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Doctoral field MECHANICAL AND MECHATRONIC ENGINEERING

DOCTORAL THESIS

(summary – english language)

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PhD supervisor: Emeritus University Professor Ph.D. Eng **RADU I. IATAN**

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NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY POLITEHNICA OF BUCHAREST

Faculty: MECHANICAL AND MECHATRONIC ENGINEERING
Department: EQUIPMENT FOR INDUSTRIAL PROCESSES
Doctoral school: MECHANICAL AND MECHATRONIC ENGINEERING

DOCTORAL THESIS

”CERCETĂRI TEORETICE ŞI EXPERIMENTALE REFERITOARE LA CONSTRUCŢIA, PROIECTAREA ŞI EFICIENŢA CICLOANELOR CU ALIMENTARE TANGENŢIALĂ, FOLOSITE LA SEPARAREA PARTICULELOR SOLIDE DIN EMISIILE GAZOASE POLUANTE DEGAJATE ÎN MEDIU DE INDUSTRIILE PENTRU PROCESE INDUSTRIALE”

"THEORETICAL AND EXPERIMENTAL RESEARCH ON THE CONSTRUCTION, DESIGN AND EFFICIENCY OF TANGENTIAL FEED CYCLONES USED TO SEPARATE SOLID PARTICLES FROM POLLUTING GASEOUS EMISSIONS RELEASED INTO THE ENVIRONMENT BY INDUSTRIES FOR INDUSTRIAL PROCESSES"

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TABLE OF CONTENTS

Keywords: atmosphere, pollutants, pollution sources, human activities, industrial activities, air quality, emissions, imissions, solid pollutants, suspended particles (PM - Particulate matter), dust, dedusting, dry gases, heterogeneous gas systems, technical procedures, equipment, installations, processes, industrial gases, centrifugation, cyclones, construction, operation, theories, models, separation efficiency, limiting diameter, particle in cyclone, sizing, design, deformations, loads, stresses, strains, super cyclones, cyclonetes, supports, cyclone with tangential feed, research, experimental study, apparatus, granulometry, cyclone separation.

F O R E W O R D

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I N T R O D U C T I O N

The present paper "Theoretical and experimental research on the construction, design and efficiency of cyclones with tangential feeding, used to separate solid particles from polluting gaseous emissions released into the environment by industries for industrial processes" falls within the context of global air quality issues, as a result of the impact of pollution generated by anthropogenic sources on environmental factors.

The identification through scientific research of some effective technical depollution solutions, for the separation of solid particles from the polluting gaseous emissions released into the environment by industries for industrial processes, with the help of cyclones, is opportune both for the study of the current trend in the construction of equipment for the dedusting of dry polluting gases by centrifugation (cyclones, constructive types, functional study, energy efficiency, etc.) as well as for the constructive design of tangentially fed cyclones for dedusting dry industrial gases and the study on the process of separating dust from dry industrial gases in tangentially fed cyclones.

To achieve the content of the thesis, the following was taken into account: Studying the specialized literature regarding the production of atmospheric pollutants, especially the gases impure with solid particles, and the practical ways of reducing their values; Identification of areas with maximum concentration of these pollutants, especially in Romania, and the legislation in force, correlated with European norms; The specific procedures and equipment, geometric and operational characteristics, economic efficiency; Current trends in the construction of equipment for the dedusting of dry polluting gases by centrifugation (cyclones, constructive types, functional study, energy efficiency, etc.); Constructive design of tangentially fed cyclones for dedusting dry industrial gases; Experimental research on the process of separating dust from dry industrial gases; Conclusions. Own contributions. Perspectives.

The thesis is structured in 6 chapters, as follows:

Chapter 1. Aspects regarding the evolution of atmospheric pollution and modern technical solutions to reduce it - Some clarifications are made regarding the evolution of atmospheric pollution and modern technical solutions to reduce it.

Chapter 2. General aspects regarding atmospheric pollutants and special equipment for the dedusting of dry gases, contaminated with dust - Some general aspects regarding atmospheric pollutants and special equipment for the dedusting of dry gases, contaminated with dust are indicated.

Chapter 3. Equipment for dedusting dry gases by centrifugation - Equipment for dedusting dry gases by centrifugation is presented - cyclones with tangential feeding, construction, operation, pressure loss, particle separation efficiency (corresponding theories), sedimentation speed. Other types of cyclones with tangential feeding (large, medium, rotary, multicyclones).

Chapter 4. Constructive design elements of tangentially fed cyclones - Constructive design of tangentially fed cyclones (component elements – covers, flanges, specific joints, supports).

Chapter 5. Experimental research on the process of separating dust from impure dry gases, in the cyclone with tangential feeding - Experimental research on the process of separating solid particles, with the help of a laboratory model. Experimental data processing. Conclusions.

Chapter 6. Conclusions. Own contributions. Perspectives.

CHAPTER 1

ASPECTS REGARDING THE EVOLUTION OF AIR POLLUTION AND MODERN TECHNICAL SOLUTIONS FOR ITS REDUCTION

1. 1. Introduction

The following presents a succinct overview of the theoretical concepts used in the field of atmospheric protection, as well as the methods and techniques commonly employed to reduce or combat this phenomenon. These actions align with the current concerns of the international scientific community for the protection and conservation of the external environment.

An original contribution of future research can be achieved by establishing a theoretical correlation with practical applications between air quality monitoring and the most effective depollution technical solutions used for separating pollutant particles and harmful components from gaseous emissions discharged into the external environment.

In Romania, intense actions are being developed to reduce air pollution, including appropriate ecological policies and specialized programs (**Annex 1/chapter 1.1**).

Law No. 278/2013 **[19]** refers to industrial emissions and legal thresholds.

Natural sources (volcanoes, dust storms, fog, etc.) generally produce accidental pollution, which is less harmful than ***artificial/anthropogenic*** sources. In technical analyses, the percentage of the urban population and the necessity of not exceeding certain life-threatening limits must also be considered [**26, 27, 48**].

Note: A method for retaining carbon from the atmosphere can be achieved through agricultural crops, retaining it in the soil and in primary production [**91**].

*** * ***

For assessing the quality of the atmosphere, there are legal documents at the international, European, and national levels **[25, 26, 28, 34**], referring to pollutant sources and emissions, their transfer to the external environment, concentration values, and spatio-temporal distribution, as well as the possible effects on living organisms (including humans), and the biotic and abiotic environment. A series of documents at the European level have been issued in this regard (**Annex 1/chapter 1.2).**

***

Modeling is an important complementary tool on which the development of action plans is based. The distribution/contribution of atmospheric pollutant sources (SA), including the evaluation of cross-border and natural contributions, is an important application of models if sufficient knowledge must be obtained for the effective implementation of such plans [**25, 26, 28, 40, 42, 73, 74, 76**].

***

Current environmental software products cover five major categories of air quality:

- Modeling the dispersion of air pollutants;
- Ensuring compliance;
- Triggering emergencies;

- ➢ Emission management;
- ➢ Risk assessment;
- ➢ Software that is freely available.

Several models have been adopted for modeling (**Annex 1/chapter 1.3**).

***

Emergency-triggered modeling is a specific type of air dispersion modeling that deals with accidental releases, usually denser than air. This type of modeling is used to evaluate accident scenarios and create emergency response plans.

***

The following presents some specialized equipment schemes for cleaning air of harmful substances containing solid pollutants.

***

For the realization of the thesis content, the following general aspects are considered:

1. Studying the specialized literature on the production of atmospheric pollutants, especially gases impure with solid particles, and practical ways to reduce their values.
2. Identifying areas with the maximum concentration of these pollutants, especially in Romania, and the current legislation, correlated with European norms.
3. Specific procedures and equipment, geometric and operational characteristics, economic efficiency.
4. Current trends in the construction of equipment for dedusting polluted dry gases by centrifugation (cyclones, construction types, functional study, energy efficiency, etc.).
5. Constructive design of cyclones with tangential feed for dedusting industrial dry gases.
6. Experimental research on the process of dust separation from industrial dry gases.
7. Conclusions. Personal contributions. Perspectives.

CHAPTER 2

GENERAL ASPECTS REGARDING ATMOSPHERIC POLLUTANTS AND SPECIAL EQUIPMENT FOR DEDUSTING DRY GASES IMPURIFIED WITH DUST

2.1. Introduction

It is well-known that among the atmospheric pollutants is dust created in industrial areas as well as in road transport [**1**], which has negative effects on human life, vegetation, and the animal spectrum **[2 - 6**]. There is a significant concern for controlling the amount of dust present in the atmosphere, considering some essential elements [**22, 23, 26, 30**]:

- Researching variants to improve the optimal functioning of industrial equipment;
- Eliminating or reducing the amount of dust expelled into the atmosphere;
- Recovering and utilizing important materials for new products with lower prices.

Rigorous dust collection leads to a clean outdoor atmosphere, a healthy working environment within work enclosures, and adequate protection of industrial installations [**7 – 8, 30, 39].**

Several interacting bodies, hypothetically without the influence of the external environment, form a **system: homogeneous** (parts with different properties do not separate from each other); **heterogeneous** (with two or more components with separated surfaces; one part is the **dispersed or internal phase**; the other phase, which surrounds the particles of the internal component, is called the **external or dispersing phase**) [**9**]. The homogeneous part of the system, with well-defined physical properties, is called the **phase**. Heterogeneous systems can be gaseous, liquid, or solid (**Annex 1/chapter 2.1**).

***

The above points draw attention to the design of industrial installations (sealing issues in dust-producing systems, where the risk of explosion is also observed) [**11, 12**] and technological processes. In practice, it has been found that dust can self-heat and ignite (the finer the dust, the more likely this is) without the transmission of heat from the outside [**13, 14**]. The action of determining dust levels in rooms by gravimetric methods should not be overlooked [**15, 16**]. Also, the ***Barth W***. apparatus [**17**], for example, can be used.

***

Additionally, a series of emissions, vibrations, electromagnetic and ionizing radiations, and noise are directly or indirectly discharged into the atmospheric air.

***

The main characteristics of atmospheric air and how to evaluate them are presented in **Annex 1/chapter 2.2**.

* * *

An extremely important role is played by determining the sedimentation velocity of solid particles in gaseous media, taking into account the characteristics of the materials and gases. Expressions such as the following can be used:

$$w_s = 0{,}056 \cdot d_p^2 \cdot \frac{\rho_p}{\eta} \cdot g\,, \quad Re \le 1; \tag{2.1}$$

$$w_s = 0{,}1528 \cdot \frac{d_p^{1{,}114} \cdot \rho_p^{0{,}72}}{\rho_g^{0{,}29} \cdot \eta^{0{,}43}} \cdot g^{0{,}72}\,, \quad 1 \langle Re \langle 10^3; \tag{2. 2}$$

$$w_s = 1{,}74 \cdot \left(\frac{d_p \cdot \rho_p \cdot g}{\rho_g} \right)^{0{,}3}, \quad Re \ge 10^3; \tag{2. 3}$$

$$d_{cr} = C_{Re} \cdot \sqrt[3]{\frac{\eta^2}{\rho_p \cdot \rho_g \cdot g}}\,. \tag{2.4}$$

Note: Another method for estimating the sedimentation velocity is illustrated in the work [**19**], with configuration (2.3.1) (**Annex 1/chapter 2.3**).

The action of preventing and combating air pollution considers:

Physical-mechanical methods for gravitational and centrifugal separation (considering the differentiated action of gravitational and centrifugal forces on the particles) or filtering [**24, 27 – 29**].

Physical-chemical methods for the removal of gaseous pollutants [**24, 27 - 29**].

* * *

The continuation of the study presents some brief characteristics regarding "Equipment for dedusting industrial gases - construction and functional calculation elements" – settling chambers (**Annex 1/chapter 2.4**); dust separators by inertia; ring dust separators (**Annex 1/chapter 2.5**); grate dust separators, and specific technical-economic aspects.

* * *

CHAPTER 3

CYCLONES FOR DEDUSTING DRY GASES

Note: The first appearance of cyclones with tangential gas feed is indicated in Annex 1/chapter 3.1.

Observation: In the period 1930 – 1950, the first research on the general characterization of cyclones was conducted [**93**].

* * *

A presentation of these equipments regarding their characteristic construction is carried out, synthesized in an appropriate table.

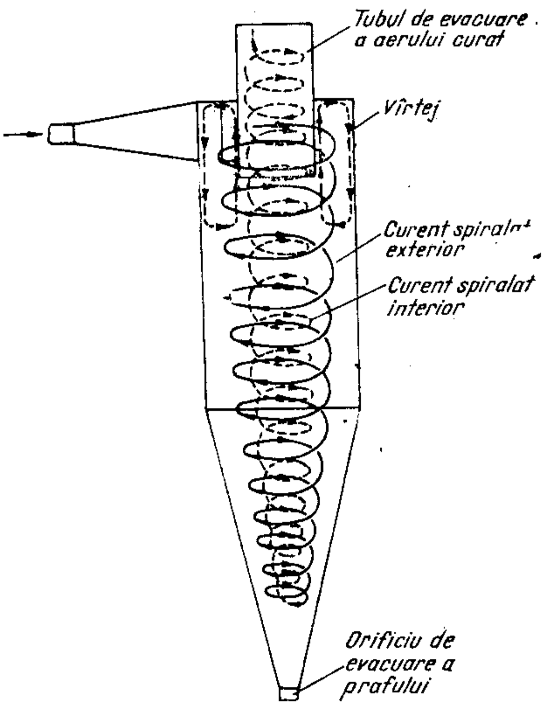

Fig. 3. 1. The movement of impure gas in the cyclone [7].

Note: As materials can be used: sheet metal and steel profiles, ceramic material **[51]**. In the case of chemically aggressive gases, the cyclone is built from anti-corrosive materials. At temperatures below 40 0 C, plastic/polymeric materials can be used **[2]**.

* * *

An extremely important aspect is the one related to the movement of particles in the cyclone. Referring to the balance and the effect of the forces manifested inside the cyclone on a particle, some simplifying hypotheses are discussed, such as:

- the particle is spherical in shape, with a smooth surface;
- there is no interaction between particles;
- the radial velocity of the current is zero;
- tangential speed is related to the radial position of the particle: [**3, 53, 81, 82, 85, 87 – 90, 92, 93**].

* * *

The time required for the particle to travel the distance from entering the cyclone to reaching its inner surface is calculated with the relation:

$$t = \frac{9 \cdot \mu_g}{\rho_p \cdot (n+1)} \cdot \left(\frac{R_2}{v_{t2} \cdot d_p} \right)^2 \cdot \left[1 - \left(\frac{R_1}{R_2} \right)^{2 \cdot n + 1} \right], \tag{3.8}$$

in which the geometric characteristics of the cyclone and those of the particles and gas are included.

* * *

Particular attention is paid to the forces acting on the particle: the centrifugal force (**Annex 1/chap. 3. 11**) and the **floating force (buoyancy) [54]**.

When the particle size is comparable to the free path of the gas molecules, the "**discontinuity**" effect of the impurity gas is taken into account. Introducing the ***Cunningham E***. correction factor or the sliding factor C_c, it follows:

$$F_d = -9{,}42 \cdot d_p \cdot \mu_g \cdot v_r / C_c , \tag{3. 10}$$

with the notation:

$$C_c = 1 + K_n \cdot \left[1{,}257 + 0{,}40 \cdot exp\left(-1{,}10 / K_n \right) \right], \tag{3.11}$$

where K_n - number of ***Knudsen M***. (b. 1871 – d. 1949) [103**]**.

For the calculation of the **centrifugal force**, neglecting the gas density, the following expression can be taken into account:

$$F_c = 0{,}523 \cdot \rho_p \cdot d_p^3 \cdot v_t^2 / r , \tag{3.12}$$

* * *

The movement of an individual particle (or in a group) is analyzed in a complex manner, referring to the equilibrium of forces in a spatial reference system – the BBO equation [122] (see Annex 1/chapter 3.7).

* * *

The efficiency of particle separation in the cyclone is evaluated by considering: **laminar gas flow** [**51, 71**] or **turbulent gas flow [51**].

In the case of laminar gas flow, the following relation can be considered for evaluating the separation efficiency:

$$\eta\left(d_p\right)=\left\{1-\sqrt{1-\frac{\rho_p\cdot Q_v\cdot d_p^2\cdot\theta_f}{9\cdot\mu_g\cdot b\cdot r_2^2\cdot ln\left(r_2/r_1\right)}}\right\}\Big/\left(1-r_1/r_2\right),\tag{3.25}$$

which includes the gas flow rate, its and particle characteristics, as well as the geometric characteristics of the considered cyclone.

Modeling the turbulent motion of the impure gas flow is very difficult [**93**].

In this case the expression can be considered:

$$\eta\left(d_p\right)=1-\frac{N_p\left(\theta_f\right)}{N_{p0}}=1-exp\left[-\frac{v_{r2}\cdot r_2\cdot\theta_f}{v_{\theta 2}\cdot\left(r_2-r_1\right)}\right],\tag{3.33}$$

considering the number of particles collected from the total of those that entered the cyclone.

* * *

The theory developed by the authors ***Leith D. and Licht W***. (1972) [**34**] proved useful in the design of cyclones. There are other works on the efficiency of the cyclone with tangential feeding, such as [**34 - 36**].

* * *

Several theories have been developed over time to estimate the height of the gas column in the cyclone: **Barth W**. (1956); **Stairmand CJ** (1949); **First WM** (1949, 1950); **Alexander R. McK** (1949); **Dirgo JA; Hashemi BS** (2003, 2006).

* * *

3. 1. 3. 4. 1. 2. Theories regarding the assessment of pressure loss in the cyclone

Knowing the size ΔH , the value of the pressure loss can be evaluated using the expression (3. 34), in the form [**3, 95**]:

$$\Delta p=0,5\cdot\rho_g\cdot v_i^2\cdot\Delta H\ .\tag{3.59}$$

The paper **[3**], for the field $40\ m\ \langle\ \Delta H\ \langle 100\ m$, recommends the formula:

$$\Delta p=K_1\cdot Q^2\cdot\rho_g\ /\ D^4\ ,\tag{3.60}$$

in which K_1 - factor that also includes the effect of friction.

* * *

The work [**94],** according to the suggestion of the authors ***Shepherd C. B., Lapple C. E***. (1951), recommends introducing the density of the gas and particle mixture ρ_{g-p} .

* * *

Estimation of pressure loss $\Delta\ p$, it is done according to the opinion indicated by the works**[92, 107]**:

$$\Delta p=0,5\cdot\left(\xi_i+\xi_e\right)\cdot\rho_g\cdot v_i^2\ ,\tag{3.61}$$

where ξ_i and ξ_e - factors that reflect the influence of the pressure loss when the gas enters the cyclone and when the purified gas is discharged, respectively the friction.

* * *

3. 1. 3. 4. 2. Theories/models regarding the evaluation of cyclone efficiency

* * *

Studies conducted over time show that the efficiency of solid particle separation in a cyclone depends on:

a) The sizes and densities of the particle material;
b) The entry and rotation speed of the particles inside the cyclone;
c) The geometry of the cyclone;
d) The speed of the purified gas current at the exit of the cyclone;
e) The humidity inside the cyclone;
f) The temperature of the impure gas [**25, 90**].

* * *

3. 1. 3. 6. Solid particles separated in cyclone - diameter limit

The efficiency of a cyclone's operation is illustrated by the size of the smallest retained dust particles. The limit diameter of a particle, d_{pm}, can be calculated with the formula **[2, 11]**:

$$d_{pm} = 1{,}5 \cdot \sqrt{\left[\left(D^2 - D_{pe}^2 \right) / D \right] \cdot \left[\mu_g / \left(\pi \cdot \rho_p \cdot v_i \cdot N \right) \right]}, \tag{3.77}$$

where: D, D_{pe} - the inner diameter of the cyclone and of the particle's trajectory; v_i - the peripheral speed on the diameter circle D, at the entrance to the cyclone; N - the number of helices of the particle until separation.

Other calculation relationships:

$$d_{pm} = 0{,}599 \cdot \sqrt{\mu_g \cdot D / \left[N \cdot v_i \cdot \left(\rho_p - \rho_g \right) \right]}; \tag{3. 78}$$

$$d_{pm} = 0{,}977 \cdot \sqrt{\left[\mu_g \cdot b / \left(\rho_p \cdot v_i \cdot N \right) \right] \cdot \left(1 - b / D \right)}; \tag{3. 79}$$

$$d_{pm} = 1{,}197 \cdot \sqrt{\mu_g \cdot r / \left(N \cdot v_i \cdot \rho_p \right)},. \tag{3.80}$$

$$d_{pm} = 1{,}693 \cdot \sqrt{\left[\mu_g / \left(N \cdot \rho_p \right) \right] \cdot \left(r_m / v_m \right) \cdot ln \left(r_e / r_i \right)}, \tag{3.81}$$

$$d_{pm} = 0{,}846 \cdot \sqrt{\left[\mu_g / \left(N \cdot \rho_p \cdot r_m^3 \cdot v_m \right) \right] \cdot \left(r_e^4 - r_i^4 \right)}; \tag{3.82}$$

$$d_{pm} = 4{,}24 \cdot \sqrt{\left\{ D^2 \cdot \mu_g / \left[\left(\rho_p - \rho_g \right) \cdot v_{gi} \cdot H \right] \right\} \cdot \left[1 - \left(D_0 / D \right)^4 \right]}, \tag{3.83}$$

From the analysis of the previous expressions, the following aspects are deduced:

- The influence of the temperature of the gases being purified on the limit size of the particles is noticeable, for cyclones with different diameters;
- Cyclones characterized by small diameters are more efficient than those with large diameters;
- The efficiency of separation increases with the size of the particles;

- Particle separation is also dependent on the nature of the dust;
- There are situations where some dusts break down into smaller particles; the actual separation efficiency is lower than the calculated one;
- For a significant influence on efficiency, continuous dust discharge is recommended.

* * *

CHAPTER 4

CONSTRUCTIVE DESIGN ELEMENTS OF CYCLONES WITH TANGENTIAL FEED

4. 1.Construction

The geometric dimensions of the cyclones allow their classification into: **large (super cyclones), medium and small (mini cyclones)**.

Note: Cyclones can be made from uncoated or coated metal sheet, especially when the gases exhibit high chemical aggressiveness. In some practical situations, an external layer for thermal insulation can be applied. In other situations, layered composite materials can be used. The following focuses on the construction made from simple, continuous, and isotropic metal sheet, stressed within the elastic domain.

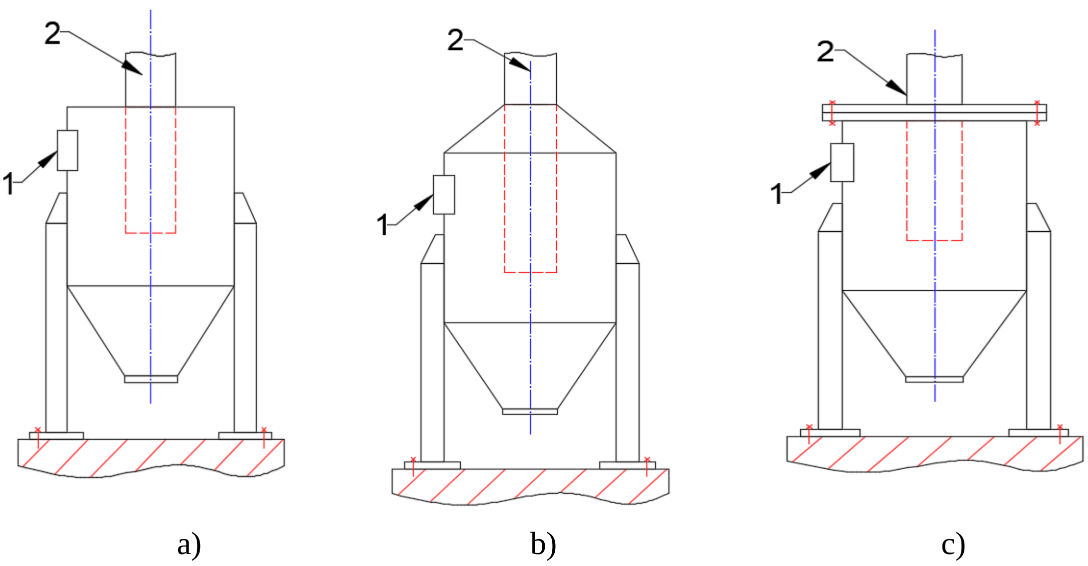

Fig. 4. 1. Fixing methods between the cylindrical body, cover, and dust evacuation tube:
a) fixing by welding between a flat cover and the cylindrical body;
b) fixing between the cylindrical body and a conical cover;
c) fixing between the cylindrical body and a flat cover through flat flange assemblies.

The support of the cyclones' body can be achieved on individual supports or on cylindrical shells provided with appropriate spaces for evacuating the dust collected in the conical hopper.

4. 2. Stress States in the Fixing Area of the Cover to the Cylindrical Body

4. 2. 1. Flat Cover Fixed by Welding (without Transition Zone)

The analysis of stress states developed in a flat plate and cylindrical body joint has been the subject of several scientific papers [**1 - 6; 8 - 19**].

4. 2. 1. 1. Simplified Study Hypotheses

The following effects of external loads are considered simultaneously:

a) Construction materials are considered isotropic and stressed within the elastic domain.

b) The presence of the separate dust evacuation tube is neglected.

c) The loads acting on the plate are considered situated in its median plane [**2, 3, 9, 10**]; consequently, the unit bending moment has the expression $M_Q = 0,5 \cdot h \cdot Q_0$, where Q_0 is the unitary cutting force (fig. 4. 2);

d) the simplifying assumptions characteristic of the rotating envelopes under the action of axially-symmetrical loads are accepted.

Other calculation elements, specific to the present problem, are indicated in detail in the work [**76**].

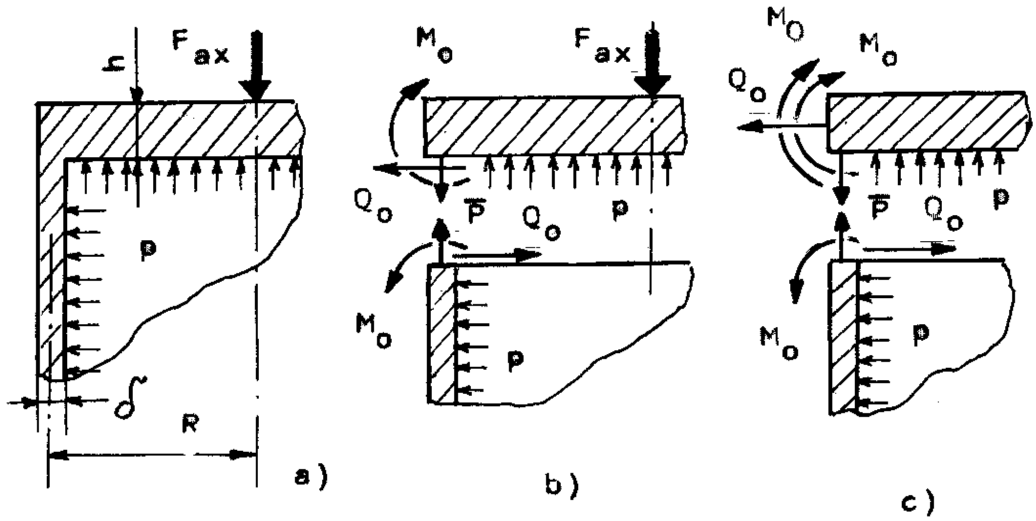

Fig. 4. 2. Scheme for evaluating the stress state in a circular flat plate – cylindrical shell joint:

a) Configuration of the joint;
b) Hypothetical separation of the adjacent constructive elements;
c) Reduction torsor of the unit shear connection force

4. 2. 1. 2. Continuity of Deformations. Connection Loads

The compatibility equation of deformations (fig. 4.2) has the form:

$$\begin{pmatrix} a_1 & a_2 \\ a_4 & a_5 \end{pmatrix} \cdot \begin{pmatrix} M_0 \\ Q_0 \end{pmatrix} = \begin{pmatrix} a_3 \\ a_6 \end{pmatrix}. \tag{4.1}$$

From equality (4.1) we obtain:

$$M_0 = \frac{a_3 \cdot a_5 - a_2 \cdot a_6}{a_1 \cdot a_5 - a_2 \cdot a_4}; \; Q_0 = \frac{a_1 \cdot a_6 - a_3 \cdot a_4}{a_1 \cdot a_5 - a_2 \cdot a_4}. \tag{4. 4}$$

Observation: Details regarding the choice of different values of the quantities indicated in the calculation expressions are indicated in the work [**76**].

* * *

4. 2. 1. 3. Stress State

The stresses developed in the cylindrical shell under the action of external loads are as follows:

$$\sigma_{1c} = \sigma_1(m) + \sigma_1(M_x), \tag{4.9}$$

where σ_{1c} - the meridional stress, $\sigma_1(m)$ – the axial membrane stress; $\sigma_1(M_x)$ – the meridional stress produced by M_x, at a certain current distance x, measured along the generator of the cylinder:

$$\sigma_1(M_x) = 6 \cdot M_x / \delta^2; \tag{4.10}$$

$$M_x = M_0 \cdot f_1 - Q_0 \cdot f_2; \tag{4.11}$$

$$f_1 = (cos\ k \cdot x + sin\ k \cdot x) \cdot exp(-k \cdot x); \tag{4.12}$$

$$f_2 = \frac{1}{k} \cdot exp(-k \cdot x) \cdot sin\ k \cdot x; \tag{4.13}$$

$$\sigma_{2c} = \sigma_2(m) + \sigma_2(M_x) + \sigma_2(T_x), \tag{4.14}$$

where σ_{2c}- is the total hoop stress; $\sigma_2(m)$- membrane hoop stress; $\sigma_2(M_x) = \nu \cdot \sigma_1(M_x)$– the hoop stress given by M_x; $\sigma_2(T_x) = T_x / \delta$ – is the bending-induced hoop stress T_x, where:

$$T_x = -f_3 \cdot Q_0 + f_4 \cdot M_0, \tag{4.15}$$

in which

$$f_3 = 2k \cdot R \cdot \exp(-k \cdot x) \cdot \cos k \cdot x; \tag{4.16}$$

$$f_4 = 2k^2 \cdot R \cdot (\cos k \cdot x - \sin k \cdot x) \cdot \exp(-k \cdot x), \tag{4.17}$$

where: k - the *mitigating factor* of the influence of contour loads;

Paper [**2**] proposes to take into account the shearing effect of the loads M_0 and Q_0 as:

$$\tau_c = \frac{1}{\delta} \cdot \left(-\frac{1}{2k^2 \cdot R} \cdot f_4 \cdot Q_o + 2k^2 \cdot f_2 \cdot M_0 \right). \qquad (4.18)$$

Juravski's formula leads to the maximum value in the median surface of the shell:

$$\tau_c^* = 1,5 \cdot \tau_c . \qquad (4.19)$$

* * *

4. 3. Variants for Evaluating the Stiffness of Flat Ring Flanges

The constructive complexity of industrial process equipment used for processing various substances has posed significant challenges in scientific research, design, manufacturing, and transportation, generally involving large masses and sizes. The issues mentioned above include dynamic or static seals (flat or necked annular flanges [**21 – 29**], as well as annular flanges with radial ribs [**30 – 32**]), tightened with bolts, clips, or clamps [**33, 34**], with flat or lenticular annular gaskets [**35, 36**], or without gaskets [**37, 38**].

4. 3. 2. Simplified Working Hypotheses

The following considers the simplified hypotheses detailed in the works [**28, 41**], among which the most significant are:

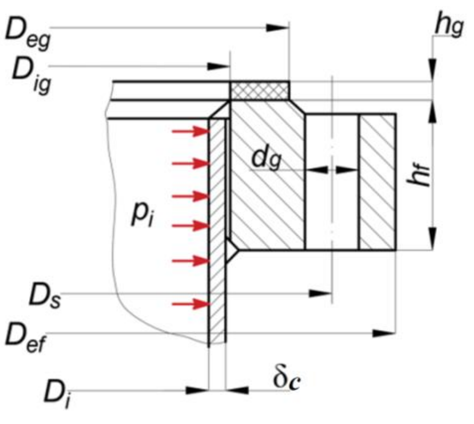

Fig. 4. 3. Flat annular flange type A

(dimensional characteristics – diagram) **[29, 42].**

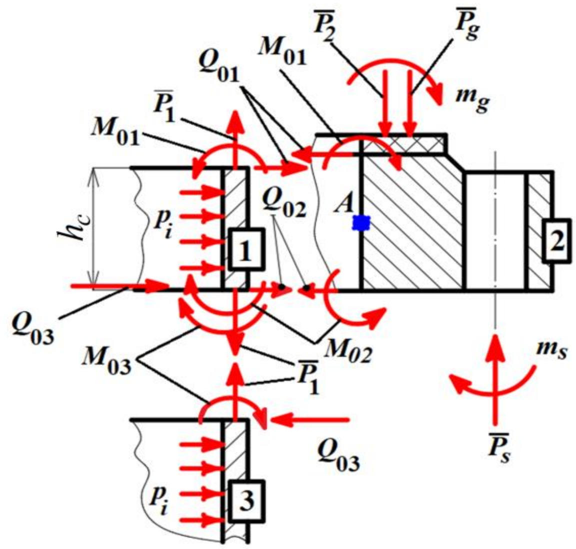

Fig. 4. 4. Hypothetical Separation of Flange Assembly Elements (Diagram):
1 – Adjacent cylindrical shell to the flange ring; 2 – flange ring; 3 – Cylindrical shell (container body) [**29, 42].**

5. The present study considers three analysis variants for evaluating the rotation of the flange ring:

- **Variant 1** – The rotation of the flange ring occurs around its median circumference;
- **Variant 2** – The rotation of the flange ring is considered around its inner (median) circumference;

- Variant 3 – The rotation of the flange ring occurs around the circumference of the bolt hole centers (at the median surface level of the ring).

* * *

4. 3. 3. Continuity Equations for Deformations. Connection Loads

To deduce the expressions for the unit bending moments, $M_{0j}^{(v)}$ and the unit connection forces $Q_{0j}^{(v)}$, the assembly is hypothetically decomposed into its component elements (fig. 4. 4). In this regard, the compatibility equations for deformations (radial displacements and rotations) between the mentioned elements are written: 1 – 2 (top), 1 – 2 (bottom), 1 (bottom) – 3, resulting in the algebraic system written as:

$$\left[A^{(v)}\right]\cdot\left\{S_l^{(v)}\right\}=\left\{T_l^{(v)}\right\}, \tag{4. 27}$$

where:

$$\left[A^{(v)}\right]=\begin{bmatrix} a_{11}^{(v)} & a_{12}^{(v)} & \ldots & a_{16}^{(v)} \\ a_{21}^{(v)} & a_{22}^{(v)} & \ldots & a_{26}^{(v)} \\ \ldots & \ldots & \ldots & \ldots \\ a_{61}^{(v)} & a_{62}^{(v)} & \ldots & a_{66}^{(v)} \end{bmatrix}, \tag{4.28}$$

represents the ***influence factor*** matrix $a_{ij}^{(v)}$ ($v=1,2,3;\ i=1,\ldots,6;\ j=1,\ldots 6$); is the transposed vector of unit connection loads:

$$\left\{S_l^{(v)}\right\}=\left\{Q_{01}^{(v)}\quad M_{01}^{(v)}\quad Q_{02}^{(v)}\quad M_{02}^{(v)}\quad Q_{03}^{(v)}\quad M_{03}^{(v)}\right\}^T; \tag{4.29}$$

is the transposed vector of free terms (radial displacements and rotations under the action of external loads - pressure, temperature) -$b_j^{(v)}$ ($v=1,2,3;\ j=1,\ldots,6$):

$$\left\{T_l^{(v)}\right\}=\left\{b_1^{(v)}\quad b_2^{(v)}\quad \ldots\quad b_6^{(v)}\right\}^T. \tag{4.30}$$

From the equality (4. 29) the method for evaluating the unknown values of the present problem - unit shear forces, $Q_{0j}^{(v)}(j=1,2,3;\ v=1,2,3)$ and unit bending moments, $M_{0j}^{(v)}(j=1,2,3;\ v=1,2,3)$ – is deduced, written as:

$$\left\{S_l^{(v)}\right\}=\left[A^{(v)}\right]^{-1}\cdot\left\{T_l^{(v)}\right\}, \tag{4. 31}$$

in which $\left[A^{(v)}\right]^{-1}$ represents the inverse of the matrix $\left[A^{(v)}\right]$, whose determinant has a non-zero value.

* * *

The expressions of the ***influence factors***, for each variant, are given by the forms (4. 32) ….... (4. 35).

On the other hand, the relations for estimating the ***free terms*** (***radial displacements*** - b_1, b_3, b_5 and ***spins*** - b_2, b_4, b_6) the expressions ¤ are used. (4.36)...(4. 38). For the auxiliary quantities, the expressions (4. 39) and the appropriate notations are taken into account.

* * *

4. 3. 4. Conclusions

The above content discusses the deformation of the ring of a flat annular flange, welded to the cylindrical shell of a rotational shell. The deformation of the ring is considered around circumferences placed in the medial plane of the ring, in three variants: a) at the median surface (characteristic of the mean radius of the ring); b) at the inner surface; c) at the level of the bolt hole centers. Static loads are considered, acting as: the internal pressure of the working medium and the temperatures developed during operation characteristic of the median surface of the cylindrical shell and along the radius of the ring (according to a specific law [**25**]). The material of the cylindrical shell and the ring (the same or different from the shell) is isotropic, continuous, and homogeneous.

Mechanical and thermal stresses can be analytically evaluated through the theory of compatibility between the elastic deformations produced in the component elements.

An appropriate calculation program can lead to the optimization of the construction, with minimal material consumption and ensuring safe operation. The methodology outlined above also allows for the evaluation of stresses using discrete values of external loads in the case of a transient regime of pressure and temperature.

The results obtained through the aforementioned methodology can be further developed in additional research concerning the behavior of flange assemblies in areas such as creep, fatigue, the effect of residual stresses in weld seams, or crack prevention.

* * *

4. 4. Stresses in the Joint Area of the Purified Gas Exhaust Tube and the Upper Fixing Plate (I – *Super Cyclones*) the simplifying hypotheses of the study are detailed (paragraph 4. 4. 1.)

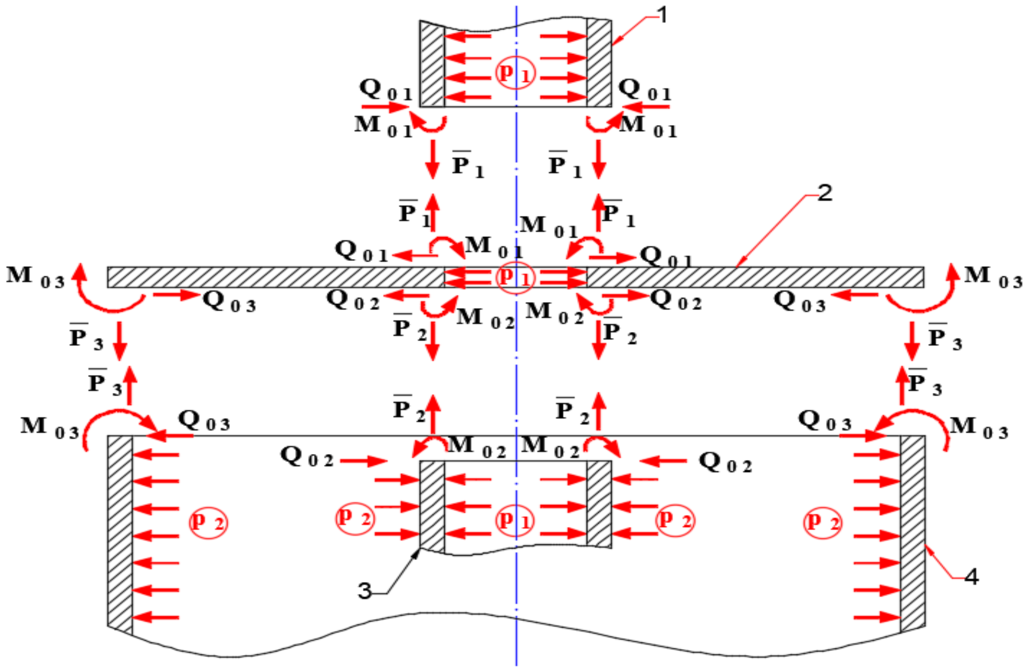

Fig. 4. 5. Joint of the Purified Gas Exhaust Tube from the Cyclone with the Outer Body Cap [**76**]
1 – Upper (outer) part of the purified gas exhaust tube; 2 – Flat plate for fixing the tube; 3 – Inner part of the separated gas exhaust tube; 4 – Outer cylindrical body of the cyclone

In this case, a large-sized cyclone is considered, where the loads at the edges of the plate do not influence each other in terms of stress and deformation.

4. 4. 2. Continuity Equations for Deformations. Connection Loads

Writing the continuity equations of radial deformations and rotations, for elements 1 and 2, respectively 2 and 3, results in the algebraic system written in the form [**76**]:

$$[A]\cdot\{S_l\}=\{T_l\}, \quad (4.40)$$

where the determinant of ***influencing factors*** has the form [**76**]:

$$[A]=\begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix}; \quad (4.41)$$

VECTOR (transposed of) connection loads: $a_{ij}\,(i=1,\,...\,4;\;\; j=1,\,...\,4)$:

$$\{S_l\}=\{Q_{01}\;\;M_{01}\;\;Q_{02}\;\;M_{02}\}^T; \quad (4.42)$$

VECTOR(transposed of) ***free terms*** $b_j\;(j=1,...\,4)$:

$$\{T_l\}=\{b_1\;\;b_2\;\;b_3\;\;b_4\}^T. \quad (4.43)$$

From the equation (4. 40) the values of the connection loads are deduced, in the form:

$$\{S_l\}=[A]^{-1}\cdot\{T_l\}, \quad (4.44)$$

where $[A]^{-1}$ represents the inverse of the determinant of the ***influencing factors*** (the value of the determinant is not zero).

*** * ***

The expressions of the ***influencing factors*** are presented in the forms - relationships (4. 45), and those of ***free terms*** *(*radial displacements: b_1, b_3; spins: b_2, b_4) – relations (4.46....4.49)**[76].**

The other quantities characteristic of the study are illustrated by the forms (4. 50) …….(4. 68).

*** * ***

<u>**Note**</u>: For writing the radial deformations and rotations, the following bibliographic sources and the previously mentioned expressions have been used:

a. 1- ***<u>The effect of the unit axial forces</u>*** $\overline{P}_1, \overline{P}_2$, ***<u>uniformly distributed on the inner contour</u>*** of plate 2 (fig. 4. 5) is introduced through of the expression:

$$F_i(p_1, p_2), \text{ choosing } F_{i1}(p_1, p_2) \text{ or } F_{i2}(p_1, p_2) \text{ or } F_{i3}(p_1, p_2),$$

where:

$F_{i1}(p_1, p_2) = F_{1p} \cdot p_1 + F_{2p} \cdot p_2 -$ variant I - a [**1, 44, 47, 48**];

$F_{i2}(p_1, p_2) = K_1 \cdot p_1 + K_2 \cdot p_2 -$variant II - a**[44, 49, 50]**;

$F_{i3}(p_1, p_2) = C_{31}(R_{m1}) \cdot p_1 + C_{32}(R_{m1}) \cdot p_2$ - variant III – a **[44, 51]**;

b. 1- ***<u>The effect of the uniformly distributed pressure on the lower surface of plate 2, at the level of the inner circumference</u>***, is assessed through the quantity:

$$c_k(p_2), \text{ choosing } c_1(p_2) \text{ or } c_2(p_2),$$

where:

$c_1(p_2) = c_{1p_2n}$ - variant I – a [**44, 49, 50, 52**];

$c_2(p_2) = c_{3p_2n}$ - variant II – a [**44, 51, 53, 54**];

c. 1- ***<u>the simultaneous effect of unit radial moments developed by</u>*** M_{01}, M_{02} **and** ***<u>by the unitary cutting forces</u>*** Q_{01}, Q_{02}, along the radius circumference R_{m1},is included via the sizes:

$$f_{jMR_{m1}}, \text{ choosing } f_{1MR_{m1}} \text{ or } f_{2MR_{m1}},$$

where:

$f_{1MR_{m1}}$ - variant Ia [**44, 49, 50**];

$f_{2MR_{m1}}$ - variant II – a [**44, 51, 53, 54**];

d. 1- ***<u>the simultaneous effect of the radial pressure developed on the inner surface of plate 2 by the pressures</u>*** p_1, p_2 ***<u>and unitary cutting forces</u>*** Q_{01}, Q_{02} is included through the sizes $c_{1p_r}, c_{2p_r}, c_{3p_r}, c_{4p_r}, c_{5p_r}$ [**44**];

e. 1- ***<u>the effect of temperature</u>***, developed in the form of radial displacement, is illustrated by the quantities $C^{\bullet}_{1T}, C^{\bullet}_{2T}$ [**44, 55**].

4. 4. 3. Stress states [76]

4. 4. 3. 1. Radial and Hoop (annular) Stresses

The radial σ_1 and hoop σ_2 stresses, which are constant along the length of cylindrical elements 1 and 3 (fig. 4. 5), have the forms $(4.69)_1$ ...$(4.70)_3$, for cylindrical elements 1 and

3, while the expressions of the stresses developed by the connection loads along the length of cylindrical elements 1, 2, and 3 are illustrated by forms (4. 71) $_1$....(4. 75) $_2$.

4.4.3.2. Equivalent stresses developed by external loads – constant

Assuming that pressures and thermal gradients—external loads—are constant along cylindrical elements 1 and 3, the equivalent stresses in this case are not dependent on the coordinate zzz (considering the theory of strain energy variation - ***Huber-Hencky-Mises*** variants) [**54, 56**] and have the forms (4. 76) $_1$…(4. 76) $_4$.

Equivalent stresses developed by the connection loads

In the present case, it is taken into account that the connection loads are dependent on the variable length along the considered cylindrical element. The equivalent stresses are characterized by the relations (4. 77) …..(4. 82), without the effect of unit shear forces. Taking their effect into account, the expressions (4. 83) ... (4.90) are used.

* * *

Note: It is necessary to evaluate the maximum values of the equivalent stresses - relations (4. 87) and (4. 88), respectively (4. 89) and (4. 90) - on the surfaces of cylindrical elements 1 and 3, to compare them with the admissible strength characteristic of the construction materials under operating conditions. Thus,

$$\left\{ \left(\sigma_{ech} \right)_{1x} \right\}_{max} \le \sigma_{1a} = c_s \cdot \sigma_c \text{ or} \left\{ \left(\sigma_{ech} \right)_{3x} \right\}_{max} \le \sigma_{3a} = c_s \cdot \sigma_c ,$$

where σ_c represents the conventional yield strength of the metallic material.

* * *

Using the criterion of participation or contribution of the loads regarding the load-bearing capacity of the analyzed structure, we can write:

$$\left[f_{pp} \right]_j + \left[f_{p\Delta T} \right]_j + \left[f_{pM_x} \right]_j + \left[f_{pT_x} \right]_j + \left[f_{p\tau_x} \right]_j \le 1, \quad (4.\ 91)$$

where the following notations were used: f_{pp} – ***the participation/contribution factor*** corresponding to the working pressure; $f_{p\Delta T}$ - ***the participation/contribution factor*** of the thermal effect; f_{pM_x} - ***the participation/contribution factor*** of the unit radial bending moment, with a maximum value, at a current coordinate x, located along the cylindrical shell; f_{pT_x} - he ***participation/contribution factor*** of the unit tensile/compressive hoop force, at a current coordinate x, located along the analyzed cylinder shell; $f_{p\tau_x}$ - the ***participation/contribution factor*** of the cutting force, unitary, at a current rate x, measured along the cylindrical shell; j – represents the number of the considered cylindrical shell.

Expressions of ***participation/contribution factors*** are presented in the following forms:

$$\left[f_{pp} \right]_j = \left[\left(\sigma_{ech} \right)_{jx} \right]_p \Big/ \sigma_a ; \quad \left[f_{p\Delta T} \right]_j = \left[\left(\sigma_{ech} \right)_{jx} \right]_{\Delta T_j} \Big/ \sigma_a ;$$

$$\left[f_{pM_x} \right]_j = \left[\left(\sigma_{ech} \right)_{jx} \right]_{M_{jx}} \Big/ \sigma_a ; \quad \left[f_{pT_x} \right]_j = \left[\left(\sigma_{ech} \right)_{jx} \right]_{T_{jx}} \Big/ \sigma_a ;$$

$$\left[f_{p\tau_x} \right]_j = \left[\left(\sigma_{ech} \right)_{jx} \right]_{Q_{jx}} \Big/ \sigma_a . \quad (4.\ 92)$$

4. 4. 4. Conclusions

The preceding analysis considers the stress states developed in the cylindrical sections of the exhaust tube for the separated dust from the impure gas, which is introduced tangentially into the cyclone. These two sections can be made from different materials or the same material, in which case the calculation relationships are adapted accordingly. Specific working hypotheses are considered for the given case. The basic hypothesis accepted here is that the flat plate of the cyclone, to which the exhaust tube is fixed, is an extensive construction (characteristic of super cyclones), with the edges not influencing each other in terms of both deformations and stresses.

* * *

4. 5. Stresses in the Joint Area of the Purified Gas Exhaust Tube and the Upper Fixing Plate (II – mini cyclones)

Note: The hypotheses mentioned in paragraph 4.4.1 are maintained.

4. 5. 2. Continuity Equations for Deformations. Connection Loads

In this case the relation (4. 40) becomes) [**77**]:

$$\left[A^{\bullet}\right]\cdot\left\{S_l^{\bullet}\right\}=\left\{T_l^{\bullet}\right\}, \quad (4.91)$$

in which the determinant of ***influencing factors*** takes the form [**77**]:

$$\left[A^{\bullet}\right]=\begin{bmatrix} a^{\bullet}_{11} & a^{\bullet}_{12} & a^{\bullet}_{13} & a^{\bullet}_{14} & a^{\bullet}_{15} & a^{\bullet}_{16} \\ a^{\bullet}_{21} & a^{\bullet}_{22} & a^{\bullet}_{23} & a^{\bullet}_{24} & a^{\bullet}_{25} & a^{\bullet}_{26} \\ a^{\bullet}_{31} & a^{\bullet}_{32} & a^{\bullet}_{33} & a^{\bullet}_{34} & a^{\bullet}_{35} & a^{\bullet}_{36} \\ a^{\bullet}_{41} & a^{\bullet}_{42} & a^{\bullet}_{43} & a^{\bullet}_{44} & a^{\bullet}_{45} & a^{\bullet}_{46} \\ a^{\bullet}_{51} & a^{\bullet}_{52} & a^{\bullet}_{53} & a^{\bullet}_{54} & a^{\bullet}_{55} & a^{\bullet}_{56} \\ a^{\bullet}_{61} & a^{\bullet}_{62} & a^{\bullet}_{63} & a^{\bullet}_{64} & a^{\bullet}_{65} & a^{\bullet}_{66} \end{bmatrix}; \quad (4.92)$$

Vector (transposed of) ***connection loads***: $a_{ij}\,(i=1,\ ...6;\ \ j=1,\ ...6\ )$:

$$\left\{S_l^{\bullet}\right\}=\left\{\ Q_{01}\ \ M_{01}\ \ Q_{02}\ \ M_{02}\ \ Q_{03}\ \ M_{03}\ \right\}^T; \quad (4.93)$$

VECTOR (transposed of) ***free terms*** $b_j\ (j=1,...6)$:

$$\left\{T_l^{\bullet}\right\}=\left\{\ b_1^{\bullet}\ \ b_2^{\bullet}\ \ b_3^{\bullet}\ \ b_4^{\bullet}\ \ b_5^{\bullet}\ \ b_6^{\bullet}\right\}^T. \quad (4.\ 94)$$

From the equality (4. 91) the values of the ***connection loads*** are deduced, in the form:

$$\left\{S_l^{\bullet}\right\}=\left[\ A^{\bullet}\right]^{-1}\cdot\left\{T_l^{\bullet}\right\}, \quad (4.\ 95)$$

where $\left[A^{\bullet} \right]^{-1}$ represents the inverse of the determinant of the ***influencing factors***. In this case, the value of the mentioned determinant is not null.

* * *

Factors of influence have the forms (4. 96), the ***free terms*** the formulas (4. 97)…..(4. 102), while the formulas (4. 103)…(4. 110) are used for the ***auxiliary quantities***.

* * *

Note: For writing the expressions of radial deformations and rotations, the following bibliographic sources and the expressions specified above were used:

a. 2)- ***the effect of unitary axial forces*** $\overline{P}_1, \overline{P}_2$, ***uniformly distributed on the outer contour*** of plate 2 (fig. 4. 5) is introduced by means of the expression:

$$F_l\left(p_1, p_2\right), \text{ choosing } F_{l1}\left(p_1, p_2\right) \text{ or } F_{l2}\left(p_1, p_2\right) \text{ or } F_{l3}\left(p_1, p_2\right),$$

where:

$F_{l1}\left(p_1, p_2\right) = F_{3p} \cdot p_1 + F_{4p} \cdot p_2 -$ variant I - of [**1, 44, 47, 48**];

$F_{l2}\left(p_1, p_2\right) = K_3 \cdot p_1 + K_4 \cdot p_2 -$variant II – of **[44, 49, 50]**;

$F_{l3}\left(p_1, p_2\right) = C_{31}\left(R_{m4}\right) \cdot p_1 + C_{32}\left(R_{m4}\right) \cdot p_2$ - variant III – of **[44, 51]**;

b. 2- ***the effect of the uniformly distributed pressure on the lower surface of plate 2, at the level of the outer circumference***, is appreciated by means of the quantity:

$$c_{l p_2 n}\left(p_2\right), \text{ choosing } c_{l1}\left(p_2\right) \text{ or } c_{l2}\left(p_2\right),$$

where:

$c_{l1}\left(p_2\right) = c_{1 p_2 n}$ - variant I – a [**44, 49, 50, 52**];

$c_{l2}\left(p_2\right) = c_{3 p_2 n}$ - variant II – a [**44, 51, 53, 54**];

c. 2- ***the simultaneous effect of unit radial moments developed*** by M_{01}, M_{02}, M_{03} and by ***the cutting, unifying forces***, Q_{01}, Q_{02}, Q_{03}, along the radius circumference R_{m4}, is included via the sizes:

$$f_{jMR_{m4}}, \text{ choosing } f_{1MR_{m4}} \text{ or } f_{2MR_{m4}},$$

where:

$f_{1MR_{m4}}$ - variant I of [**44, 49, 50**];

$f_{2MR_{m4}}$ - variant II – of [**44, 51, 53, 54**];

4. 5. 3. Stress states

4. 5. 3. 1. Radial and Hoop Stresses

The action of external - constant loads: the expressions **(4. 111)** $_1$**...(4. 111)** $_3$.

The action of the connection loads: the expressions (4. 112) $_1$...(4. 114).

4. 5. 3. 2. Equivalent Stresses Developed by External Loads – Constants

Assuming that pressures and thermal gradients—external loads—are constant along element 4 (fig. 4.5), the equivalent stresses, in this case, are not dependent on the coordinate x (considering the theory of strain energy variation – ***Huber – Hencky - Mises*** variants) **[54, 56**]: relations (4. 115) and (4. 116).

Equivalent Stresses Developed by Connection Loads

The appropriate relationships (4.117) … (4.120) are adopted without the effect of unit shear forces, and expressions (4.121) … (4.128) are used accordingly.

4. 5. 4. Conclusions

The previously presented content develops the method for evaluating the stress states developed in the mantle of small-sized cyclones, correlated with the analysis from chapter 4.4. It is observed that the connection loads in the structural discontinuities shown in figure 4.5 influence each other. The final conclusion of the analysis must consider the stress states in the three sections 1-2, 2-3, and 3-4. Simultaneously, the conditions of maximum equivalent stresses compared to the admissible strengths of the construction materials in each structural discontinuity must be met.

* * *

4. 6. Stresses in the Support Area of Pressure Vessels

4. 6. 1. Introduction

The support of pressure vessels (including cyclones), in terms of sizing or verifying the geometry of lateral supports, is a significant concern for researchers and users of such mechanical structures [**57 - 67**]. There are, as known, a series of standards and norms that present different geometries of lateral supports, as well as appropriate calculation methods [**68 - 75**].

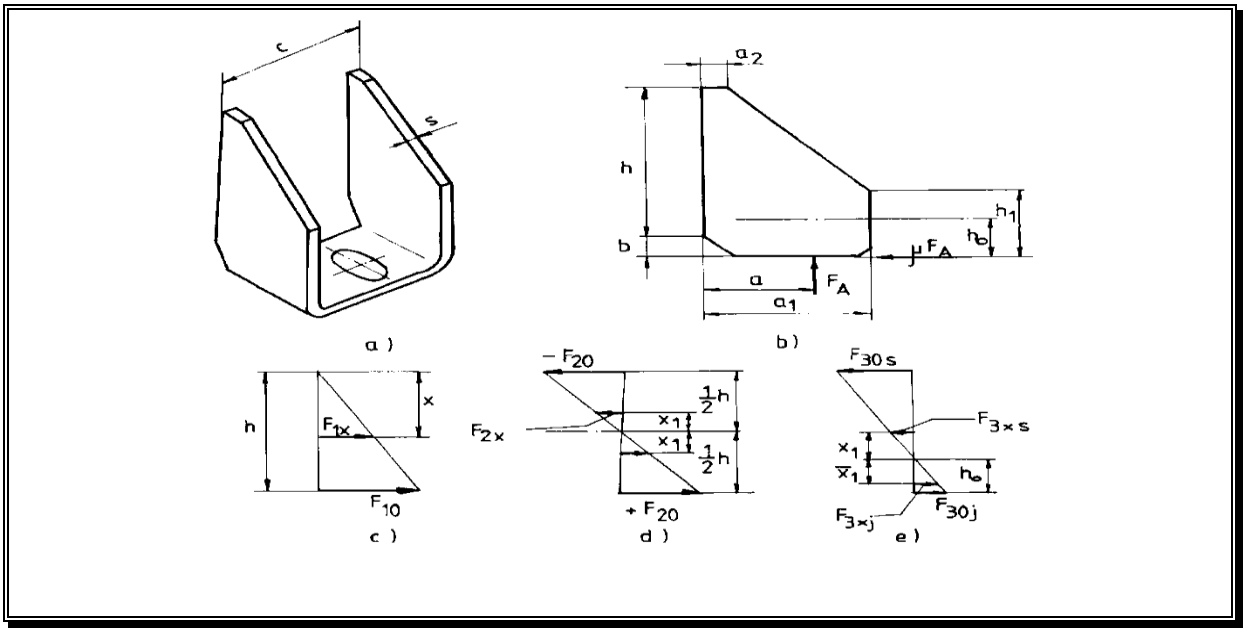

Fig. 4. 6. . Variants of Loading on a Lateral Support

a) Constructive form of the support; b) Loads acting on the support; c) Linear distribution of the normal stress at the contact surface with the vessel, with the rotation of the support around an axis passing through its upper points; d) Linear distribution of the normal stress, with the rotation of the support around a line passing through the median contact points of the support; e) Linear distribution of the normal stress, with the rotation of the support around a line passing through the center of gravity of the lateral branches

4. 6. 2. Variants of study

***Variant A*. Rotation of the support around the upper marginal axis is considered (fig. 4. 6c)**

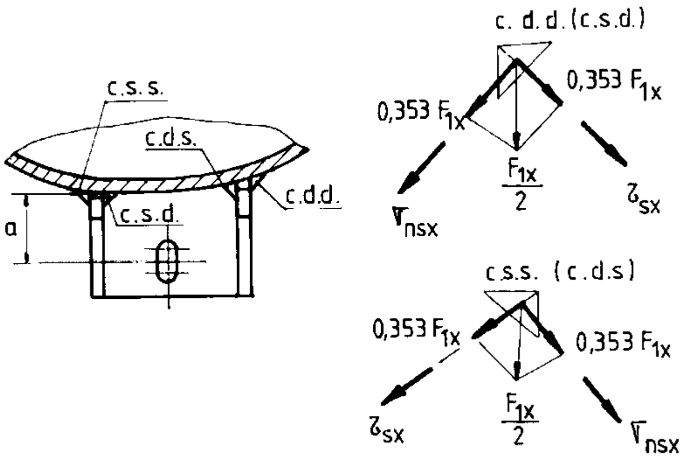

Fig. 4. 7. Schematic of the request of the welding cords for fixing the lateral support on the body of the container

css, csd– welding seam placed on the left side, respectively on the right side, of the left branch of the support; cds, cdd – weld bead placed on the left side, respectively on the right side, of the right branch of the support. Note: the observation of the bearing is made towards the axis of symmetry of the container.

***Variant B*: Rotation of the support around the transverse axis that passes through the middle of the height h (fig. 4. 6, d)**

***Variant* C: Rotation of the support around the transverse axis that passes through the center of gravity/mass of the lateral branches**

4. 6. 3. Conclusions

The content of the study presents the stress states that manifest in the sheet metal of a lateral support, as well as in the weld seams necessary for fixing it to the body of the vertical cylindrical vessel. The curvature of the cylindrical part is neglected, as it insignificantly influences the intensity of the stresses characteristic of this case.

CHAPTER 5

EXPERIMENTAL STUDIES ON THE PROCESS OF DUST SEPARATION FROM IMPURIFIED DRY GASES IN THE TANGENTIAL FEED CYCLONE

5. 1. General objectives of experimental research

This study presents two experimental studies: the first relates to the granulometric analysis of powders from granular materials in various process industries (chemical, food, wood processing, mining, etc.), and the second relates to testing the separation of these material particles in an experimentally constructed cyclone.

The experimental research aims to test the particles in terms of their average diameter, necessary for the study of centrifugal separation in an experimental cyclone installation. Such a study aims to determine the separation efficiency.

The composition of polydisperse mixtures has a different influence on industrial processes. In most cases, such mixtures of solid granules have different sizes (granulometric fractions, determined by passing through the sieves of the experimental apparatus).

Table 5. 1. Types of granular material particles tested

No. crt	Type of granular material particles
1	Graphite (PM-1)
2	Perlite (PM-2)
3	Clay (PM-3)
4	Pine Shell (PM-4)

The first experimental study aims to determine the granulometric distribution of four types of granular powders (Table 5.1), produced in various process industries (chemical, food, wood processing, mining, etc.). The study was conducted according to the standard SR EN ISO 1624:2001.

5. 2. 3. Equipment and Instruments Used in Experimental Research

Fig. 5. 2. The image of the vibration screening device with 4 standardized sieves

• sieve set with mesh opening of: 0.125 mm; 0.315 mm; 0.5 mm and 1.0 mm;

• analytical balance, Precisa brand with a weighing precision of (±0),1mg (fig. 5. 3 - fig. 5. 4).

5. 2. 6. Processing and interpretation of experimental research results

From the graphical distributions shown in figures 5.8÷5.11, the values of the average diameters (*Mr*) [mm] of the material particles tested, are as follows:

- For coal / PM-1: dm = 0.825 mm;
- for perlite / PM-2: dm = 0.775 mm;
- for clay / PM-3: dm = 0.810 mm;
- for pine shell / PM-4: dm = 0.830 mm.

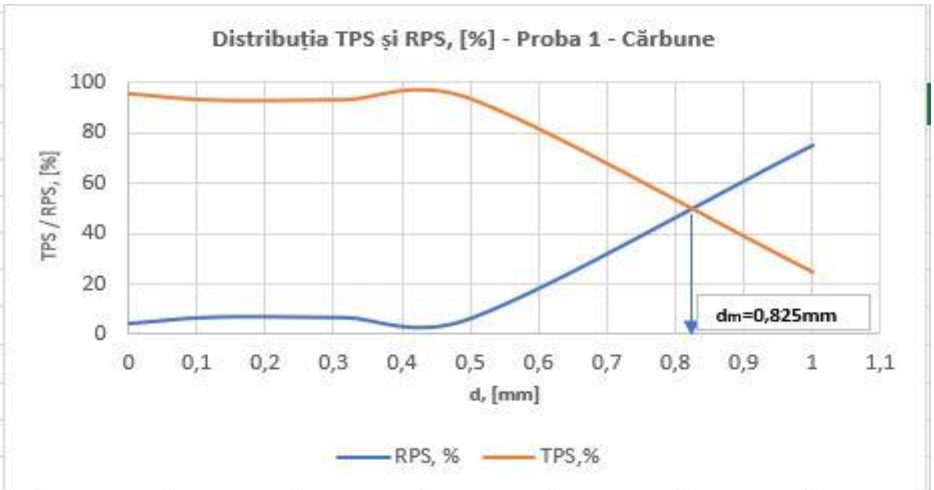

Fig. 5. 8. Graphical distribution - TPS and RPS [%], for sample 1 –**coal**/ PM-1.

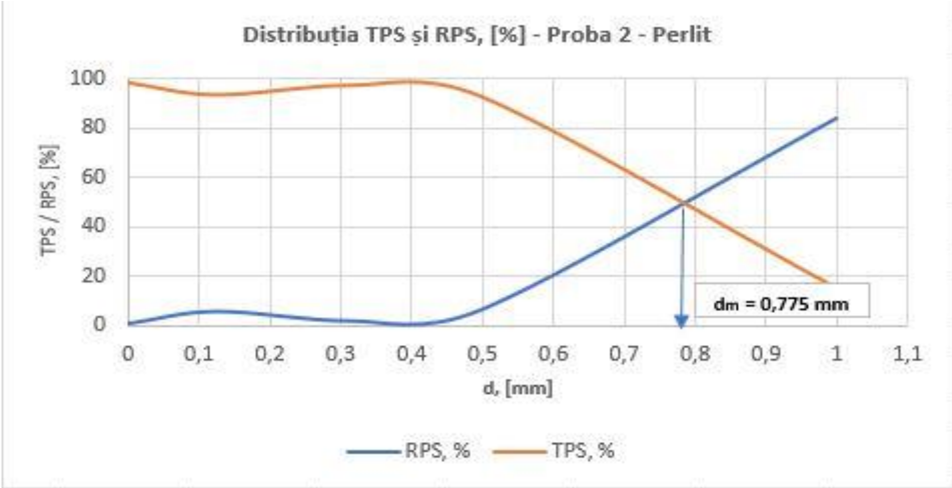

Fig. 5. 9. Graphical distribution - TPS and RPS [%], for sample 2 –**perlite**/ PM-2.

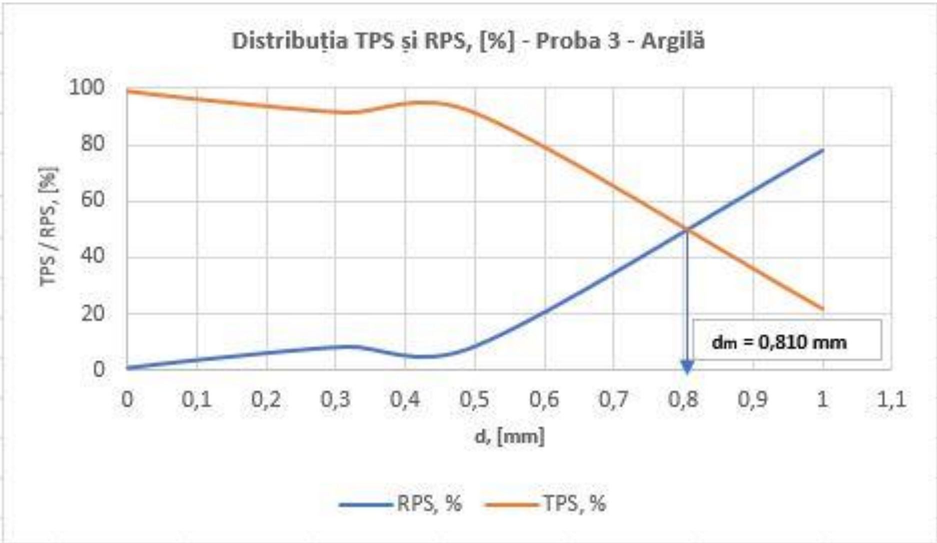

Fig. 5. 10. Graphical distribution - TPS and RPS [%], for sample 3 –**clay**/ PM-3.

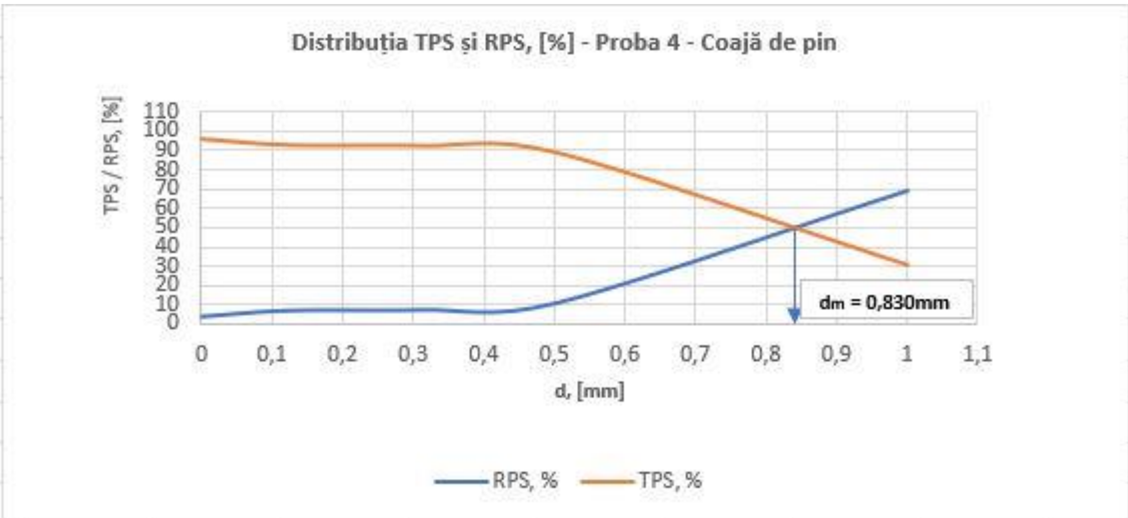

Fig. 5. 11. Graphical distribution - TPS and RPS [%], for sample 4 –**pine shell**/ PM-4.

<u>CONCLUSION</u>: *The granulometric distribution of the material particles tested in section 5.2 shows that 95% of the analyzed particles have average dimensions dp≅0.8 mm (fig. 5.8÷fig. 5.11)*

5. 3. Research on the Separation Process in the Cyclone

5. 3. 1. The object of experimental research

The main focus of the experimental research in this study is ***the possible optimization of the solid particle separation process in the cyclone***. The research followed these steps:

- Practical creation of an experimental cyclone model to allow the study of the separation process of the four types of tested material particles (section 5.2), developed within the Department of Industrial Process Equipment.
- Comparison of the theoretical research results with those obtained from laboratory experimental investigations, to validate the designed and constructed technical equipment.
- Drawing pertinent conclusions regarding the effect of the cyclone's geometry and the particle sizes used in the granulometric analysis on the separation efficiency, and specifying future research directions related to this topic.

Given the results obtained in the granulometric analysis, the second experimental study was conducted: *examination of the influence of the particle sizes used in the granulometric analysis on the separation efficiency in a tangential feed cyclone centrifugal mechanical equipment*.

To achieve this:

- **A tangential feed experimental cyclone model** was technologically/constructively designed and practically created (Fig. 5.16) by additive deposition of PLA plastic material / Ø1.75 mm using a 3D printer, based on the theoretical constructive dimensions of the conventional cyclone, **to allow the study of the separation process of the four types of tested material particles (PM-1 ... PM-4) for determining the efficiency in the separation of solid-gas biphasic mixtures** in an experimental installation presented in fig. 5.15 .

The experimental installation (Fig. 5.15) consists of the experimental cyclone (1), coupled via a connection to a vacuum cleaner (4) through a flexible discharge hose (3) and another connection to a flexible suction hose (3bis). The airflow rate is adjusted using a vacuum cleaner equipped with an 8-speed/frequency variable controller (5).

Fig. 5. 16. Modelul de ciclon experimental

5.3.3.3. Experimental installation for the separation of material particles in a centrifugal field

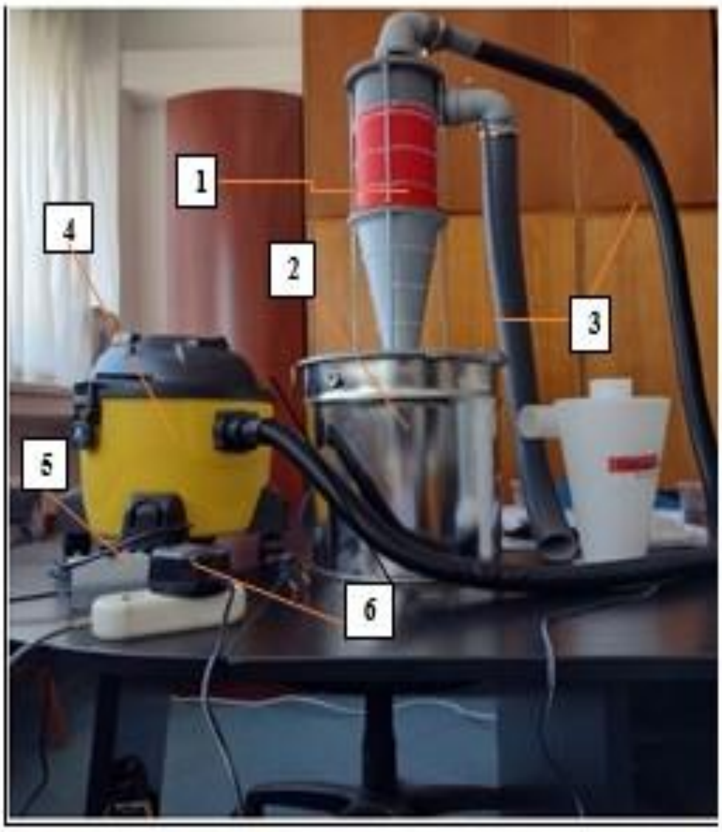

Fig. 5.15. Imaginea ciclonului experimental
1 – ciclon experimental cu alimentare tangențială; 2 – găleată de colectare pulberi; 3 – furtunuri elastice de aspirație și refulare; 4 – aspirator; 5 – variator de turație / 8 trepte; 6 – sistem de alimentare cu curent electric

Using the experimental installation, the following technical parameters were measured and determined, which are of particular importance in this experimental study:

- *average speed* (variable) of the gas (air) in the cyclone, v_i [m/s], measured with the propeller anemometer (table 5.7);
- *the flow rates Qi* [m^3 / s], (i = 1….8), based on the calculation relationship: *Qi*= (π· d^2 / 4) · v_i (table 5.8);
- Interior surface area of the gas inlet connection Ar in the cyclone:

$$Ar = \pi \cdot d^2 / 4 = 1661.06 \text{ mm}^2$$

- *intrinsic density of material particles* ρ_p separated from the air in the cyclone (table 5.9);

- Granulometric distribution of the material particles tested in section 5.2: *95%* of the amount of particles analyzed has the average dimensions dp≅0.8 mm (fig. 5.8÷fig. 5.11);

- density of the air subject to dedusting: $\rho_g = 1{,}225\ kg/m^3$;
- the kinematic viscosity of the air subject to dedusting $\nu_g = 1{,}44 \cdot 10^{-5}\ m^2/s$ (with these data, the dynamic air viscosity was calculated $\eta_g = \nu_g \cdot \rho_g = \nu_g \cdot \rho_g = 1{,}765 \cdot 10^{-5}\, Pa \cdot s$)

The technological sizing of the experimental cyclone was carried out using the values of the technical parameters determined earlier (Table 5.7 and Table 5.8), as well as by using the specific theoretical brief for the technological and constructive sizing calculation of the conventional cyclone, according to the relations (5. 1)÷(5. 26).

5. 3. 6. Results of experimental research

5. 3. 7. Processing and interpretation of experimental research results

Sedimentation time t_{s_i} in which the material particles (PM-1, PM-2, PM-3 and PM-4) reach the exhaust connection from the cyclone (tab. 5. 11÷table 5. 14):

$$t_{s_i} = 18 \cdot \frac{\eta_g}{\rho_{p_{PM_i}}} \cdot \frac{1}{d^2} \cdot \frac{r_m^2}{v_i^2} \cdot \ln \frac{r_e}{r_i} = [\text{s}].\frac{557{,}29}{\rho_{p_{PM_i}} \cdot v_i^2}$$

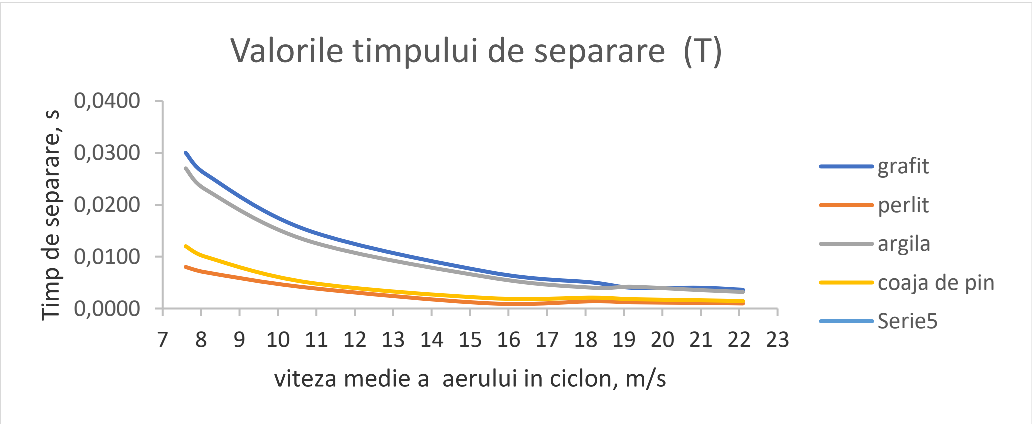

Fig. 5. 17. Variation of sedimentation (separation) time based on the average air velocity in the cyclone (for particles passed through sieves – T)

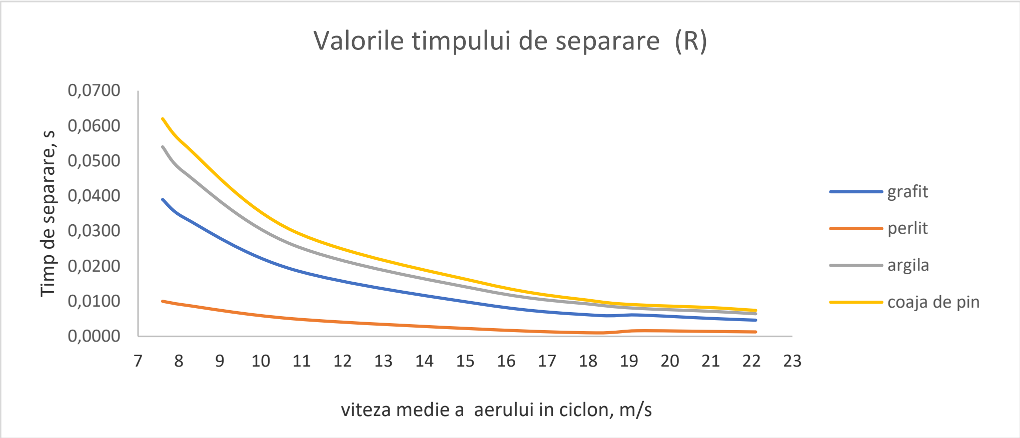

Fig. 5. 18. Variation of sedimentation (separation) time based on the average air velocity in the cyclone (for particles passed through sieves – R)

After processing the sedimentation (separation) time values for which the material particles (graphite/PM-1, perlite/PM-2, clay/PM-3, and pine shell/PM-4) reach the exhaust connection from the cyclone (Table 5.11 to Table 5.14), the graphical distributions represented in Figures 5.17 and 5.18 were obtained.

From these graphical distributions (fig. 5. 17 and fig. 5. 18), it results that pearlite material particles (PM-2) have the smallest variation in separation time based on the average air velocity in the cyclone.

The necessary length of the path for the particle to be deposited on the wall (table 5.15÷table 5.18), is calculated using the formula:

$$s = v_i \cdot t_{si} [\text{m}].$$

The length of the air current path (with particles) for a single helix in the cyclone:

$$s_1 = \frac{2 \cdot \pi \cdot r_m}{cos 9^\circ} = \frac{2 \cdot \pi \cdot 0,045}{cos 9^\circ} = 0.285 \text{ m}$$

where β - is the winding angle of the helix, given by $= \beta = arctg \frac{d}{2 \cdot \pi \cdot r_m} = 9^0$

The number of helices of the gas until the particle reaches the cyclone wall (Table 5.19 to Table 5.22) is calculated using the formula:

$$n = \frac{s}{s_1} [-].$$

By processing the results obtained for the path length of the air current until the particle is deposited on the cyclone wall (Table 5.15 to Table 5.18), graphical distributions of this path length based on the average air velocity in the cyclone were obtained, as shown in Figures 5.19 and 5.20, for both particles passed through sieves (T) and particles retained on sieves (R).

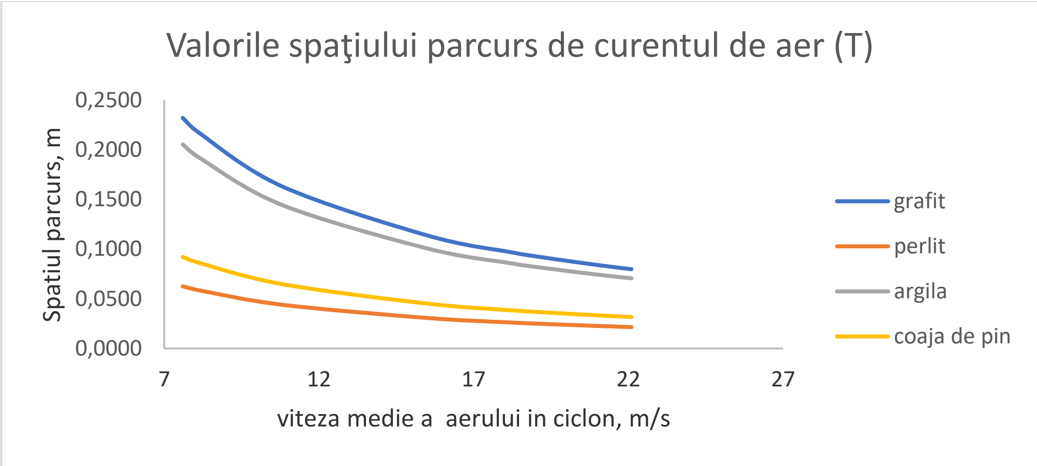

Fig. 5. 19. Variation of the path traveled by the air current based on the average air velocity in the cyclone (for particles passed through sieves – T)

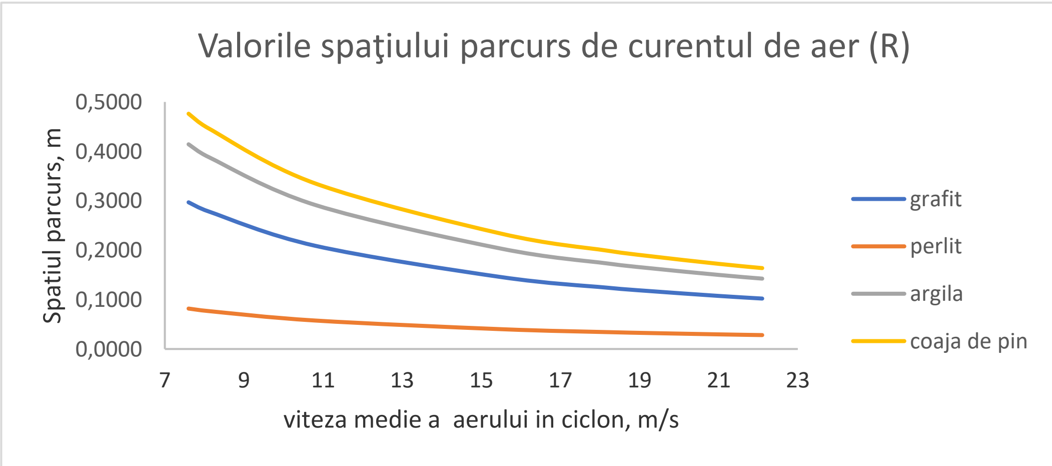

Fig. 5. 20. Variation of the path traveled by the air current based on the average air velocity in the cyclone (for particles retained on sieves – R)

From the examination of the graphical variations in Figure 5.19 and Figure 5.20, it can be concluded that the perlite particles (PM-2) travel the shortest distance in the cyclone to be deposited on its wall compared to the other analyzed material particle samples.

Additionally, after processing the values obtained for the number of rotations/helices of the air current until the material particle reaches the inner surface of the cyclone (Table 5.19 to Table 5.22), the graphical distributions shown in Figure 5.21 and Figure 5.22 were obtained for the four types of material particles analyzed experimentally (particles passed through sieves – T and particles retained on sieves – R).

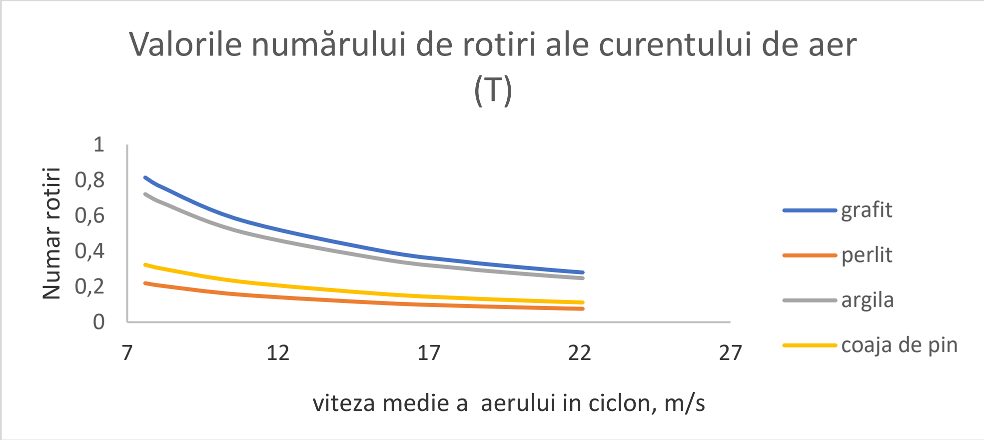

Fig. 5. 21. Variation in the number of rotations of the air stream based on the average air velocity in the cyclone (for particles passed through the sieve – T)

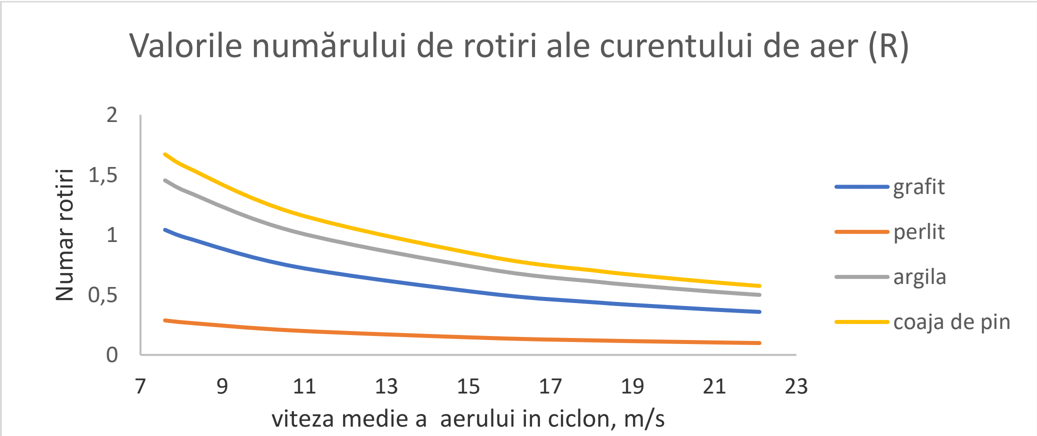

Fig. 5. 22. Variation in the number of rotations of the air stream based on the average air velocity in the cyclone (for particles retained on the sieve– R)

From the analysis of these two graphical distributions (Fig. 5.21 and Fig. 5.22), it is evident that the perlite sample (PM-2) exhibits the smallest variation in the number of rotations of the air stream in the cyclone for depositing particles on the cyclone wall, compared to the other tested samples.

Limit size of the particles retained by the experimental cyclone (table 5.23÷table 5.26), is determined using the calculation formula:

$$d_{lim} = 3.\cdot \sqrt{\frac{\eta_g}{\pi \cdot n \cdot \rho_p} \cdot \frac{r_m}{v_i} \cdot ln\frac{r_e}{r_i}} \cdot = 1.25 \cdot 10^{-9} \cdot \sqrt{\frac{1}{n \cdot \rho_p \cdot v_i}} \; [\mu m]$$

The graphical distributions for the variation in the limit size of the four tested material particle samples (passed through sieve – T and retained on sieve – R), based on the average air velocity in the cyclone, were obtained from the latest processing of the results (Table 5.23 to Table 5.26), as shown in Figures 5.23 and 5.24.

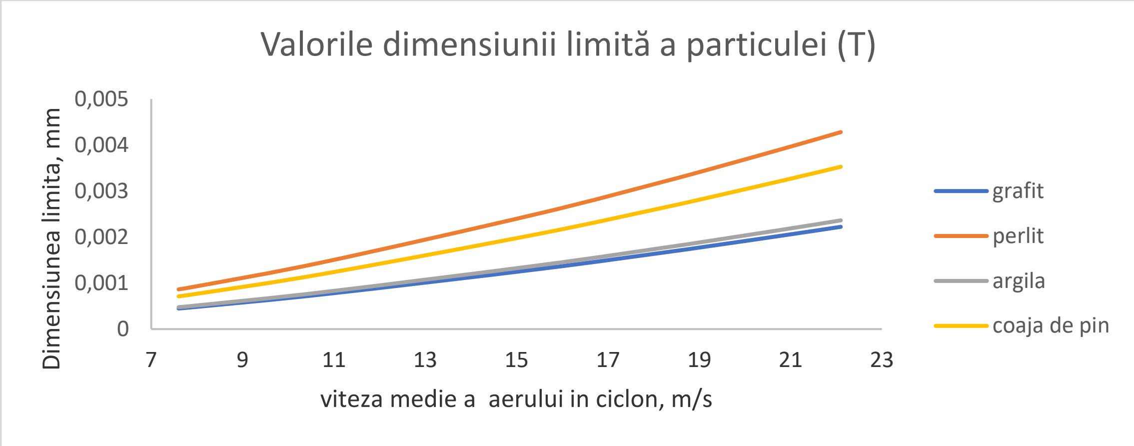

Fig. 5. 23. Variation in the limit size of the particle based on the average air velocity in the cyclone (for particles passed through the sieve – T)

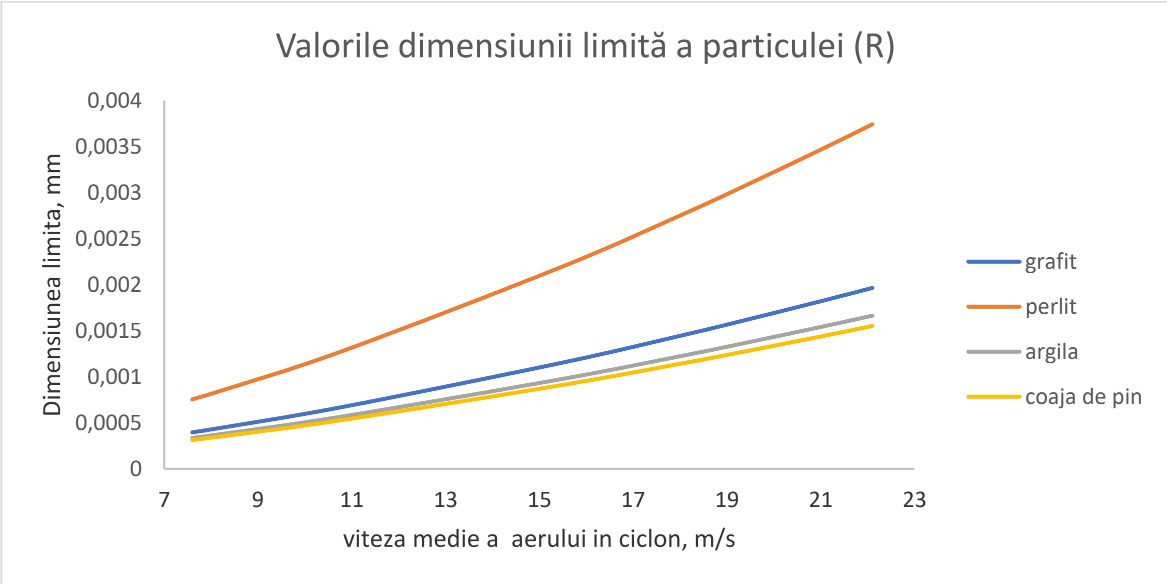

Fig. 5. 24. Variation in the limit size of the particle based on the average air velocity in the cyclone (for particles retained on the sieve – R).

Thus, from the examination of these graphical distributions (Fig. 5.23 and Fig. 5.24), it can be observed that the smallest limit sizes correspond to graphite particles (PM-1) (for particles passed through the sieve - T) and pine shell particles (PM-4) (for particles retained on the sieve - R). This, in fact, represents a particularly important characteristic for ensuring the maximum efficiency condition of material particle separation in a centrifugal mechanical *cyclone*.

5. 4. Conclusions

The present experimental research aimed, on the one hand, at determining the granulometric distribution of four types of granular powders (graphite / PM-1, perlite / PM-2, clay / PM-3, and pine shell / PM-4), for which the *average diameter values* (d_m) [mm] were determined, and on the other hand, it studied under laboratory conditions the influence of the particle sizes used in the granulometric analysis on the separation efficiency in a centrifugal mechanical *cyclone*.

Using the equipment for both types of experimental research, a number of specific characteristics of the tested granular materials could be highlighted. Thus, the graphical distribution of the percentage values of the passages through the sieve (TPS) [%] and the percentage values of the retentions in the sieve (RPS) [%] (for the four types of granular materials tested) was determined, at the intersection point of which the average (critical) separation size of the analyzed material particles, d_m [mm], was found.

Furthermore, with the help of the experimental installation for separating the four types of material particles in a centrifugal field using an experimentally constructed cyclone (according to the technical requirements of the conventional cyclone), it was possible to correlate the experimental results with those determined through the specific theoretical brief, leading to the determination of the separation efficiency of the particles in the cyclone based on the limit size d_{lim} of the particles.

5. 4. 2. Future Research Perspectives

- Specific studies to contribute to the design, technological, and constructive planning of new cyclones for separating solid particles from impure industrial gases.
- Studying the duration of gas movement inside cyclones, resulting in increased separation efficiency of solid particles.

CHAPTER 6

CONCLUSIONS. PERSONAL CONTRIBUTIONS. PERSPECTIVES

6. 1. CONCLUSIONS

Atmospheric pollution represents a major concern for the external environment and human health, as observed in the European Union (EU). There is an exceeding of the permissible limits for the quality of air inhaled by humans and animals (according to the World Health Organization – WHO). In Romania, significant efforts are being made to ensure legal conditions as mentioned earlier. In this regard, current technologies are being improved and new, high-performance technologies are being introduced.

There is a noticeable major concern, especially in urban agglomerations, to limit or eliminate atmospheric pollutants produced by the increasing number of motor vehicles, construction site activities, and unjustified deforestation.

6. 2. PERSONAL CONTRIBUTIONS

The present thesis contains both elements existing in the specialized literature and new elements, respectively, personal contributions, harmoniously combined to fulfill the proposed objectives:

1. Studying the specialized literature on the production of atmospheric pollutants, especially gases contaminated with solid particles, and practical ways to reduce their values.
2. Identifying areas with the maximum concentration of these pollutants, especially in Romania, and the current legislation, correlated with European standards.

3. Specific processes and equipment, geometric and operational characteristics, economic efficiency.
4. Current trends in the construction of equipment for dedusting dry polluted gases through centrifugation (cyclones, construction types, functional study, energy efficiency, etc.).
5. Constructive design of tangential feed cyclones for dedusting dry industrial gases.
6. Experimental research on the dust separation process from dry industrial gases.
7. Conclusions. Personal contributions. Perspectives.

* * *

The content of the thesis reflects some personal contributions of the author, as follows:

6. 2. 1.Theoretical aspects

6. 2. 1. 1. Literature study

<u>Chapter 1</u>

- Presentation of the current state of atmospheric pollution in the European Union (EU) and Romania, through the exposure of specific legislation in the field.
- Sources of atmospheric pollution developed by industrial activities; legal documents.
- Categories of industrial activities and their impact on the external environment.
- Evolution of pollutants in the air in Romania (graphical representations).
- Atmospheric pollutants – properties and sources, toxicity and actions, limit values, methods of measuring their values.
- Specific problems of air quality; quality regulations.
- Case study: the air quality monitoring system in Romania.
- Actions to improve air quality and control pollutant emissions into the atmosphere at the level of Romania; software solutions in the environment.
- Technical processes, equipment, and specific installations used in industry for retaining solid pollutants from gaseous media.
- Perspectives on techniques for separating polluting particles suspended in atmospheric air.

<u>Chapter 2</u>

- General characterization of air; physical-chemical properties.
- General observations on gas dedusting.
- Perspectives on the construction of gas dedusting equipment.

<u>Chapter 3</u>

- Analysis of the gas residence time in a tangential feed cyclone.
- Differential equation of particle movement in a cyclone.
- Study of pressure drop in a cyclone.
- Theoretical models for evaluating the efficiency of a cyclone.
- Establishing the expression for the sedimentation velocity of solid particles in a cyclone.
- Expressions for evaluating the limit diameter of solid particles retained in a cyclone.
- Analysis of stress states in the area of fixing the flat cover to the cylindrical body.
- Variants for evaluating the stiffness of flat annular flanges.
- Models for calculating the lateral supports of pressure vessels; study variants.

Chapter 4

- Stress and deformation states in the areas of fixing circular flat plates and cylindrical bodies.
- Variants for evaluating the stiffness of flat annular flanges.
- Stress states in the support area of pressure vessels.

6. 2. 1. 2. Personal theoretical research

Chapter 4

- Stress and deformation states developed in the joint area of the purified gas exhaust tube from the cyclone and the upper fixing plate (I – super cyclones); continuity equations of deformations; connection loads; stress states.
- Stress and deformation states developed in the joint areas of the purified gas exhaust tube from the cyclone and the upper fixing plate (II – mini cyclones); continuity equations; connection loads; stress states.

6. 2. 2.Experimental aspects

Chapter 5

- Four polydisperse materials were chosen and subjected to granulometric spectrum determination: graphite / PM-1, perlite / PM-2, clay / PM-3, pine shell / PM-4.
- Existing equipment at the Process Equipment Department, Faculty of Mechanical Engineering and Mechatronics, National University of Science and Technology Politehnica Bucharest was used.
- The results of the planned analyses are specified in appropriate tables and graphs.
- Exposure of the experimental stand designed and built within the aforementioned Department for Industrial Processes.
- From the analyses carried out, some future research for determining the efficiency of tangential feed cyclones is anticipated; the specialized literature clearly reflects theoretical and experimental research on concrete cases.

6. 3. PERSPECTIVES

From the study conducted, it is clear that, although many years of concrete analyses have passed, the specific problem of tangential feed cyclones for dedusting dry industrial gases, in this case, remains open for specific studies to establish concrete solutions for their efficiency.

Suggested perspectives:

- Establishing a concrete program for the constructive sizing of such types of cyclones, in which useful modifications for each specific case are inserted;
- Accordingly, an appropriate design program must be implemented, adapted for specific cases, characteristic of different impure gaseous materials;
- Granulometric analysis of the tested materials can be performed through efficient, modern methods recognized in practice.
- Study of stress states in the structure of cyclones using the finite element method.

APPENDIX 2. Published works (list)

PUBLISHED ARTICLES

NOTE*: *THE PLACES WHERE THE RESPECTIVE ARTICLES WERE CITED ARE PRESENTED IN THE FOLLOWING

1. Durbacă I., Iatan. I. R., Durbacă C. A., Săcuiu V., **Corleciuc (Mitucă) Melania,** Rusănescu Otilia Carmen, *Abordari privind analiza cu elemente finite a unui model structural de capac stratificat cu miez polimeric celular specific unui recipient sub presiune* (*Approaches looking finite elements analysis of a structural model of lied stratified with cellular poymeric core specific to a pressure vessel)*, Materiale Plastice, 56, nr. 1, **2019**, p. 156 – 162 (DOI:10.37358/MP.19.1.5142 ; ISSN 2537 - 5741; ISSN - L 0025 - 5289; WOS 000464604100031).

   - https://www.researchgate.net/publication/338940172_Approaches_Looking_Finite_Elements_Analysis_of_a_Structural_Model_of_Lid_Stratified_with_Cellular_Polymeric_Core_Specific_to_a_Pressure_Vessel (accesat la 12.07.2024).

   Quoted in:
     - X S Nyathi, Francis Tekweme (University of Johannesburg), Sareta Kiji, *2DOF flexible Link Manipulator Model Simulation Inventor: Finite Element Analysis with varying payloads at the tip*, Conference paper, mai 2021.
     - Ion Durbacă, Radu Iatan, Elena Surdu, Claudia-Dana Farcaș – Flamaropol, *Approaches to the evaluation of the mechanical properties of single-layer composite plates made of recyclable polymeric and protein materials,*The 8th International Conference on Advanced Materials and Systems, noiembrie 2020 (DOI:10.24264/icams-2020.I.8) .
     - Lucreția Miu, Simona Maria Păunescu, Maria-Cristina Micu, Iulia Maria Caniola, Mădălina Ignat, Claudiu Sendrea, Elena Badea, *Chemical and physico-mechanical characterizations of leather for restoration*, The 8th International Conference on Advanced Materials and Systems, noiembrie 2020 (DOI:10.24264/icams-2020.V.7).

   - https://www.academia.edu/45486431/Approaches_Looking_Finite_Elements_Analysis_of_a_Structural_Model_of_Lid_Stratified_with_Cellular_Polymeric_Core_Specific_to_a_Pressure_Vessel (accesat la 12.07.2024).

2. **Corleciuc (Mitucă) Melania**, Durbacă I., Sorescu G., Ciocoiu Gh., Nistea Luana, Săcuiu V., *Exemplu Procedural și Metodologic de Măsurare Gravimetrică a Pulberilor PM 10 din Mediul Ambiant cu Ajutorul Aparatelor de Prelevare (Procedural and methodological example of gravimetric measurement of polluant particles in the environment using sampling devices)*, Hidraulica, nr. 1, **2020**, p. 33 – 39 (ISSN 1453 – 7303).
   - https://scholar.google.ro/scholar?q=Procedural+and+methodological+example+of+gravimetric+measurement+of+polluant+particles+in+the+environment+using+sampling+devices&hl=en&as_sdt=0&as_vis=1&oi=scholart (accesat la 11.07.2024).
   - https://www.proquest.com/openview/7611e6b99370c0cda90793dcfc118a61/1?pq-origsite=gscholar&cbl=136245 (accesat la 11.07.2024).

- https://hidraulica.fluidas.ro/2020/nr1/33-39.pdf (accesat la 11.07.2024).
- https://openurl.ebsco.com/EPDB%3Agcd%3A14%3A19391182/detailv2?sid=ebsco%3Aplink%3Ascholar&id=ebsco%3Agcd%3A142469212&crl=c (accesat la 11.07.2024).

EXTERNAL EXPERT OPINION

De la: Sandra Huang <sandrahuang@ajomaie.com>
Către: "ion.durbaca@yahoo.com" <ion.durbaca@yahoo.com>
Trimis: luni, 20 noiembrie 2023 la 15:33:26 EET
Subiect: Dear DURBAC?, Ion: Establishing a Special Issue and Becoming the Lead Guest Editor -- Procedural and Methodological Example of Gravimetric Measurement of ...

If you no longer want to receive such kind of emails, please click here to unsuЬscriЬe.

Establishing a Special Issue

Joining Us as a Lead Guest Editor of Your Special Issue

(Facilitate the Development of Your Scientific Community)

Dear DURBAC?, Ion,
Hope you're having a great week.
Recently, the published paper of yours has been noticed by the editorial team of the scientific journal ***American Journal of Mechanical and Industrial Engineering*** (e-ISSN: 2575-6060).

Title of your previous paper:

Procedural and Methodological Example of Gravimetric Measurement of Pollutant Particles in the Environment using Sampling Devices.

This email is to invite you to propose a special issue due to the big influence of your published article.

Propose a Special Issue and Be a Lead Guest Editor

A special issue is a collection of academic articles concentrating on a specific theme in accord with the aims and scope of the journal. You are welcome to propose a special issue according to your research interests for this journal. Once your proposal is accepted, you will be the lead guest editor of your proposed special issue and be responsible for handling the special issue.
If you want to propose a special issue, please click the following linк and follow the procedures to propose the issue: **http://www.ajomie.org/asxf/8W9rP**
The commitments of becoming the Lead Guest Editor:
1. Define the topics and scope about the special issue;

2. Promote this special issue and invite scholars to contribute papers;

3. Assign the paper to the guest editor and ensure that the peer review is timely;

4. Decide if the paper can be accepted or not after reviewed by peers.

Here enclosed the details of your research which has given us a deep impression: This paper deals, using a demonstrative example, with the methodological procedure of gravimetric measurement of the polluting particles, according to the standard SR EN 12341/2014, for the real evaluation of the 10 μm particle in the biphasic suspensions discharged into the environment. The procedure can be used to compare a non-certified measuring instrument with a reference instrument by verifying that the conditions for the difference between the particle-specific concentration of the particulate immissions (<± 10 μg / m3) and their concentration in the environment (< 100 μg / m3). The mathematical processing of the comparative results through the regression equation must verify that a correlation coefficient value is obtained to validate the fulfillment of the standard requirements.

3. Iatan I. R., Tomescu Gheorghiţa, Roman (Urse) Georgeta, **Corleciuc (Mitucă) Melania**, Panait Constanţa Iolanda, *Studiu analitic al tensiunilor termomecanice statice ale ansamblurilor cu flanse inelare optionale. Rotirea inelului de flanșă în jurul circumferinței centrelor de găuri pentru șuruburi*, (*Analytical study of the static thermomechanical stresses of the assemblies with optional ring flanges. Rotation of the flange ring around the circumference of centers for bolt holes)*, Journal of Engineering Studies and Research, Volume 27, nr. 2, **2021**, p. 29 – 38 (ISSN 2068 – 7559, DOI: https://doi.org/10.29081/jesr.v27i2.268).

- https://jesr.ub.ro/1/article/view/268 (accesat la 13.07.2024).
- https://www.academia.edu/88482595/Analytical_Study_of_the_Static_Thermomechanical_Stresses_of_the_Assemblies_with_Optional_Ring_Flanges_Rotation_of_the_Flange_Ring_Around_the_Circumference_of_Centers_for_Bolt_Holes?uc-sb-sw=31930691 (accesat la 13.07.2024).
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EXTERNAL EXPERT OPINION

London Journals Press

London Journal of Engineering Research (LJER)

Dr. Paige Wheeler chiefauthor@londonjournalspress.com
To: RADU IATAN <iatan.radu@gmail.com>
Tue, Jul 5 at 8:14 PM

To,

Dr. RADU IATAN
Polytechnic University of Bucharest
Romania

Dear Dr. RADU IATAN,

I am writing this email with regard to your research paper entitled **"Some Comparative Opinions regarding the Working of Fibers and Matrix on Axial Stress Limit. Matrix with Longer Fiber Extensions"**. I have read your research online and found its conclusions remarkable. This significant work has the potential to inspire fellow researchers and scientists working in the same domain. In fact, I have also shared the findings of your research paper with my colleagues.
I was impressed by your research aptitude and a profound understanding of your field of study. I found that your research matches the scope of our journal and would like to invite you to associate with us. Our editorial board, management and I have agreed to recognise you as an **invited author of London Journals Press**.
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I look forward to hearing from you soon and having a successful academic relationship in the future.

Regards

Dr. Paige Wheeler
D.Sc. in Integrated Electronic & Electrical Systems
Managing Editor, London Journal of Engineering Research (LJER)
https://journalspress.com/journals/london-journal-of-engineering-research/general-engineering/ (accesat la 13.07.2024).

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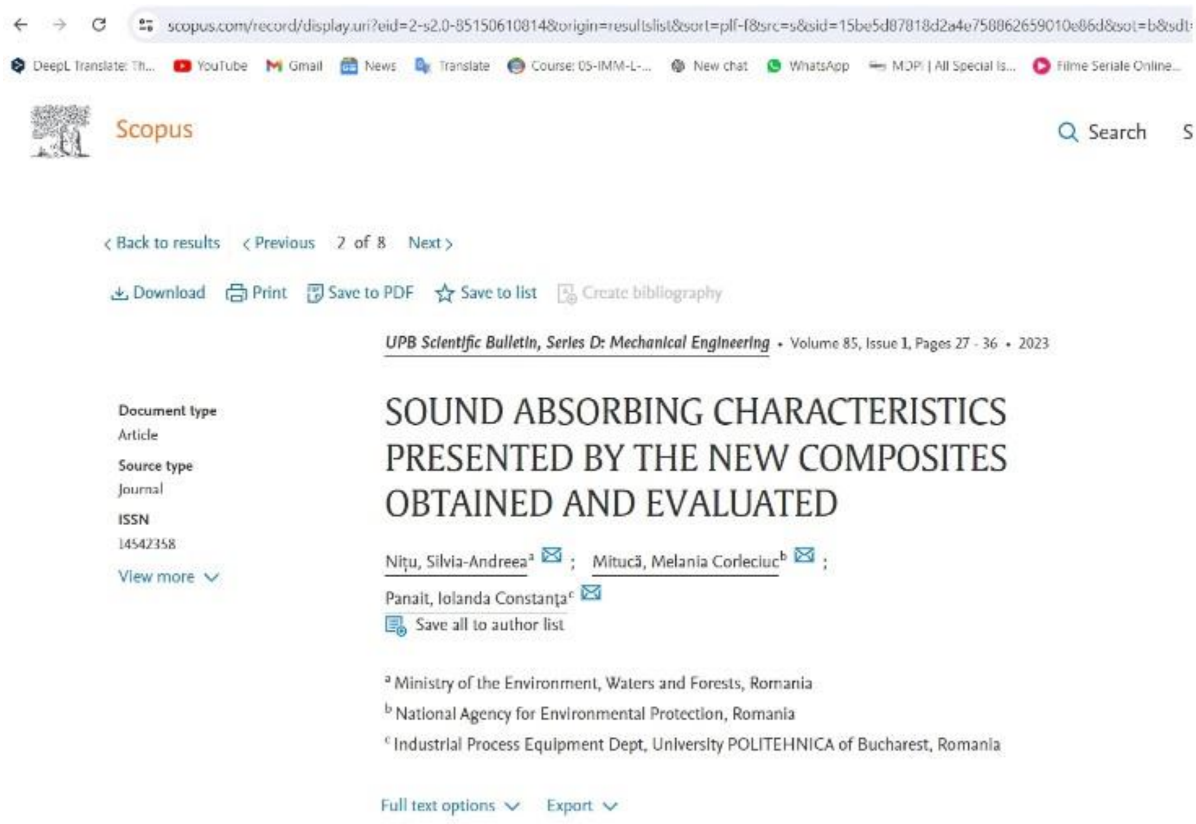

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APPENDIX: THE FOLLOWING ARE SPECIFIED THE BDIs IN WHICH THE CONTENTS OF THE JOURNALS WHERE THE ABOVE MENTIONED ARTICLES WERE PUBLISHED ARE RECOGNIZED

- **Revista Materiale Plastice** (ISI): Web of Science Master Journal List - Search (clarivate.com), https://www.scopus.com/sourceid/14217, Journal Selector Tool (letpub.com), https://www.scimagojr.com/journalsearch.php?q=14217&tip=sid&clean=0, CAS Source Index (CASSI) Search Tool, ISSN 2668-8220 (Online) | Materiale plastice | The ISSN Portal, ICMJE | Journals stating that they follow the ICMJE Recommendations, https://www.revmaterialeplastice.ro/RCIndexing.asp (accesat la 11.07.2024).

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