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Polyphasic dynamics in pneumatic transport. A review

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Abstract

A special field of fluid mechanics is the study of ***the dynamics of polyphasic fluids,*** attached ***to pneumatic transport*** operation. ***The "mechanical" displacement, polyphasic*** (the relocation in time and space of a mobile under the mutual action or of the forces that generate the movement), has as object of study the phenomenon(s) of flow, the action of mixtures on solid bodies at the contact interface, the energetic changes determined by the transformations that intervene in the flow of the polyphasic environment in which the interactions between the constituent phases are involved. Pneumatic transport moves granular/powdered materials by engaging them in a gas current (frequently air). In industrial applications, the system proved to be economical, presenting several advantages: **1.** constructive simplicity; **2.** barrier to contamination of materials of food technological interest; **3.** the possibility of automation and ease of operation and maintenance. Used intensively in the milling and bakery industry, but also in other food technologies where granular and/or powdery materials are circulated.

Keywords: pneumatic transport, fluid, polyphasic medium, bulk materials, granulometry, the principle of operation

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1. Introduction

Pneumatic transport installations are widely used in almost all industrial fields (chemistry, pharmaceutical, *food,* etc.), for the *transport of granular and/or powdery materials with moisture limits* (dry). The study and observation of the behaviour of fluids (fluid *mechanics),* at their flow limited by a solid contour (pipes), determined their adoption in the circulation of solid food materials, limited by the size *(grain size)* and geometry of the material [1].

The word ***pneumátic*** has the following meanings: about machines, apparatus, machinery, etc.; which operates with compressed air; which is used to compress or move air; part of the physics that studies the properties of air and other gases. [Pr.:*pne-u-*] – from fr. *pneumatique***,** lat. *pneumaticus***,** it. *Pneumatico* [33].

From the constructive-functional point of view, they are simple, with a minimum of moving organs; they require small spaces, horizontal/vertical displacement, high transport capacity, hygiene conditions and safety in operation [2, 3].

For example, 70% of the raw and auxiliary materials involved in the manufacturing process are in the form of granules, powders or dust. However, the design of new installations, machinery, equipment, transport lines is limited (40% of the productive volume) [4]. This shows the shortcomings of proper knowledge in the field of sizing and designing of pneumatic transport, which at first glance seems simple. Solving these issues involves the ≈ collaboration of three interconnected fields (Fig. 1).

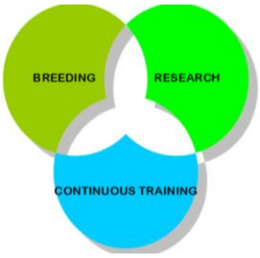

Figure 1. Knowledge, study and solution of an engineering problem.

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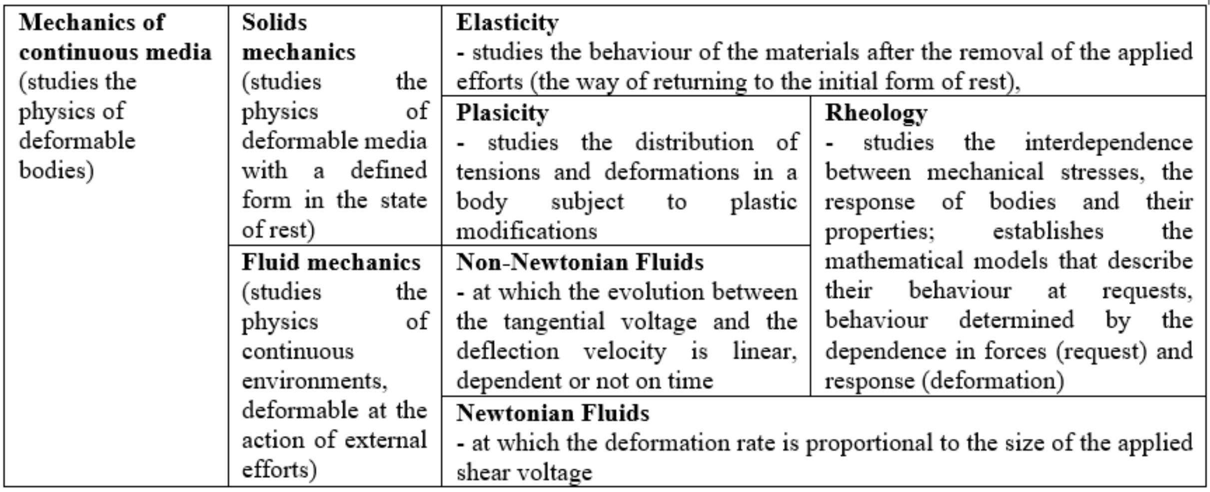
The development and implementation of the manufacturing of new products are also dependent on the mutual interactions between the components and their effects, as handling and transport units, neglected at the stage of sizing and subsequent design of the new production lines. It is important to know the behaviour of the material to establish the characters and manifestations under the differentiated action of the forces.

Evolution. The study of the manifestations/interactions of a *polyphasic* medium/fluid is not recent: **a)** *iv-iii century A.C.*: Alexandria School: *Cestibius* and *Hero* – make contributions to the study of soda and push pumps; Rome: *Sextus Julius Frontinus* – studies on the influence of nozzles when passing a water flow and the way of water distribution in aqueducts and wells [5, 6, 7]; **b)** *XIXth* century: *Stokes* and *Reynolds* – carry out research on the movement of viscous fluids and the way of moving solids in fluid current; ***1847*** – the first written documentation about the movement ***of solids in pipes*** (Peugeot applies the principle of pneumatic transport for dust evacuation with the help of a fan (exhauster)) [5, 8, 9];**c)** *XXth* century: *Prandtl* – establishes the laws of fluid movement in the boundary layer; *Blasius* - carries out studies on hydraulic resistances to the movement of fluids in smooth pipes; *Nikuradse* – consists of the diagram of hydraulic resistances in pipes, which also bears his name; *Batchelor*, *Truesdell*, *Bogardi*, *Nuntiato*, *Drew* – lay the ***foundations of the mechanics of polyphasic fluids*** [5, 10]; ***1958*** the first attestation in our country (the „*Furnica*” mill, Bucharest) [1]. *Advantages:* the ability to transmit energy over long distances with good efficiency; high force amplification ratio *(Pascal* principle); small gauge installations compared to mechanical ones, but performing the same functions. It can be said that pneumatic transport is an efficient means of transport for the group of granular/powdered materials (bulk *materials).* The displacement of the fluid environment is defined *by the impulse transfer* under the effect of the external forces *generating flow* and *energetic transformations, energetic* on an imposed route. The domain belongs to *the mechanics of continuous media,* which treats the model at the macro level with information from the microscopic level. The field is an active one, of *interdisciplinary research,* with problems that involve a careful information in solving the applicative casuistry (Table 1) [5, 11, 12, 13, 14].

Table 1. Interdisciplinary relationships in the field of continuous environments [5, 11, 12, 13, 14].



<table>
<tr><td rowspan="4">Mechanics of continuous media (studies the physics of deformable bodies)</td><td rowspan="2">Solids mechanics (studies the physics of deformable media with a defined form in the state of rest)</td><td colspan="2">Elasticity
- studies the behaviour of the materials after the removal of the applied efforts (the way of returning to the initial form of rest),</td></tr>
<tr><td>Plasicity
- studies the distribution of tensions and deformations in a body subject to plastic modifications</td><td rowspan="2">Rheology
- studies the interdependence between mechanical stresses, the response of bodies and their properties; establishes the mathematical models that describe their behaviour at requests, behaviour determined by the dependence in forces (request) and response (deformation)</td></tr>
<tr><td rowspan="2">Fluid mechanics (studies the physics of continuous environments, deformable at the action of external efforts)</td><td>Non-Newtonian Fluids
- at which the evolution between the tangential voltage and the deflection velocity is linear, dependent or not on time</td></tr>
<tr><td colspan="2">Newtonian Fluids
- at which the deformation rate is proportional to the size of the applied shear voltage</td></tr>
</table>

Fluid mechanics can generate a complex of equations, relationships, numerical constants, which can be solved mathematically and/or computationally. This led to the emergence of a new field of problem solving, of a dynamic order, called: "*Computational Analysis in Fluid Dynamics*"(Computational Fluid Dynamics (CFD) = imaging analysis) [15].

Terms of definition: **1.** ***material body*** – matter organized in a form defined by the structural characters of form and manifestation at the action of external stimuli; **2.** ***continuous environment*** – material body, conditioned by time, fully occupies a domain of space and which allows the establishment of a relationship between pairs of elements formed from each point of space and the centers of mass of the material body; **3.** ***displacement of the***

continuous medium – sequence of possible conformations present at the movement of particles as a whole; **4.** ***fluid*** – a material body that supports continuous deformation under the action of forces of low intensity, homogeneous and isotropic, characterized by the property of flow; it does not have its own form; also known as *monophasic fluid* or *fluid phase;* the intermolecular cohesion forces have low values, but sufficient to maintain contact between molecules; the two states (liquid, gaseous), are perfectly elastic to compression efforts, and the laws of fluid mechanics are valid for both states conditioned by reduced volume changes in the movement of gases [4,12,14, 16]; **5.** ***fluid particle*** – extension/similarity of the notion of material point; portion of fluid of arbitrary shape that preserves the proprieity of the continuous environment; the characteristic physical magnifications (speed, acceleration, pressure, density, viscosity, temperature, etc.), attached to the fluid particle, at the time t_0, correspond to the center of mass of the particle determined in the time interval Δt; for representation, established experimentally, the notion of *elementary mass* was attached (***dm***), *the elementary volume* (***dV***), of arbitrary geometric shape (tetrahedron, parallelepiped, cylinder, sphere, etc.) [4, 5, 11]; **6.** ***phase*** – part of a heterogeneous system separated from another by a continuous surface or a number of surfaces; in general, the term refers to the environment that ensures the fluidity of the dispersing system; **7.** ***polyphasic medium*** – a mixture consisting of two phases of different states (gaseous, liquid, solid); it proves that in nature there is no homogeneous and isotropic fluid, with some exceptions (pure water, liquids of analytical purity); **8.** ***polyphasic fluid*** – continuous, inhomogeneous and non-irysotropic medium characterized by the property of flowing, as a result of the immimable mixture between media with different aggregation states (liquid-solid, solid-gas, liquid-gas).

A ***gas-solid polyphasic*** fluid consists of: **a)** *the gas phase* - the continuous dispersion medium, *the utility carrier* (motor phase); **b)** *solid phase* – dispersed medium (transported phase). So, *the polyphasic fluid* is a material system dispersed in a single-phase fluid (liquid or gas), separated by continuous surfaces. Under certain conditions, the constituents may react chemically (flocculation processes, coagulation, precipitation). In a defined space, the presence of polyphasic fluid is conditioned by: **1.** the three-dimensional space;**2.** if the fluid particle, ***M***, belongs to the domain occupied by the continuous fluid phase;**3.** if the fluid particle, ***M***, belongs to the domain in which the dispersed phases are found, then ***M*** belongs to the dispersed phase [16, 17].

2.Method

Methods of study [5, 12]: **1.** *theoretical* – based on principles, theorems, laws, physical-mathematical relationships; involves the formal identification of equations differentiating them for the different processes/physical phenomena that govern the reference; **2.** *experimental* – consists in the reproduction of a real natural phenomenon at a convenient scale in the initial and final states, with the purpose of identifying general laws of phenomena, verifying theoretical conclusions, introducing correction factors, solving problems that cannot be solved theoretically; **3.** *mixed* – the result of the combined application of the two methods mentioned above.

3.Discussions

From the point of view of impulse transfer operations, in the case of pneumatic transport of solid granular/powdered materials, is necessary to define some notions and ***principles*** (constraints, influence factors), which govern the phenomenon.

Bulk materials. It conditions the choice of machine characteristics according to the granular dimensional structure/distribution, cossection, density, temperature. They are granular materials, dimensional different, defined by particle size *analysis.* This determines the percentage of granules of different sizes in the mass of the product by successively passing through a series of mesh sieves arranged descendingly. In the case of granules below 0, 1 mm, the fractionation is carried out based on the difference in sedimentation rates. The extreme sizes, the relative proportions, the distribution of the granules in the mass to be transported, determine the choice of the characteristics of the machine. *The particle size*, the largest of the three dimensions (length, width, height) of the parallelepiped that can inscribe the particle [1, 3, 18] is determined. Bulk materials fall into two broad categories: **1.** *unclassified* for which the ratio of the largest to the smallest particle is greater than 2,5; **2.** graded for which the ratio of the largest and the smallest particle is less than or equal to 2,5, including materials of a single size; they are defined by their maximum size (d_{max}) and minimum size (d_{min}) [1, 3, 18, 19, 20, 21].

Another classification model is conditioned by the size **d'** (characteristic width grain) (Table 2) [18,19].

Table 2. Classification of bulk materials according to the characteristic grain size d' [18, 19].

Tip material	Characteristic grain d' [mm]
Small size pieces	d' >160
medium-sized pieces	60 < d' <160
Petty	10 < d' < 60
granular	0.5 < d'<10
powders	d'<0,5

Cohesion. Characteristic size in the pneumatic transport, having as a determining element, the angle of the *natural slope* (sliding) [1, 18, 19, 20]. *The natural slope* (Fig. 2), expression of the friction forces in the dulls, is defined by the angle, formed ***α*** by the horizontal and the slope generated by the particles of material in constant free fall, from a predetermined height, on a flat surface [1, 18, 19, 20, 22].

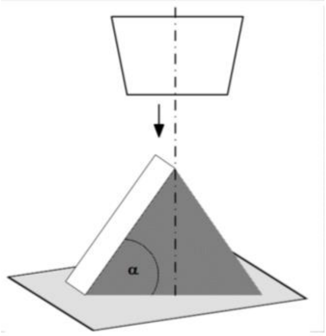


Figure 2. Natural slope.

Depending on the size of the natural slope angle, **α.** a classification of the material particle characters was elaborated (Table 3) [3, 4, 18, 19].

Table 3. The character of the particles of the material according to the angle of the natural slope α [18].

Conventional sign	Material character
1	can diffuse in air and can become as fluid as a liquid
2	very fluid (α 30≤°)
3	fluid (30 < α < 45°°)
4	less fluid (45 a 60°≤≤°)
5	compost (α > 60°)
6	does not slip and forms the vault

The principle of the operation is based on the analysis of the speed of air movement through the *product layer*. We encounter the following cases, depending on the speed of airflow and the direction of travel:

A. ***Vertical*** transport, with the following constraints:

1. *low speed* – the weight of the product mass opposes the airflow force; the displacement does not occur, the layer is immobile; the air travels through the spaces between the solid, ⇒ fixed charged layer (Fig. 3) [3, 5, 16, 17, 23];

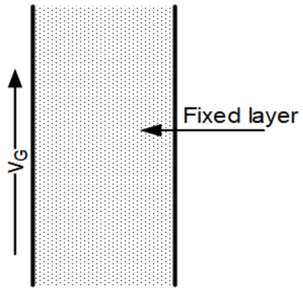


Figure 3. Evolution of granular layer in vertical transport. Unde: VG – gas velocity in pipes, [m/s] [16, 17].

2. *balance between the force generated by the airflow rate and the weight of the solid – the size of the* force determines the floating of the solid part = the *initiating of the fluidization* characterized by the floating speed ($\mathbf{v_P}$), of the solid particle. The formation of the fluidized layer is directly influenced by the coefficient of resistance to progress ($\mathbf{C_R}$) of the suspended solid particles, limited by the degree of aggregation of the particles [17]. The minimum and maximum values of $\mathbf{C_R}$ define two classical models of fluidization: **a)** *particular fluidization* – characterized by high values of the ratio of the densities of the two components (gas-solid), at relatively low speeds; **b)** *aggregator fluidization* – the ratio of densities has a low value at relatively high gas flow speeds [5, 16, 17, 23];
3. *the airflow rate defeats the weight of the particle* – the space between the particles increases; an increase in volume appears; the movement is disordered; the friction occurs, which causes the reduction of the airflow rate; the displacement does not occur; the particle returns to the initial layer, but with the change of the homogeneous⇒*fluidization* position;
4. *the speed* increases, *the force exceeds the weight of the pneumatic* ⇒ ***transport*** particle – the particle is evenly distributed and moves in the air current; the solid speed (v_{s}),is higher than the critical airspeed (v_{cr}).

These considerations are shown in Figure 4, and Figure 5 shows graphically the amplitude of the concentration of solid particles distributed in the fluidized layer, characteristic of pneumatic transport [16].

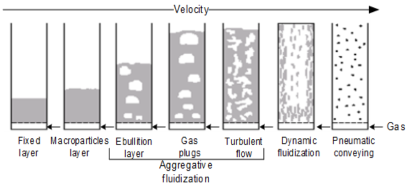


Figure 4. Evolution of the pneumatic transport phenomenon according to the air flow rate [16].

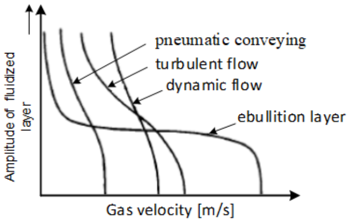


Figure 5. Evolution of solid particle concentration depending on the amplitude of the fluidized layer and the air flow rate [16].

B: *Horizontal transport* with the following phases:

1. *homogeneous flow= homogeneous flux = pneumatic conveying* (Fig. 6) – the airflow rate is high enough to keep the particulate matter in suspension;

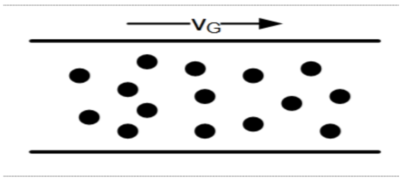


Figure 6. Homogeneous displacement (flow) – ***pneumatic conveying*** (V_G – gas velocity in pipes, m/s).

2. "sand *dune"* type flow (Fig. 7) – transition regime: the speed is reduced (11÷14 m/s) [17, 24]; most of the particles settle according to a pattern similar to sand dunes, and a small part continues to move; the shape of the deposit varies from the characters of the solid;

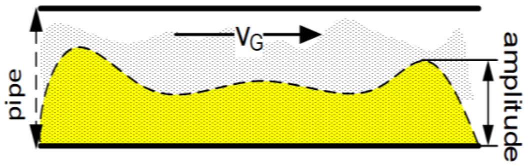


Figure 7. Displacement type "***sand dune***"(V_G – gas velocity in pipes, m/s).

3. flow type "*snail*" (Fig. 8) – further the speed decreases; alternative regions occur where the particles fill the pipe and where they are found in suspension; the displacement flow imitates the shape of *the*"*snail*"; further reduction of the velocity (v<5 m/s), causes over time the formation of a compact layer in which the air moves through the interstitial region of their particles– the phenomenon *of clogging* occurs [17, 24].

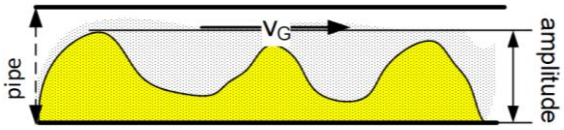


Figure 8. Displacement type "***snail***". Precedes clogging (V_G – gas velocity in pipes, m/s).

The applicability of this phenomenon is, however, reduced, due to the physical characteristics of the phenomenon (high energy consumption of 24 kWh/t produced) [25], conditioned by a series of variables *(speed, the character of the emergency and the rheological* manifestation of the system as *a unit, determining* the concentration of *transport, the optimum speed of airflow* ($\boldsymbol{v_g}$), the critical speed of *transport* ($\boldsymbol{v_{cr}}$), *the regime velocity of the solid* ($\boldsymbol{v_s}$), *temperature and pressure differences that generate changes in the speed, time of ui and acceleration length* of the solid particle). All this requires laborious calculations and raises problems from the perspective of efficiency and economic returns. *The model can be applied to solid, granular or powdery materials, which do not show a tendency to agglomeration and plastic behaviour at flow.* Therefore, pneumatic transport must be adapted for each type of solid, for which the establishment of the optimum flow regime is determined experimentally.

If horizontal and vertical displacement is considered, as independent cases, then the components of the biphasic mixture can be considered as distinct entities and we can independently treat the phenomenon as one-dimensional displacement in time and space. Thus, when moving the solid particle in a fluid current, through a pipe, the following phenomena occur: **1.** the rotational motion of the particle around its own axis; **2.** the displacement in jumps generated by the turbulent flow; **3.** friction pressure loss (particle – solid contour/between particles/between particles /between particles and fluid).This manifestation being conditioned by the flow domain expressed by the criterion of *Reynolds* (Re) (Fig. 9) [5, 16, 23]. Experimentally it was found that the passage of a fluid over a solid body generates a pattern of motion: **1.** *laminar* (Re < 2300); **2.** *turbulent* (Re > 3000); **3.** *transition* (2300 < Re < 3000) [13, 14, 26]:

$$\mathrm{Re} = \frac{w \cdot l}{\nu} = \frac{w \cdot d}{\nu} = \frac{w \cdot d \cdot \rho}{\eta} \qquad (1)$$

where: w – velocity of the fluid, [m/s]; l – characteristic length, [m]; ν – kinematic viscosity, [m/s$^{2]}$; d – pipe diameter, [m]; ρ – fluid density, [kg/m^3]; η – dynamic viscosity, [Pa·s].

The transition from the laminar to the turbulent regime occurs at a critical value, Re_{cr} (Re_{cr} = 2300), corresponding to a critical speed (***w_{cr}***) [13, 14, 26].

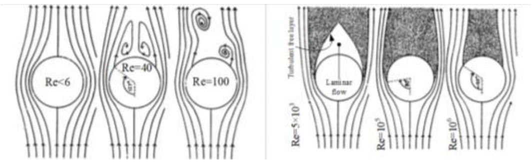


Figure 9. The size of *Reynolds'* criterion and the profile of current lines when passing over a solid body [27].

For Re<6, the flow rate is constant and symmetrical in particle ratio. The fluid lines accelerate towards the middle of the pipe section, where the flow lines are closer and the pressure is at maximum. As the Re increases (Re≅40), the interruption of the current≈line and the separation of the flow lines occur. The lines in the boundary layer separate from the body, with the formation of two vortices, contrary to the rotation of the body. The increasing evolution of the re-value (Re≥100), causes the removal of their body vortices in a downward direction. Above this value occurs with turbulent flow, with the formation of a laminar flow zone in the back of the particle. At very high values (Re=10^5), the turbulent flow occupies a large part of the back of the particle, and when this size is exceeded (Re=10^6), there is a reduction in the intensity of the displacement [27]. The transition from turbulent to laminar is also dependent on the geometry of the particle, with an influence on the flow rate of ui for both flow forms. When the fluid in the boundary layer has exhausted its kinetic energy at the contact surface (cause: dissipation of the local resistance force), it detaches from the it and integrates into the flow.

The transport speed, influenced by the speed of the gas (v_g), necessary for the floating of the particles initially at rest (Fig. 10a), can be defined as the fluid speed necessary to initiate a sliding, moving and floating motion of the particle (Fig. 10b) [28].

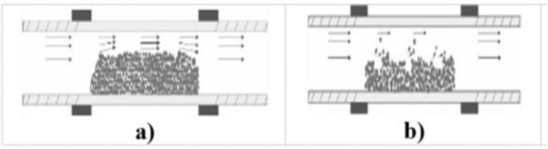


Figure 10. Behaviour of particles in the flow: **a)** the gas velocity is lower than the floating speed; **b)** initiation of the movement of the solid (gas velocity equal to or greater than the floating speed) [28].

In the literature it is stated a series of correlations, relationships, for estimating the critical speeds of taking over and putting into motion of the solid material [29, 30]:

*Rizk (**1976**)*	*Kalman and Rabinovich (**2008**)*
$\zeta = \frac{W_s}{\rho_F \cdot V_S \cdot A} = \left(\frac{1}{10^d}\right) \cdot Fr_S^x$ (2)	$C_V = \frac{\zeta \cdot \rho_f}{\rho_p + (\zeta \cdot \rho_f)}$ (3)

where: Fr – Froude criterion, [-]; d=1.44d_p+1.96, x=1.1d_p+2.5 [mm]; ζ - the concentration of transport of the solid, [-]; W_s - solid mass flow rate [kg/h]; d_p – particle diameter [mm];V_S – the speed of movement of the a solid [m/s];ρ_f - fluid density [kg/m^3]; g – gravitational acceleration [m/s^2]; A – the area of the flow section, [m^2]; C_V – transport concentration, [-];ρ_p – particle density [kg/m^3].

Regardless of the flow range, differences occur between the airspeed (***v_g***) and the speed of movement of the solid (***v_s***), defined by the sliding factor (***f_a***) (values 0,4÷0,9) [1, 5, 21]:

$$f_a = 1 - \frac{v_s}{v_g}\ [-] \qquad (4)$$

For example, for wheat, in pneumatic transport mode, f_a≥0.4 [1, 5, 21].

The distinction is made between the initial concentration (***C_i***) (in the area of formation of the mixture) and the regime (***C_R***), of the solid in the transport zone [5,12]:

$C_i = \frac{Q_s}{Q_g}$ (5)	$C_R = \frac{c}{(1-s)}$ (6)

where: Q_s – solid flow rate, [m^3/h]; Q_g - gaz flow rate, [m^3/h].

For fine granular materials, when ***f_a*** tends to 0, ***C_R***≅ ***C_i*** (***C_R***= ***C_i***=1,67; for wheat, ***f_a***=0,4) [5, 12].

Kinematic dimensions attached to the solid particle:

A. *Variation of the solid velocity on the pipe* section. In order to explain the phenomenon, it is a question of anticipating a route with a constant diameter, of moving the solid particle entrained by the air current (Fig. 11) [5, 31].

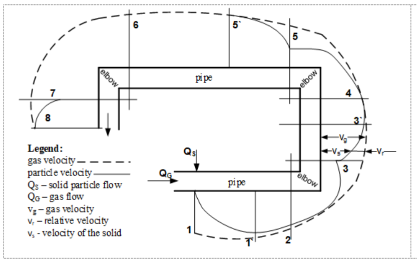


Figure 11.Variation in solid particle velocity in relation to load-bearing medium [after 5].

The movement of the material is made both horizontally (segment 1-2; 5-6) and vertically (3-4; 7-8). On the route are installed three bends consisting of segments (2-3, 4-5, 6-7). So, the velocity of the fluid particle evolves progressively, in jumps, following the route, as follows: **1-1'** – the solid is accelerated from the resting state, at the regime speed; **1'-2** – the relative velocity (***v_r***), of the two media is constant; **2-3** – transition to vertical flow regime, takes place at regime speeds close to 0 m/s; **3-3'**, **5-5'** – the solid is accelerated until the maintenance of ***v_r***.

B. *The regime velocity of the solid* particle, ***v_s*** [m/s], elaborated by *Mschelknauts*, is characterized by the balance of the forces acting on the solid dispersed in the fluid mass, concerning the constant speed of the solid and the uniform distribution of the current lines over the entire section of the pipe [31, 32].

$$\left(\frac{v_g - v_s}{v_p}\right)^2 - \left(\frac{\lambda_z^*}{2} \cdot \frac{v_s^2}{g \cdot D}\right) - \beta = 0 \quad (7)$$

$$v_p = \sqrt{\frac{4}{3} \cdot \frac{g \cdot d}{C_R} \cdot \frac{\gamma_s - \gamma_g}{\gamma_g}} \quad (8)$$

$$\beta = \frac{v_p}{v_g} \quad (9)$$

where: v_g – gas mode rate [m/s], for air, v_g = 2030 m/s; v_s – the rate of the solid particle in the sorb [m/s]; v_p – the floating rate of the particle [m/s]; D – pipe diameter, [m]; d – solid particle diameter, [m]; C_R – resistance coefficient, [-], C_R = 0,42; γ_s - the specific gravity of the solid, [N/m^3]; γ_g – the specific gravity of the gas at atmospheric pressure, [N/m^3], γ_g = 12,9 N/m^3; g – gravitational acceleration, [m/s^2]; λ^*_z – the constant of the mode speed, [-], λ^*_z = 0,0024 0,0032; β - proportionality coefficient, [-].

It is necessary the condition $v<v_g$, as true, of the two solutions resulting from the equation of the second degree.

C. *The analysis of the above statements shows that the length of the pipe on the linear portion must be greater than the length required to accelerate the material, otherwise the phenomenon of clogging occurs.*

D. *Optimal transport speed, **v***. This parameter, is conditioned by the phenomenon of clogging, implicitly by the transport concentration (***C***) and the size of the pressure losses generated by the entire system in motion. The necessary condition for putting the installation into operation is determined by the absence of clogging conditions, which occur mainly in the vertical portions. The optimum speed can take values in the range: v = (1,2÷1,25 m/s)·v_{cr} (v_{cr} – experimentally determined critical speed) [1, 5].

4.Conclusions

By the complex nature of the phenomena that define the flow of a granular and / or powdery solid in a gas current and of the multitudes of variables that intervene in determining the optimal transport speed, it can be stated that only through careful analysis and correlation of all data we can estimate the movement speed of the solid. Thus, it is argued the importance of engineering research in the field of dynamics and dispersion of polyphasic media, a particular case being the transport of solid particles *„suspended”* in a moving fluid. If horizontal and vertical displacement is considered, as well as independent cases, then the components of the biphasic mixture can be considered separately and we can independently analyze the process as a one-dimensional displacement in space. For the analysis of such a problem, it is necessary to apply the general principles of impulse transfer, in a certain time, as part of the mechanics of the fluids that lead to obtaining predictive results. The conditions of formation and dissolution of the structure of a gas-solid biphasic transport mixture under the movement trends of solid particles and gas are brought into consideration. For the characterization of the movement of the biphasic gas/solid mixture, it is assumed that particles that come into contact with the fluid have the same speed, a phenomenon known as „*borderline conditions*”, which compensates for energy loss by friction.

In the evaluation of such a structure, we do not need a multiple solution way concerning the size, amplitude and periodicity of the phenomenon. It is necessary to treat separately, single-phase, the displacement of the fluid current and the movement of the solid particle in the fluid mass.

Compliance with Ethics Requirements. Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human or animal subjects (if exist) respect the specific regulation and standards.

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References

1. Costin, I., *Tehnologii de Prelucrare a Cerealelor în Industria Morăritului*, Ed. Tehnică, **1983**, Bucureşti.
2. Hapenciuc, M., *Sisteme de Transport Hidro-Pneumatic*, Editura Fundaţiei Universitare "Dunărea de Jos", **2004**, Galaţi.
3. Banu, C. et al., *Tratat de Industrie Alimentară. Tehnologii Alimentare*, Ed. ASAB, **2009**, Bucureşti.
4. Bratu, Em., *Operaţii şi utilaje în industria chimică*,vol.I, ed.a-II, Ed. Tehnică, **1969**, Bucureşti.
5. Floarea, J. et al., *Dinamica fluidelor polifazice şi aplicaţiile ei tehnice*, Ed. Tehnică, **1987**, Bucureşti.
6. Datta, B. K. et al., **2003**, A New Design Approach for Pneumatic Conveying, *Annual Transactions of the Nordic Rheology Society*, **2003**, *11*, ISSN 1601-4057, pp. 57-62.
7. Datta, B. K. et al., Influence of Fines Concentration on Pneumatic Transport Capacity of Alumina, *Particulate Science and Technology*, Taylor & Francis Inc., **2003**, *21*(3), 283-291.
8. Datta, B. K. et al., Hole Cleaning and Pressure Loss Prediction from a Bulk Transport Perspective, *SPE International, Society of Petroleum Engineers*, **2005**, SPE 96315.
9. Datta, B.K. and Ratnayake, C., **2005**, A possible scaling-up technique for dense phase pneumatic conveying, *Particulate Science and Technology*, Taylor & Francis Inc., **2005**, *23*(2).
10. Datta, B.K. and Ratnayake, C., Variation of Pneumatic Transport Characteristics of Alumina with Change in Size Distribution, Bulk India 2003 - The *International Conference and Exhibition for Handling, Processing, Storing and Transporting Bulk Materials*, Mumbai, India, **2003**, 9 -11 Dec.
11. Stan Soare, *Procese Hidrodinamice*, Ed. Didactică şi Pedagogică, **1972**, Bucureşti.
12. Floarea, J., Robescu, D., *Transportul hidraulic şi pneumatic*, Institutul Politehnic Bucuresti, **1979**
13. Pavlov, C., et al., *Procese şi Aparate în Ingineria Chimică. Exerciţii şi Probleme*, Ediţia a 8-a, Editura Tehnică, **1981**, Bucureşti.
14. Reynolds, A.J., *Curgeri turbulente în tehnică*, Ed. Tehnică, **1982**, Bucureşti.
15. Blazek, J., *Computational Fluid Dynamics: Principles and Applications*, 2nd Edition, Elsevier Science Ltd., **2005**
16. Green, Don W. and Perry, Robert, H., *Perry's Chemical Engineers' Handbook*, 7th Edition ed., **1997**
17. David Mills, *Pneumatic Conveying Design Guide*, 2nd Edition., Pub. Elsevier Butterworth-Heinemann, **2004**
18. Traşcă, T., I., *Operaţii, Aparate şi utilaje În Industria Alimentară, Operaţii mecanice, hidro- şi aerodinamice*, Ediţia a II-a revizuită, Ed. Eurostampa, **2006**, Timişoara.
19. Jianu, I., Alexa, E. *Tehnologia morăritului, Editura Eurobit*, **1998**, Timişoara.
20. Ersilia Alexa, *Tehnologii de prelucrare a cerealelor*, ISBN 973-620-031-0, Editura Eurobit, **2003**, Timisoara.
21. Hapenciuc, M., *Sisteme de Transport Hidro-Pneumatic*, Editura Fundaţiei Universitare "Dunărea de Jos" Galaţi, **2004**
22. Stoin Daniela, *Tehnologia Morăritului şi Panificaţiei*, Editura Eurobit, **2008**, Timişoara.
23. Floarea, O., Dobre, T., *Inginerie Chimică. Transferul cantităţii de mişcare*, Editura Matrix Rom, **1997**, Bucureşti.
24. Bhatia, A., *Pneumatic conveying system*, **1982**, Course No: M05-010
25. Ioancea, L. şi col., *Maşini, Utilaje şi Instalaţii în Industria Aliemntară*, Ed. Ceres, **1986**, Bucureşti
26. Răşenescu, I., **1971**, *Operatii şi utilaje în industria alimentară*, vol. I, Ed. Tehnică, Bucureşti.
27. Gerard V. Middleton, John B. Southard, *Mechanics of Sediment Movement*, no. 3, Ed. SEPM., **1984**
28. Gomes, L. M. Et. al., On the prediction of pickup and saltation velocities in pneumatic conveying, Braz. J. Chem. Eng., **2014**, *31*(1), 35 – 46.
29. Rizk, F., Pneumatic conveying at optimal operation conditions and a solution of Bath's equation. *Proc. Pneumotransport*, 3, Bath, England, **1976**, 443-58.
30. Kalman, H., Rabinovich, E., Boundary saltation and minimum pressure velocities in particle–gas systems. *Powder Technology*, **2008**, *185*, 67-79
31. Bulat, A., *Instalaţii de transport pneumatic*, Ed. Tehnică, **1962**, Bucureşti
32. Florea, J. şi col., *Mathematical modelling of the hydrodynamic processes of the biphasic fluids das-liquid flow application in the calculus of the turbulent diffusivity*, **1983**, vol. I al Congresului al XX-lea IAHR, Moscova.
33. https://dexonline.ro/definitie/pneumatic