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THE VIZUALIZATION OF THE FLUIDIC FLUXES IN THE MILLS WITH JETS

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Abstract. The visualization of the fluidic jets, as they appear in the mill with spiral jets is essential for the understanding of the physical phenomena that are at the base of the micronization of the particles of all nature (metallic carbides, ceramics, cosmetics, and pharmaceutics). In the paper is shortly presented the necessary drives to realize this demarche, inclusive some experimental results that acknowledge their correctness and their functionality. The obtained information is essential for the elaboration of a mathematical-physical model of the fluidic mills with spiral jets.

Keywords: fluidic mills, spiral jets, microphotography, mathematical model of the mills

1. Introduction

Phenomena that loose in the mills with fluidic jets and the study of the fluid mechanics where not sufficiently explored until now, although these equipments are knew and used for 70 - 80 years.

The purpose of that paper is to investigate the trajectory of the fluidic currents and the behaviour of the particles transported by them, with they interacts, determining very strong collisions. After the collisions the fragmentation is produced, respectively the milling of the particles is realized.

The study of the fluidic flows in the mills with spiral jets represents a fundamental stage in the elaboration of the milling process's mathematical model and for an eventual optimization of the performances of this kind of mills. It must begin from a quantitative study of the fluidic flows in a mill with spiral jets and from a statistic examination of the alimentation flux of the particles.

This is suit by a qualitative research of some properties of the fluidic flux.

It is made a theoretical research using very sophisticated instruments for the fluxes' measurements and it is proposed a mathematical model for the flux, presenting the implications of particular phenomena, discovered in the working of these fluidic mills, bound by a possible optimization of the working.

The experimental study used the photograph with high resolution and velocity, the obtained results being compatible with the theoretical data elaborated on the computer.

The quantitative researches proved that the fluidic flux is very complex and ask for a three-dimensional examination of the different flows that produce the collision effect and inter particles' rubbing. The attention was in focus about the characterization of the flux in the exit area that is much more complex that it is presented in the specialty literature.

2. The methodology of the visualization of the peripheral fluxes

For the realization of these experimental parts it was realized a transparent model (figure 1), of a mill with spiral jets with a milling room of 12", which presents supersonic nozzles for the milling.

The inclination angle of the nozzles from their direction, the nozzles diameter, the alimentation system of the particles and the charge (the powder flow rate) introduced in the mill where chosen conformal the production practice of APTM.

For seeing fluxes it was used a mixture formed from filtrated masut and micronized powder from active coal, with a determinate granulometry with values in the field 1.5 - 3.5 µm.

The consistence of that mixture, very viscous, was chosen with the purpose to present enough resistance to the compressed air fluxes from the mill during the time necessary to make photos of the traces let along the walls.

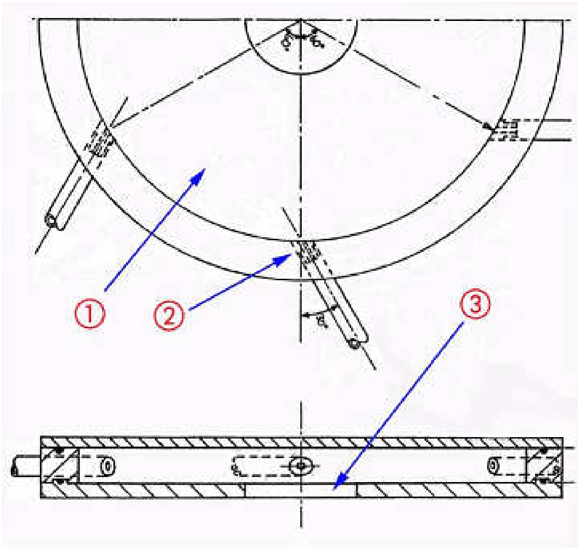

Figure 1. The sketch of the transparent model for the fluxes visualization
1 - milling room; 2 - supersonic nozzles;
3 - central hole for the evacuation

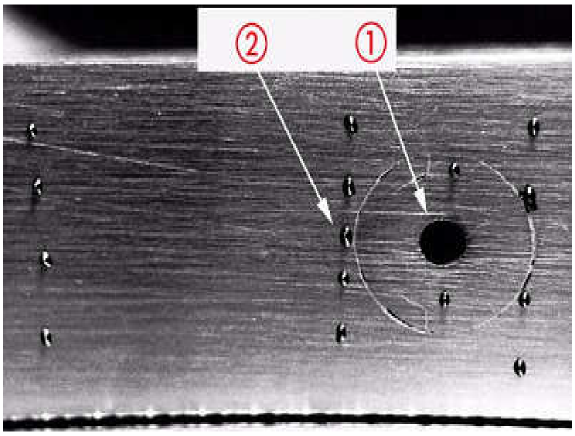

Figure 2. The markers' distribution on the peripheral wall
1 - the supersonic nozzle; 2 - the drops' disposition

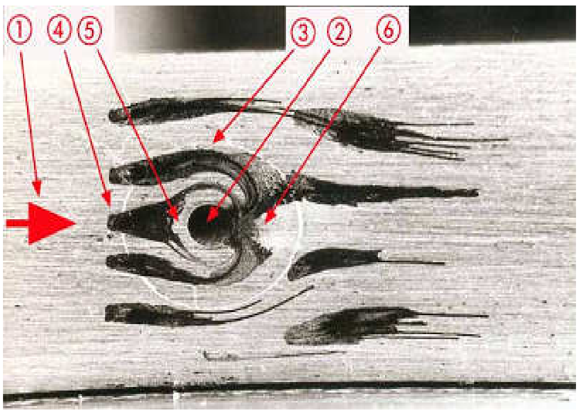

Figure 3. Identification of the peripheral flowing area around the jet
1 - flux direction; 2 - super-sonic nozzle;
3 - transversal divided flux; 4 - the anterior area's peak;
5 - stagnation area; 6 - posterior area

For simplifying, in the next presentation, that mixture will be named simple “olio”.

The profile of the fluidic flux along the peripheral wall of the mill with spiral jets was studied by the deposition of the family containing 11 drops of olio around every milling jet, as is shown in the figure 2.

The dispersal of the stagnation area marked the necessity to exact study that area of the transversal flux, and for that reason we used another olio drops' distribution, right linear, on the axis and behind the supersonic jet, as is shown in the figure 3.

The initial results presented in the figure 2 for the exit area and in figure 3 for the surface between two consecutive jets, are very similar with the results given by other authors that have studied the profile of the flows in transversal fluxes.

We can observe from the figure 2 the well marked existence of the point and of the stagnation area in front of the jet, of the areas of lateral carrying away, determined by the transport flux deviation by the supersonic jet and of the stagnation area adjacent to the supersonic jet behind the jet.

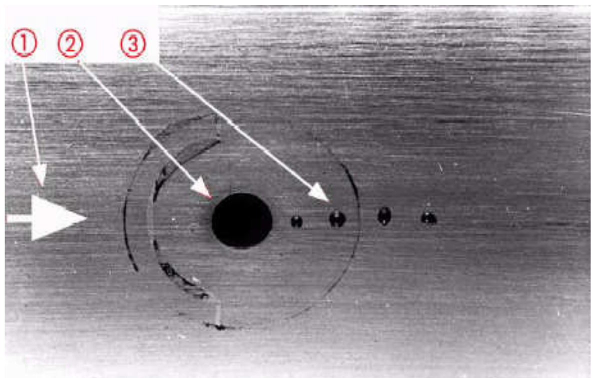

Figure 4. The tracing points' distribution for the study of the posterior area
1- flux direction; 2 - supersonic jet; 3 - the tracing points

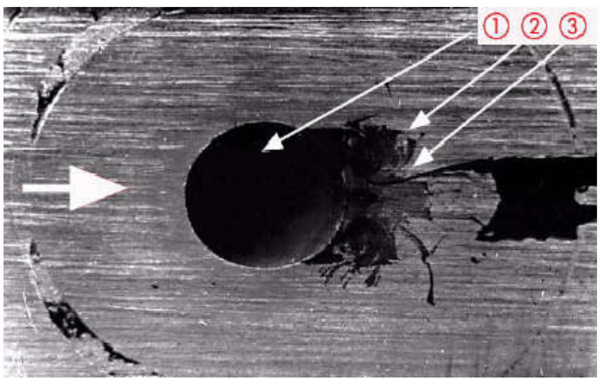

Figure 5. The photo visualization of the imprint from the posterior area
1 - supersonic jet; 2 - markers' imprint

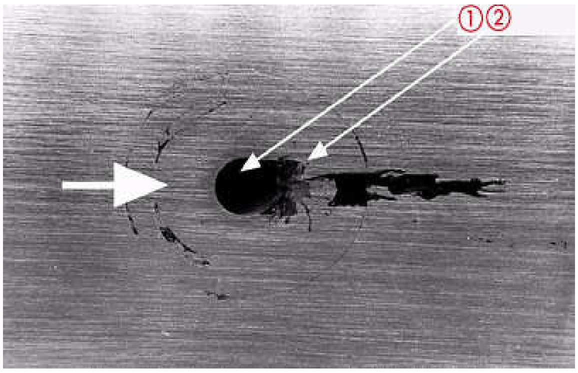

Figure 6. Photo visualization of the imprint from the posterior area
1 - supersonic jet; 2 - imprint of the tracing points

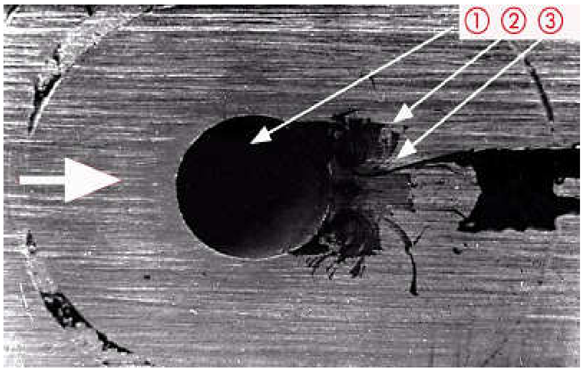

Figure 7. Greater image from the posterior area
1 - supersonic jet; 2 - imprint of the lateral-posterior whirl; 3 -posterior area

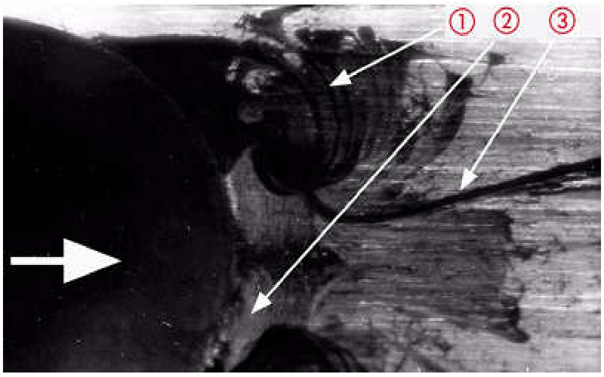

Figure 8. Detailed photo of the whirls lateral-posterior
1 - imprint of the lateral-posterior whirl; 2 - carrying away area; 3 - third flux of collision of the particles

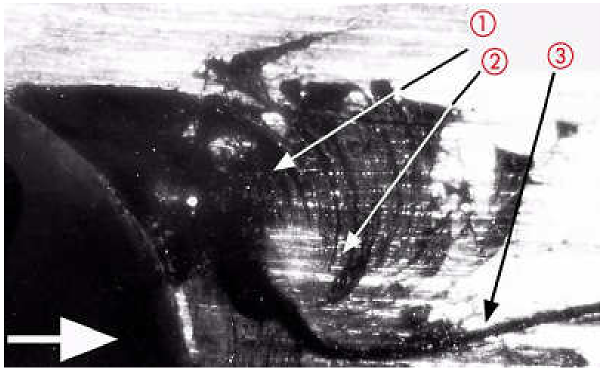

Figure 9. The visual original distinction of the origin of the third collision flux
1 - imprint of the whirl lateral-posterior; 2 - carrying away area; 3 - third flux of the particles collisions

The dispersion of the stagnation area marked out the necessity to study exactly that area of the transversal area, and, for that reason we made another disposition of the olio drops, right linear, on the axis and behind the supersonic jet, as is shown in the figure 4.

It is to observe the character of absolute novelty of that assay, because any anterior research did not work about the phenomena from that area of the flux. In this way, we observed very interesting aspects, as will be shown down.

The making photos in a large field (figure 5) mark a certain evasion of the stagnation areas and the very clear in a vertical section, in the overall size of the supersonic nozzle.

This observation acknowledges the fact that the supersonic jet works enough similarly to a solid cylinder introduced in a transversal flux of a fluid.

By a successive enlargement of the studied area (figure 6 and figure 7) we can observe that the stagnation areas present a completely different aspect by comparison with the published images, concerning the fluxes that around the solid cylinders.

This observation suggests the existence of some secondary turbulence and the reduction of the stagnation areas, aspect that must be explored.

At a sufficient magnification of the studied area (figure 8) it is clearly observed the presence of the two secondary whirls, predicted up, with the supplementary observation of a possible carrying along of some fluid masses from the transversal flux by these two whirls.

The detailed photo is so imposed (figure 9) for one of the secondary whirls, observing with this completely original determination the fact that the secondary whirls carry along a part from the fluid' flux that beset the supersonic flux, taking from it a certain air quantity and, eventually, of transported particles.

This introduced infusion is accelerated by the secondary whirl and it is easy to predict the fact that the transported particles take a position, at the periphery of whirl owing to the centrifugal forces.

Considering the anterior figure 8, it is shown the detach from the secondary whirls of a third flux - very clear collimated in the figure 9, that is mixed with the third flux product by the opposite whirl, producing in this way the particles' collision.

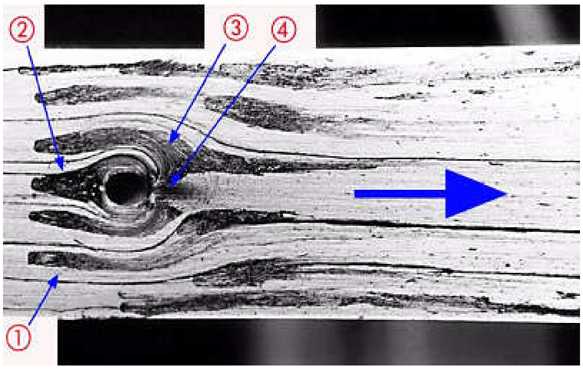

Figure 10. The show of the peripheral flux with the trace elements charge
1- transversal lateral flux; 2 - transversal flux divided in the stagnation area; 3 - lateral-posterior whirls

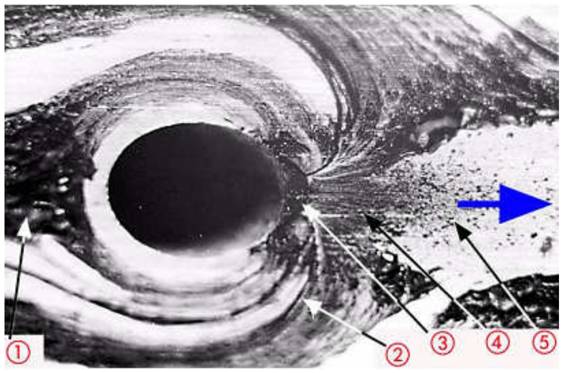

Figure 11. Entrainment whirls and the posterior reposeful area
1 - stagnation area; 2 - transversal divided flux; 3 - lateral-posterior whirls; 4 - particles' entrainment and collision area

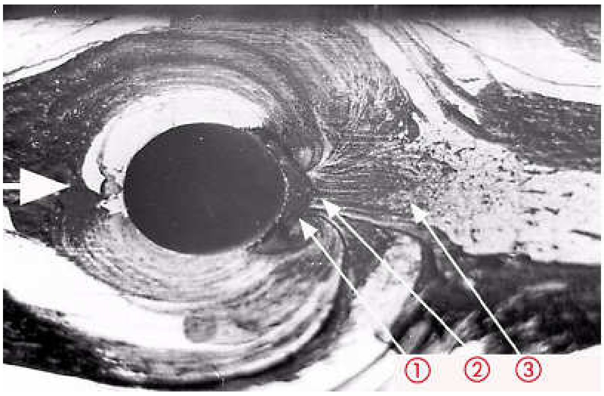

Figure 12. Posterior collision area
1- posterior-lateral whirls; 2 - transversal divided flux; 3 - particles' posterior collision area

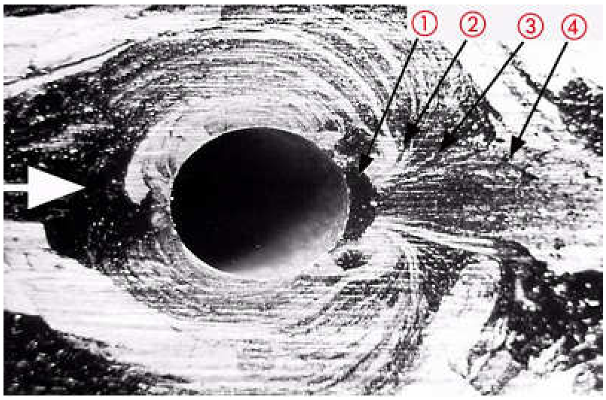

Figure 13. The detail of the particles' collision area
1 - anterior stagnation area; 2 - transversal divided flux; 3 - reverse flow in the anterior area

2.1. The detailed photo of the lateral-posterior whirls

Other researches series presented in the figure 10 acknowledge the precedent observations, made in the area behind the jets.

Determinations where made in this case using compressed nitrogen in place of air, and a very low charge, about 20 g/h active coal.

The main transversal flux from the milling room is divided in two lateral fluxes that embrace the jet, passing by a area with reduced section, that determine by successive compression and expansion, a certain acceleration of the two lateral fluxes.

2.2. The posterior area of the particles' collision

The tracing point charge made evident very clears the peripheral fluxes from the milling room, acknowledging the existence of a frontal stagnation area and of an entrainment and collision area, placed posterior.

2.3. The whirls lateral-posterior for carrying away and acceleration of the particles

A good photographical enlargement of the exit hole's adjacent areas confirmed evidently, by using a tracing point, the precedent observations.

In this case too can be observed, (figures 10, 11 and 12) the existence of a stagnation area in front of the jet and of a calm area behind it.

It is also to note the presence of the secondary whirls behind the jets, as the phenomena of entrainment (figure 12) of some masses from the secondary jets.

3. Photo visualization of the posterior collision area

It is to observe (figure 13) extremely clear the existence of the calm area behind the jet, suited by the area of it adjacent collision and separated by the two secondary whirls.

It is underlined (figure 13) the presence of some extreme turbulence in the collision area, on a length at least equal with the jet diameter, as well as the ulterior diffusion of the turbulent fluid in the transversal fluid mass, which continues to turn in the milling room.

4. Anterior area of the particles collision

The differences between these observations and the technical literature ones, makes us to concentrate on the area situated in the front of the supersonic jet.

4.1. Anterior stagnation area

The first experiments regarding this area confirmed the existence of a stagnation area in front of the supersonic jet, having a near parabolic form, with the tip point in the stagnation area predicted by several authors (figure 13).

4.2. Inverse quaternary fluxes of the posterior area

One could remark another very important new element: the existence of some currents born at the lip of the supersonic nozzle, having opposite direction from the transversal flux of the fluid and going thru the stagnation area until the proximity of the stagnation point, where they are deviated and absorbed (included) in the divided fluxed surrounding the supersonic jet.

Since the presence of the particles collision area has been qualitatively proved, it has been tried to develop a theoretical flow model, capable to explain the experimental results. This is presented in the following paragraph.

From the moment in which the presence of the collision area of the particles was qualitative proved we tried to elaborate a theoretical model of the flow, that approach to these experimental results, fact detailed presented in the future researches.

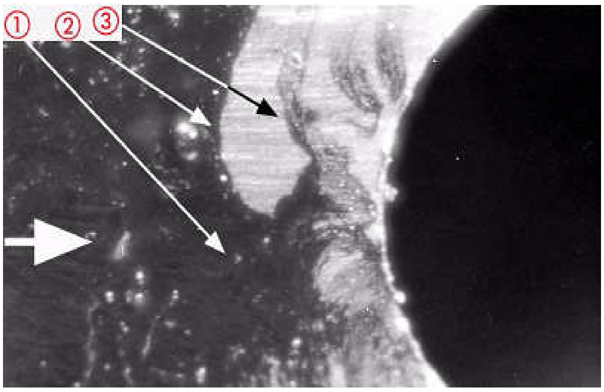

Figure 14. The detail of the stagnation anterior area
1- anterior stagnation zone; 2 - transversal divided flux; 3 - inverse flow in the anterior zone

5. The radial deviation of the jet in the transversal flux

The presented aspects materialize the curvature of the jet from it normal, while it is to remark an ulterior curvature in the tangent direction of the spiral trajectory, of exit from the mill.

That fact was ulterior put in evidence by lining out with olio drops, shown in the figure 14.

6. Experimental results: the trajectory of the micronized particles

For the experimental determination of the supersonic jet's profile it was used a special system, able to capture 12.000 images/sec., which are later interpreted by interpolation point by point.

The PIV system (Particle Image Velocimetry), existing in the APTM research laboratory is composed from a video camera with a very great speed, a laser illumination system, an optical system with prism for the leading and traverse the prove environment by the light flux, and by a computerized specialized system. The original system is integrated with a device SPM (Spray Patternation Measurement, respectively Profile Measurement in Jets with Spray), used for the characterization of the aerosols in pharmaceutics industry.

The SPM device was not used in this paper, because its constructive dimensions did not correspond with the tried models of the fluidic mills with spiral jets.

We can remark the fact that the PIV system dispose by a software VidPIV, attested by FDA (Food&Drug Administration - Health Ministery, SUA), which permit the tracing of the speeds' distribution with the module VisiVector, in a system 2D - planar that measure the speed in a single plane, generally with a speed about 15 images/sec and 3D - stereo that use simultaneous two video cameras for the spatial determination of the speeds' variation.

The figure 15 present two successive families of images at a distance of 0.01 sec, of the same area of the milling room, in which is presented only the main flux of entrainment of the particles.

Owed to the granulometry of the prove particles, which must be good enough great for to be observed, the photos with particles in the presence of the supersonic milling jets, do not give any visible indication, confirming the existence of turbulences extremely complex, three-dimensional, and because this fact the visible front of the photographed particles results with random distribution.

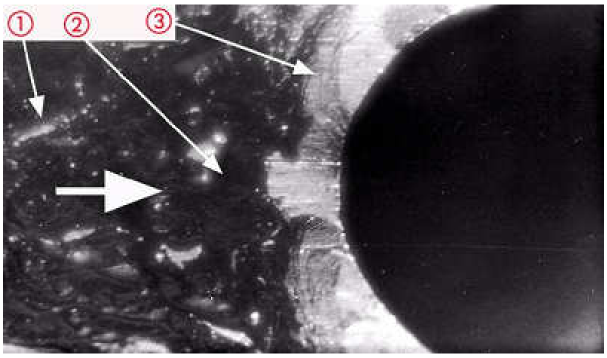

Figure 15. The detail of the visualization of the quaternary reverse fluxes
1- stagnation area limit; 2 - anterior stagnation area limit; 3 - quaternary reverse flux in the stagnation area

For these reasons, it is decided to concentrate the experiences about the profile of the supersonic jets' determination without particles.

7. Conclusions. The precision, the reproducibility and the safety of the assays

The made assays proved a perfect reproducibility for all the regions of the milling room, while the presented photographical results acknowledge very precisely the theoretical hypothesis and the practical determinations of the gradient's distribution of the speeds in the fluid flux.

We mention that the photographical determinations where made in two series of independent assays, in the moment in which it is put in evidence the influence of the powder charge present in the milling room.

The both assays series accord perfectly until the extremities of the prove area, that includes the space of 100 mm, in a radial direction, from the peripheral wall of the milling room, to the exit central exit hole, fact for that it is good enough sure to consider the extension of that area until the inferior classifier that bound the mill exit, respectively a supplementary area of about 12 mm.

Although the visual reproducibility was very high in all the made determinations in is the moment to mention some remarked differences in some photogram, due probably to the package phenomena of the charge from the mill.

That phenomenon, very complex, can surely constitute the object of another scientifically writing.

It is mentionned that the statistical standard deviation of the absolute speeds is much more greater that the standard technical expected deviation because this factor go in calculation as a square exponential function, the non-representative points will be exaggerate amplified, and for this fact it is to wait that the measurements will be, generally, superior to the mean real value.

More, because the incontestable and inevitable differences between a measurement and another one, due to the charge mill variation and to the package phenomenon of the particles, the traced values concerning the speeds distributions from the fluidic flux present limits.

In thwart of the fact that the computerized measure system presents a high amount for the determination and provable in supersonic free jets (distinguished by NASA publications), we mention that that methodology produce a real great volume of the data to be analyzed. Informally, we precise that the method generates over 1.500.000 measurements, at a scanning speed of 50 areas/sec, so, the method generates families of instant values about 7÷10 billions of data/sec. The system was connected at a PC - Cluster Net, composed from 7 nodes, with a theoretic capacity of 2.7 Gflops/sec (2.7 billions of operations/sec.), used by APTM for the interpolation of the optimization data of the production mills.

It results evidently that the limitation, determined by economical considerations of the laboratory APTM investments, influences the ability to process the data generated from assays, being processed only about 35% from these and, precisely the significant ones.

References

2. Baron, P., Willeke, K., *Aerosol measurement: principles, techniques, and applications*. Wiley-Interscience, ISBN 978-0471784920, 2001
4. Bryer, D., Walshe, D., Garner, H.: *Pressure probes for three-dimensional flow measurement.* A.R.C.R. and M. No. 3037, 1958