the importance of the separation accuracy of the system should be mentioned.

Every mechanical separation process is caracterised by the accuracy with which the bigger and finer sized particles are separated, figure 8.

The position on the separation line indicates not only the quantities in which a specific particle diameter is fractioned, but also the probability with which the particle flys in the bigger or smaller sized fraction. This probability is valuable for one throughpass through the separation zone. Normally the shot can be used for 2'000 to 4'000 cycles.

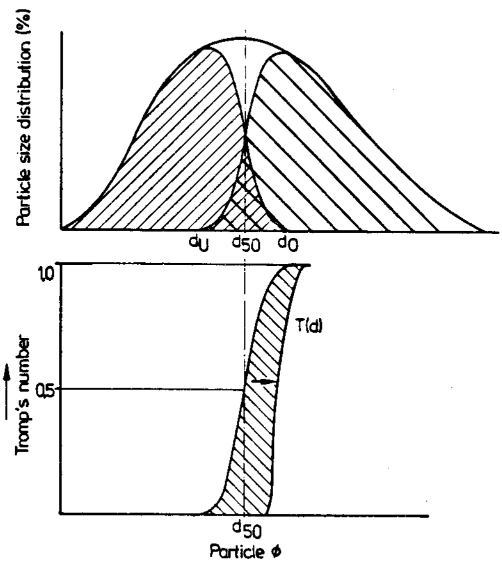

Figure 8: Separation accuracy

Consequently the separation line for the working separator on the machine is moved more or less depending on the relationship between shot consumption ("production" of fine particles) and capability of the system to extract these fine particles and feeding conditions of the new shot mixture.

In the past few years, some people started sieving the shot in the circuit instead of working with pneumatic separation systems. In principle they envisaged reaching two things:

1. to be sure that no big particles enter the circuit so that the maximal roughness of the workpieces can be guaranted and the roughness influence of the surface can be controlled. This seems to be the main task justifying working with sieves

2. eliminating the undersized particles out of the working mixture. This second task can be realized easily with a second integrated floor in the vibrating sieve

Advantages of working with sieves are:
. particle size distribution is independent from pressure drop in the dust collector
. no particles in the circuit which are too big

Disadvantages of working with sieves:
. they have to be controlled periodically and to be changed accurately
. if the sieves are destroyed, the shot can leave the circuit quickly

. the particle size distribution changes with the wearing of the sieve
. sieves can jam continuously and the function to extract the under-sized particles is jeopardised

Conclusion

From the comparison of the separation systems used today in shot-blasting technology we draw the following conclusions:

. Pneumatic counter-flow separation systems seem to be more appropriate than cross-flow systems as regards accuracy of separation and indifference to fluctuations of operating parameters.
. Multi-step pneumatic separation systems are not necessary for shot-peening applications, because usually there are no great quantities of impurities.
. Multi-step systems have the disadvantage that the air velocity of the individual steps often cannot be adapted, so that generally one cannot adjust them reliably.
. The use of sieve stations have the advantage that separation of the big sized shot is reliable and the disadvantage of more maintenance.
One can therefore assume that their use will not spread too much in the next years.

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