DEFINING OF THE LIMIT CONDITION FOR THE IN VACUUM DILUTE PHASE PNEUMATIC CONVEYING – CLOGGING CONSTANT

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Abstract: Calculation of a pneumatic conveying system requires definition from the beginning of a Theoretical Mixing Ratio. At the present time the value of this mixing ratio is a recommended one for a given product and does not exist a way for to predict from the beginning the Clogging Mixing Ratio, for some well defined dynamic conditions. Through the present research paper it is proposed a solution for to predict from the beginning this Clogging Regime Mixing Ratio. The correlation between the Mixing Ratio, Clogging Constant of the Product and Similarity Criterion Fr (Froude number) were checked. At the present time, the Clogging Constant of a product is expressed in the same way as the Mixing Ratio is, and this is [kg of product / kg of air] or is only identified as a Constant K , dimensionless. By the present study, we found out that in this correlation occurs also the cross sectional area of the conveying pipe. Interpretation of the experimental results showed the fact that the Clogging Constant must be expressed as [kg of product / kg of air / m^2 of pipe section area, which can be interpreted as the permeability of the product, rather than mixing coefficient.

Key words: pneumatic conveying ; mixing ratio; clogging constant.

1. INTRODUCTION

The aim of the present research was to find a way of defining the limit conditions in a pneumatic conveying line, to find a correlation between the parameters that are influencing the dynamic regime of the pneumatic conveying in a way that will allow from the beginning the estimation (prediction) of the clogging conditions.

We determined thus the Clogging Constants of different milling industry products. Relationship that led to the study was the correlation between the Mixing Ratio, the Clogging Constant of the Product and Similarity Criterion Fr (Froude number). Interpretation of the results showed that a revision of formula is necessary.

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2. MATERIALS AND METHODS

2.1. Products under study

The products subject to study, were sampled in a Soft Wheat Flour Mill, capacity 250 to/24 h. The sampling phase was made following-up some well defined procedures (Tănase and Danciu, 2012). The sampling was performed with the flour mill at nominal capacity operation and well cleaned and conditioned wheat.

The flour mill is designed with rollers on the 1-st floor and plansifters on the 4-th floor of the flour mill (Moraru et all., 1998), (Costin, 1983), (Hibbs and Posner, 1997) (Rohner, 1994).

For representative measurements and determinations, several granulometry classes of semolina and middlings has been defined, as follows (Moraru et all., 1998) 4(Crețu, 1997) (Willm, 2009):

- large/medium semolina having K=18 / 40 (from 1180 to 475 microns)
- medium/small semolina having K=40 / 52 (from 475 to 335 microns)
- hard/mild middlings from K=54 / VII (from 315 to 200 microns)

The products sampled from the rollermills are indetified according to the source passage they are coming from. Since they are very mixed products (as a result of the grinding action of the roll mill), a class definition is not possible.

2.2. The experimental installation

The experimental installation was built-up at an industrial scale, complete of all parts, such as dosing system with tubular screw conveyor driven by electronic inverter, steel pipes, separator provided with air-lock and a high pressure fan (Tănase and Danciu, 2012) (Rohner, 1994) (Klinzing et al., 2010) (Bortolamasi and Fottner, 2001).

2.3. Working procedures and fake air

The working procedures are described in (Tănase and Danciu, 2012). For accurate determinations, the fake air flow has been measured and estimated as presented in (Tănase and Danciu, 2012).

3. RESULTS AND DISCUSSIONS

Following up experimental determinations, various correlations has been studied , such as air flow vs. product flow (Tănase and Danciu, 2012) and theoretical mixing ratio vs. regime mixing ratio.

The correlation between Theoretical Mixing Ratio (TMR) and Regime Mixing Ratio (RMR) for some of the products in study is represented in Figures 1, 2 and 3.

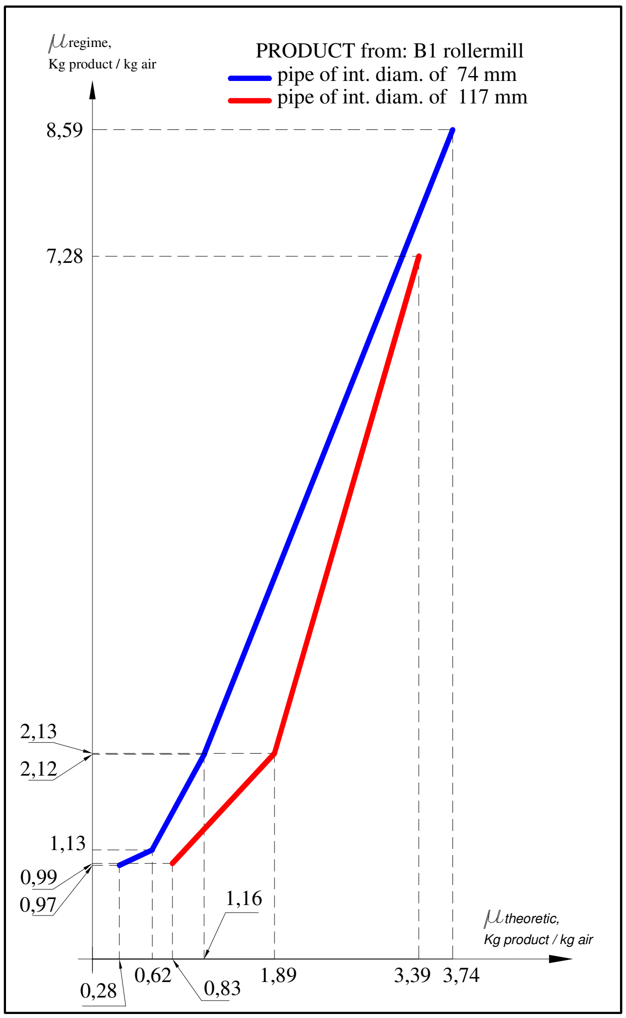

Figure 1: Variation of the Regime Mixing Ratio by the Theoretical Mixing Ratio for the product from B1-rollermill

On the abscissa The Theoretical Mixing Coefficient is represented while on the ordinate the Regime Mixing Coefficient is represented. The graph representations are for the products of the passages from B1, B2 and Large/Medium Semolina having K=18 / 40 (from 1180 to 475 microns).

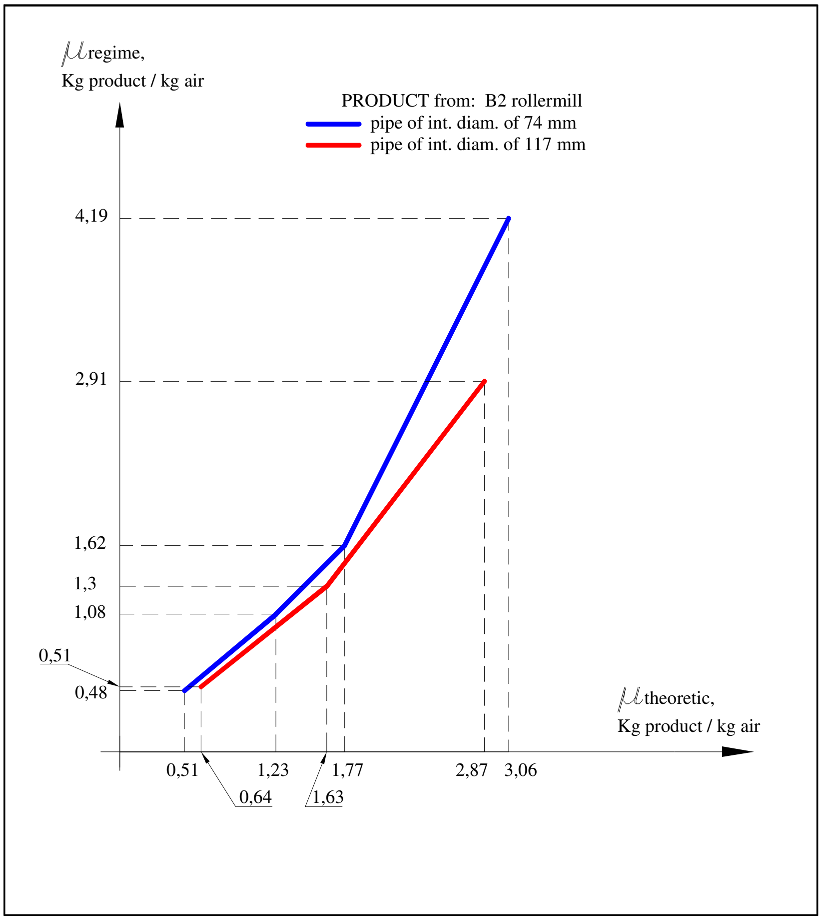

Fig.2: Variation of the Regime Mixing Ratio by the Theoretical Mixing Ratio for the product from B2-rollermill

During the experimental tests the correlation between the Regime Mixing Ratio (RMR) versus Theoretical Mixing Ratio (TMR) were performed using two pneumatic operated slide-gates. The measured values of the Regime Mixing Ratio, those close to the clogging regime (CMR-Clogging Regime Mixing Ratio), were used to calculate the Clogging Constants. The slide gates where operated as simultaneous closing (www.wam.it. Capture of the product was performed on a well-defined zone length in terms of appropriate length before and after the slide gates.

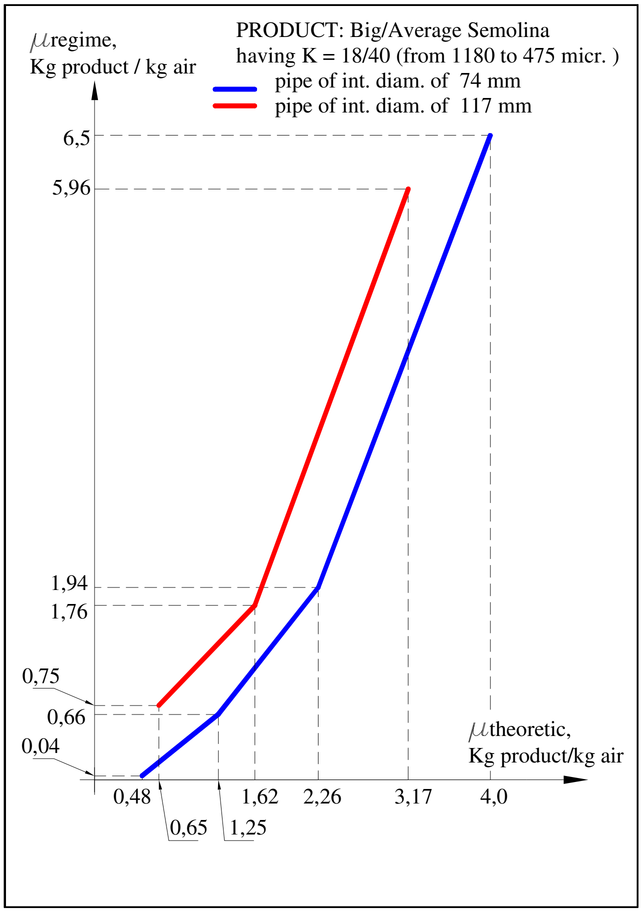

Fig. 36: Variation of the Regime Mixing Ratio by the Theoretical Mixing Ratio for the product Big-Average Semolina K=18/40 (1180 to 475 micr.)

Determination of the Clogging Constant

Based on the experimental results, we determined the Clogging Constant of the intermediate products in the milling industry. The Equation as a basis for calculations, was (Klinzing et al., 2010) (Bulat, 1962) :

$$\mu_c = C \times Fr^2 , \qquad (1)$$

where:

μ_c - Clogging Regime Mixing Ratio , expressed in [kg product / kg air]
C – Clogging Constant of the product , expressed in [kg product / kg air]
Fr – similarity criterion Froude, dimensionless

The results obtained for the Clogging Constant using the Eq. (1) are given in Table 1.

Table 1 : Values of the Clogging Constant calculated using Eq. (1)

Item pos.	Origin of the product	Values of the Clogging Constant deducted from experimental determinations		Arithmetic means value	Individual Deviation for Arithmetic Mean
		Pipe of internal Diameter of 74 mm	Pipe of internal diameter of 117 mm		
01	B1 rollermill	$597,71 x 10^{-5}$	$1460,38 x 10^{-5}$	$1029,05 x 10^{-5}$	41,92 %
02	B2 rollermill	$238,53 x 10^{-5}$	$485,46 x 10^{-5}$	$362,0 x 10^{-5}$	34,10 %
03	B3 rollermill	$154,81 x 10^{-5}$	$398,53 x 10^{-5}$	$276,67 x 10^{-5}$	44,05 %
04	B4 M (coarse)rollermill	$262,25 x 10^{-5}$	$623,73 x 10^{-5}$	$442,99 x 10^{-5}$	40,80 %
05	B4m (fine)rollermill	$254,97 x 10^{-5}$	$414,31 x 10^{-5}$	$334,64 x 10^{-5}$	23,81 %
06	Big/Medium semolina k=18/40	$392,56 x 10^{-5}$	$1165,18 x 10^{-5}$	$778,87 x 10^{-5}$	49,6 %
07	Medium/small k=40/52	$418,68 x 10^{-5}$	$549,0 x 10^{-5}$	$483,84 x 10^{-5}$	13,47 %
08	Hard/soft midlings K=54/VII	$287,39 x 10^{-5}$	$464,41 x 10^{-5}$	$375,9 x 10^{-5}$	23,55 %
09	Soft wheat Bran	$421,65 x 10^{-5}$	$740,22 x 10^{-5}$	$580,94 x 10^{-5}$	27,42 %

As one can observe, the deviations from the arithmetic mean value, are quite high. Since there are not reference value in the literature for these constants, any other way of statistical evaluation is not relevant.

Thus, I considered that such a departure is far beyond of any engineering approximation and that a revision of formulae is necessary. Thereby, I rewrote the Equation (1) (Tănase, 2012) as following:

$$\mu_c = S_c \times C \times Fr^2 \qquad (2)$$

where:

Sc – cross sectional area of the pipe , expressed in [m^2]

C – clogging constant of the product , expressed in [kg of product / kg of air / m^2 of pipe cross section area]

The results of interpretation using here above mentioned Eq. (2) are given in Table 2.

Table 2 : Values of the Clogging Constant calculated using the Eq. (2)

Item pos.	Origin of the product	Values of the Clogging Constant deducted from experimental determinations		Arithmetic means value	Individual Deviation for Arithmetic Mean
		Pipe of internal Diameter of 74 mm	Pipe of internal diameter of 117 mm		
01	B1 rollermill	$1390,0 x 10^{-3}$	$1360,0 x 10^{-3}$	$1375,0 x 10^{-3}$	1,09 %
02	B2 rollermill	$554,89 x 10^{-3}$	$451,77 x 10^{-3}$	$503,33 x 10^{-3}$	10,24 %
03	B3 rollermill	$360,12 x 10^{-3}$	$370,87 x 10^{-3}$	$365,5 x 10^{-3}$	1,47 %
04	B4M (coarse)rollermill	$610,07 x 10^{-3}$	$580,44 x 10^{-3}$	$595,26 x 10^{-3}$	2,49 %
05	B4m (fine)rollermill	$593,15 x 10^{-3}$	$385,55 x 10^{-3}$	$489,35 x 10^{-3}$	21,21 %
06	Big/Medium semolina k=18/40	$913,21 x 10^{-3}$	$1084,30 x 10^{-3}$	$998,76 x 10^{-3}$	8,56 %
07	Medium/small semolina k=40/52	$973,99 x 10^{-3}$	$510,89 x 10^{-3}$	$742,44 x 10^{-3}$	31,19 %
08	Hard/soft midlings K=54/VII	$668,56 x 10^{-3}$	$432,37 x 10^{-3}$	$550,47 x 10^{-3}$	21,45 %
09	Soft wheat Bran	$980,91 x 10^{-3}$	$688,84 x 10^{-3}$	$834,88 x 10^{-3}$	17,49 %

Defining the Limit Condition for the In Vacuum-Dilute Phase Pneumatic Conveying

Based on the above mentioned results, the Limit Condition for the In Vacuum Dilute Phase Pneumatic Conveying, for one line, can therefore be predicted from beginning using the equation 2.

The different denominations for the Mixing Ratio, used in this paper, are :

μ_t - Theoretical Mixing Ratio , expressed in [kg product / kg air]

μ_r - Regime Mixing Ratio , expressed in [kg product / kg air]

μ_c - Clogging Regime Mixing Ratio , expressed in [kg product / kg air]

For a normal operating system, we can write the following equation :

$$\mu_t < \mu_r < \mu_c \qquad (3)$$

It is obvious that for any operating system, the Regime Mixing Ration will be always smaller than the Clogging Regime Mixing Ratio and higher than the Theoretical Mixing Ration. The deviation of the Regime Mixing Ratio off the Theoretical Mixing Ratio depends on the slipping factor of the product, under the product specific load of the cross section of the pipe and under the specific dynamic conditions of the system.

4. CONCLUSIONS

The results calculated using the Eq. (2) are much more homogeneous and shows much smaller deviations from the arithmetic mean. Except for the product Medium / Small Semolina having a granulometry class of K = 40 / 52 (475 to 335 micr.), which is a product of unusual behavior, in the sense that presents some “bundles” during transport along the pipe, all other products deviations are below of an acceptable 25 %. It also notes that the averages values calculated using the Eq. (2) are significantly higher, this allowing for higher loads.

The arithmetic mean deviation depends upon the granulometry of the product to be conveyed and its distribution. Very heterogeneous products in terms of granulometry, shows very large areas of instability before clogging. This is a measure of the deviation from the mean value for the Clogging Constant.

Knowing Clogging Constant of a product, can thus estimate the critical dynamic regime, the regime that will produce clogging, and allow for a much

more accurate calculation of in vacuum dilute phase pneumatic conveying, close to the physical transport limit of the system.
Future determinations, testing and experimental should be focused on the slipping factor measurements.

SIMBOLS DEFINITION

C - clogging constant of a product, [kg of product / kg of air / m²]
Fr - similarity criterion Froude number, dimensionless
K - criteria for to evaluate the classes dimensions for intermediate stocks in the milling industry,
dimensionless
μ - mixing ratio, [kg product / kg of air]
μ_c - clogging condition mixing ratio, [kg of product / kg of air]
S_c - cross sectional area of the pipe, [m²]

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