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CUPRINS

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ECONOMIE INDUSTRIALĂ / INDUSTRIAL ECONOMY

CAD/CAPP/CAM

ABSTRACTS "INNOVATIVE TECHNOLOGY" 2-3 / 2015

PREVENIREA DEGRADĂRII SOLULUI ŞI AMELIORAREA SOLURILOR DEGRADATE PRIN TEHNOLOGII INOVATIVE CONVENŢIONALE / REDUCTION OF SOIL DEGRADATION AND IMPROVEMENT OF THOSE DEGRADED THROUGH CONVENTIONAL INNOVATIVE TECHNOLOGIES

Vlăduţoiu Laurenţiu, Radu Oana
National Institute of Research - Development for Machines and Installations Designed to Agriculture and Food Industry - INMA, Bucharest, ROMANIA

Reduction of soil degradation and improvement of those degraded through conventional innovative *technologies along with the reduction of energy consumption is a necessity for maintaining / restoration of the agro-physical state of the soil. The paper presents some issues and considerations related to the works and the factors to be taken into consideration, to maintain a good agro-physical condition of the soil.*

RĂCIREA MORILOR TUBULARE CU BILE PENTRU MĂCINAREA CIMENTULUI / COOLING OF BALL MILLS FOR GRINDING CEMENT
I. Diferite modalităţi de răcire a morilor de ciment / Different ways for cooling of cement mills

Gheorghe I. Ene, Iuliana-Marlena Prodea
University Politehnica of Bucharest, Bucharest, ROMANIA

In this paper are presented various ways to eliminate, by cooling, the heat developed in the process of grinding cement in ball mills. Are presented, for cooling of cement, a series of data necessary for the cooling of the mill (by ventilation and by spraying water) and for the adoption of the dedusting equipment.

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II. Bilanţul termic al morii de ciment / Heat balance of the cement mill

Gheorghe I. Ene, Iuliana-Marlena Prodea
University Politehnica of Bucharest, Bucharest, ROMANIA

In this paper are presented the data necessary for the achievement of thermal balance of cement mill for determining the air flow of ventilation and water spray to cool the cement mill up to a temperature that will not affect the quality of the cement and grinding process efficiency. Method of cooling determines, through the dew point of the exhaust air from the mill, the type of the dedusting equipment.

EXPERIMENTAL RESEARCHES CONCERNING THE MEASURING OF FLOW RATES IN INDUSTRIAL EQUIPMENTS

Rădulescu Alexandru Valentin
POLITEHNICA University of Bucharest, Bucharest, ROMANIA

Measurements of amount and flux of different media (liquid or gaseous) are very often done in laboratories or in industry. If the amount of flowing media is small, energy, velocity and pressure caused by the flowing are small, too. Thus, for small amounts of the flowing media it cannot be used classic flow meters (rotameters, anemometers, vibratory flow meters etc.). Application of constriction flow meters requires relatively large contractions causing suitable large pressure changes and it is not always acceptable in technological processes. If a technological process requires automated measurements at a low pressure drop and the flow varies in time, it is necessary to find other measuring methods. In this paper, the author proposes a solution enabling automated measurements and causing low pressure drops.

MECHANICAL TESTING OF ELECTRONIC PRINTED CIRCUIT BOARDS AND SOLDERING ALLOYS

Alina Maria Petrescu, Georgiana Ionela Paduraru, Andrei Tudor,
Nicolae Alexandru Stoica
"POLITEHNICA" University of Bucharest, ROMANIA

According to electronic technology theory, the electronic connection must satisfy electrical, thermal and mechanical functionalities. Is known that the resistance and mechanical integrity of the electronic assembly (composed from: printed circuit boards (PCB), devices/ electronic components and electronic component installation on printed circuit boards), is provided by the mechanical function.
The goal of the present paper is to describe some mechanical aspects regarding the behaviour of copper layer deposit on the PCB and of the soldering alloys deposit on the copper – PCB assembly used in electronic technology and also we want to determine the abrasion coefficient of those In order to highlight the mechanical characteristics of tested boards in correlation with different rigid support, there were

performed some mechanical tests using a dedicated stand. The tested PCB's is CEM (Composite epoxy material) with deposited copper, and the soldering alloy was a lead free one SAC305.

Friction forces between sliding surfaces arise due to complex mechanisms and lead to mathematical models which are highly nonlinear, discontinuous and nonsmooth.

The novelty of the present paper is given by the materials that are tested and by the fact that this type of mechanical testing was never used in electronic technology, although the subject under discussion has major importance for mechanical integrity of electronic assemblies.

INCREASING THE PERFORMANCES OF SMALL AND MEDIUM-SIZED ENTERPRISES THROUGH EXPORT STRATEGIES

Dimofte Andra, Rădulescu Alexandru Valentin
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The internationalization of business tends to become a condition of existence for every company, regardless the size or field in which it operates. Given that the national market is at its saturation level and cannot provide optimal conditions for national companies operating out only on the lands where they were founded, more and more of them are looking over their own borders in search of external space to ensure their environment for doing business.

RESEARCH ON THE ROMANIAN BUSINESS CONCERNS ON WASTE ELECTRICAL AND ELECTRONIC EQUIPMENT AGAINST ENVIRONMENTAL AND ECO-INNOVATION ISSUES

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Research on the Romanian business environment concerns on Waste Electrical and Electronic Equipment against environmental and eco-innovation issues were made by developing a questionnaire for enterprises.

The questionnaire is adressed to the companies questions on problematic theme of electrical and electronic equipment waste and eco – innovation; it has been carried out an investigation for distributing the questionnaire. Once collected, the information were processed and after their received replies, it was the finalisation, the analysis and the drafting of conclusions regarding the Romanian business position and requirements towards the WEEE issues (waste electrical and electronic equipment) and eco - innovation.

The main idea is to increase the organizational competitiveness of Romanian companies that are operatingin this area, also to increase the degree of involvement of these entities in promoting eco-innovation for green economy development.

GENERATING MACHINING SEQUENCES DURING DESIGN PHASE BASED ON CONSTRUCTIVE-TECHNOLOGICAL FEATURES - PART I

Lucia-Antoneta Chicoş
Transilvania University of Braşov, Braşov, ROMANIA

Integrated development of products in the context of concurrent engineering requires taking into consideration during the design stage of manufacturing issues. For this purpose the part model provided by a CAD system must contain, in addition to the geometrical data, information used in process planning and manufacturing such as precision, materials, machine-tools, etc. In an integrated CAD/CAPP/CAM environment all this information must be transmitted, accessed and automatically retrieved from all stages. From this point of view Design by Features facilitates the integration of design with the downstream activities and the feature is the medium of information transmission between CAD, CAPP and CAM. In this paper, definition and use of simple and complex constructive-technological features in process planning are presented. These features are contained in the system software library and they are classified in three categories: external, internal and specific features.

GENERATING MACHINING SEQUENCES DURING DESIGN PHASE BASED ON CONSTRUCTIVE-TECHNOLOGICAL FEATURES - PART II

Lucia-Antoneta Chicoş
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Using constructive-technological features makes possible, since the early design stage (CAD), generation of the machining sequence with all associated parameters such as machining methods, cutting parameters, machining time and cost, CNC file etc. This approach allows detection of various types of problems at the design stage and designer has the opportunity to correct them. To demonstrate their essential role in process planning and manufacturing, in this part of the paper is presented the methodology of selecting the manufacturing methods of ones that are associated to features, their coding as well as generation of the machining sequences during CAD phase, before the part to be completely defined from geometrical point of view.

PREVENIREA DEGRADĂRII SOLULUI ȘI AMELIORAREA SOLURILOR DEGRADATE PRIN TEHNOLOGII INOVATIVE CONVENȚIONALE / REDUCTION OF SOIL DEGRADATION AND IMPROVEMENT OF THOSE DEGRADED THROUGH CONVENTIONAL INNOVATIVE TECHNOLOGIES

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REZUMAT

Prevenire degradării solului si ameliorarea solurilor degradate prin tehnologii inovative conventionale, concomitent cu reducerea consumurilor energetice, reprezintă o necesitate pentru menţinerea / refacerea stării agrofizice a solului. Lucrarea prezintă câteva aspecte şi consideraţii referitor la lucrările şi factorii ce trebuie luaţi în consideraţie, pentru menţinerea unei bune stări agrofizice a solului.

ABSTRACT

Reduction of soil degradation and improvement of those degraded through conventional innovative *technologies along with the reduction of energy consumption is a necessity for maintaining / restoration of the agro-physical state of the soil. The paper presents some issues and considerations related to the works and the factors to be taken into consideration, to maintain a good agro-physical condition of the soil.*

KEYWORDS: soil, techniques, energetice, forces, particles

CUVINTE CHEIE: sol, tehnici, energetice, forţe, particule

1. INTRODUCTION

The soil is the perfect environment for many living organisms, " soil respiration " change the troposphere composition. The soil moisture establish in fact the chemical composition of groundwaters, rivers and even of oceans. The external loosened layer of the lithosphere found under the scope of the biosphere and atmosphere and having characteristic of fertility is called soil [1, 2].

From the physical point of view, the soil is solid, liquid, gas and consists of a set of mineral particles of various states of aggregation and size. These particles are bound to one another due to physical forces and contact forces physico-chemical functions as a binder. The soil consists of the steps of: solid, liquid and gaseous figure 1 [9].

- The solid phase, which accounts for approximately 50% of the volume is made up of a part of the mineral (approx. 45%) and an organic (approx. 5%).
- Liquid and gaseous phase represents 50% of the soil, tending to exclude each other. The liquid phase or the soil solution, the water content of the soil in which there are dissolved salts, the anions and cations resulting from the dissociation of dissolved salts, organic acids, etc.
- The gaseous phase comprises air from soil characterized by a high content of CO_2 and other gases.

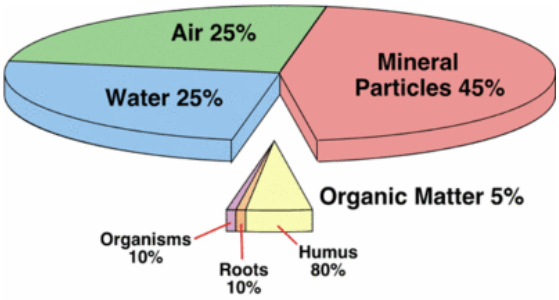

Figure 1. *Most soils contain four basic components: mineral particles, water, air, and organic matter*. Organic matter can be further sub-divided into humus, roots, and living organisms. The values given above are for an average soil. (Source: Physical Geography. net)

The surface of agricultural land, namely processed, represent only 3 % from the land surface. in most developed countries agricultural land has stabilized, while in developing countries those surface keep growing. For example, as anothers statistic, in the last century, between 1947 and 1970 arable land has doubled but this trend continues today.

Soil is a non-homogenous mixture of organic and mineral substances from rocks disintegration and decomposition of organic dead matter)[1, 3].

The soil is an exhaustible resource, also can be heavily eroded, but will remain living epidermis of the planet Earth on which terrestrial life. The man tends to regard soil as inexhaustible resource; he can learn to spare this resource, but in most situations, man exploits the soil without paying any attention to its qualities.

The soil is the result of cumulative five natural factors of soil formation factors or factors referred pedogenetical, these being: climate, rock, topography, living organisms and evolution at that time were subsequently added random factors, such as: stagnant water, human activity on groundwater and soil.

2. MATERIAL AND METHODS

The use of tractors and machines of increasingly larger and heavier , with benefits on productivity and economic efficiency has led to the emergence and expansion of soil degradation processes , especially compaction destructuration and anthropogenic [6, 8].

In drier climates , a particular problem is the intensive work the soil and plant debris removal , leading to loss of water from soil , drought and desertification processes stressing [2, 5, 7].

The mechanization in agriculture as well as in other fields represent the modality the most obvious, which is associated with the progress, with the economy development and of a prosperous society. In low-resource agriculture of small farms , the tractor quickly became the symbol of welfare , giving a higher social status.

3. RESULTS

The basic work of the soil outside of a good weed control, even of different pests in soil and sowing facilities has immediate positive effects uncontested: soil surface roughening, removing the compact layer on the surface, increasing the speed of infiltration water in the soil and reduce the risk of excess water and erosion figure 2 [9], increased nitrogen mineralization rate of organic matter decomposition processes and the rapid stimulation of plant growth and development effects that unfortunately are only short-ter.

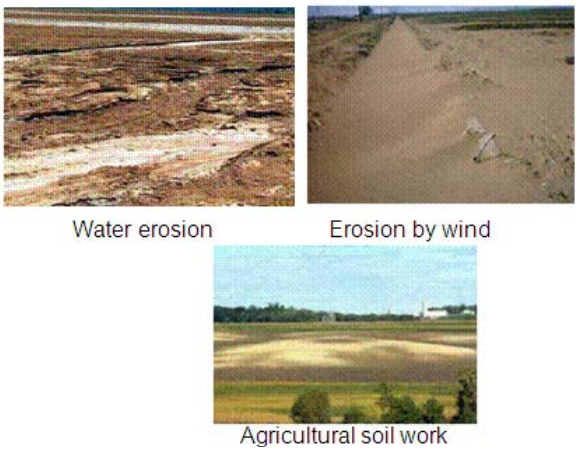

Figure 2. *The visibility of the different types of erosion*

The scientific community argues that there is compatibility between the two concepts, based on the fact that both the productivity of ecosystems and their vulnerability to degradation are basically controlled by the same factors, such as: soil, climate , topography or topography , hydrology and land management and the same processes.

Romania, although it is part of the very poorest countries, however, face particular difficulties because the large agricultural technologies are extensive areas with limited resources, relying on the minimum level of mechanization, on human labor and animal traction. Often, the so-called "agricultural technologies" sometimes are applied to plots of 1-2 ha, and where are used intensively in farms with large areas are not always in agreement with the local traditions: the requirement to work the soil with moisture condition, its level of supply in nutrients, often with crop needs etc.

Providing a healthy and harmonious environment, ie quality: soil, water, air, vegetation and food in sufficient quantity and quality is of fundamental human rights, even if much of the world's population can not benefit from them today.

This problem is unique, especially in countries in poor areas dominated by extensive agriculture with limited resources, subsistence agriculture, even primitive, and by areas where the population is growing. In these conditions, the soil degradation processes and the environment are caused by low inputs, which often causes nutritional imbalances, and / or components of agricultural technological systems that are not properly applied in relation to the degree of suitability of the land, and / or towards the crop needs.

In the energy-intensive agriculture with high inputs: work excessive soil, heavy farm machinery, very high doses of mineral fertilizers and by other agrochemicals used to control diseases, pests and weeds, emphasizing possible and even challenge of new forms of the the soil degradation and by other resources. Among the most widespread negative processes mention: ball movement and by leaching of nutrients and other chemicals causing contamination of ground water resources, soil translocation of their vegetative mass, and hence the entire food chain; excessive growth of the state of soil compactness, excess surface water and erosion risk; creşetrea emissions leading to soil degradation and global warming the atmosphere. It can not be neglected any negative influence on the agricultural technological system change and loss of biodiversity due to excessive soil loosening mode, eliminating plant debris from the surface, decrease the content and by the soil organic matter degradation.

Now, it is widely accepted by different communities: scientific, practitioners, politicians, etc., that agriculture can have a negative impact on various environmental resources regardless of their social development.

Therefore, the agriculture must take on the responsibility to protect, improve and conserve the quality of those resources that affect them. This can be achieved only through a national strategy and by through consistent and adequate legislation, which would encourage and stimulate those who do right, but at the same time and to penalize those who commit mistakes.

Numerous studies and research internationally and in our country showed that between farming systems and crop technology, state of the environment, the economic development and quality of life are closely interdependent. Continuing intensification of agriculture will intensify the negative effects on the environment by degrading various components: soil, air, surface and depth etc., affecting the development and promotion of sustainable economy and by a healthy society. Therefore, the objective of sustainable agricultural management should seek to minimize and even eliminate the adverse effects of the intensification of agriculture.

Looking at the edaphical resource, sustainable use implies the reduction to eliminate the negative impact of degradation processes, increasing the soil's resilience and the restoration of its quality status.

The decisive factor of the state of soil quality and at the same time, the most important source of nutrients for plants, particularly for farmers working in areas with limited resources, of subsistence, is the organic carbon.

Various agricultural technological systems must impose, by increasing their rings technological and conservation of organic matter, namely of the reserve of quality humus in the soil.

In the agricultural policies of various countries, especially in the last 50 years, huge efforts have been made to modernize agriculture to increase productivity, increasing agriculture's contribution to economic development, but unfortunately, it was this development was accompanied by a number serious negative effects on the environment.

In the European Union is estimated that almost 30% of the territory is the 50.5% for forestry and agriculture; the most widespread agricultural system, the conventional practice has been generalized. It was characterized mainly by: loosening and processing works with returning excessive soil tillage, crop residues total elimination from the surface or even the burning of stubble, intense fertilization and short rotations.

It is recognized not only by specialists in the field, but also by ever larger communities, the fundamental role of soil by its functions: the changing biodiversity, climate change, protecting the environment, promoting and developing agriculture as a form of the conservative sustainable agriculture, in economic development and in the prosperity of the society.

The soil functions, related to the non-agricultural human activities, refer to:

- the soil as a physical environment, serving as a space for the development of technical and industrial structures, rural and urban settlements, access roads and surface socio-cultural activities;
- the soil as a source of the natural raw materials providing water, clay, sand, gravel, minerals, fibrous and of construction materials etc.;
- the soil as cultural space, representing each nation a true "museum" of preservation or wealth, paleontological and geological treasures and relics.

The ecological functions of the soil covers: the production of biomass, environmental protection, biological habitat and reserve the genes.

In the production of biomass fundamental role of soil is the soil representing the very basis of the existence of human life and animals by providing the necessary resources for food and renewable energy materials. Soil, by its very nature, through its

components, through its natural processes ensure production of biomass.

To achieve biomass crops of high energy-intensive agriculture, they are usually used excessive doses of fertilizer and other agrochemicals used to control diseases, pests and weeds, soil amid the intensive work that can have negative effects on soil . Uncontrolled application of "fertilizer" unconventional organic (sewage sludge, industrial sludge, domestic waste) containing large amounts of organic material, but often some toxic chemical compounds can have serious negative effects in the the environment pollution. In the intensive farming systems, but also in the extensive low-input or may be present technological errors in the agricultural practices [4].

Among the most common are: inadequate irrigation, soil Working without respecting workability and trafficability optimal conditions (optimum water content in soil cultivation, harvest, transport crops); unbalanced application of mineral fertilization and / or organic without taking into account reserves in the soil and plant requirements; short rotations without ameliorative crops. These are soils with use arable major causes degradation processes that determine and enhance the physical, chemical and biological soil, which in turn causes damage to other resources: surface water and groundwater, the atmosphere, flora and fauna.

At the same time, this function înconurător environmental of soil is the extremely complex, depending on stability, quality and nature of macro and micro-pore system of the soil.

The porosity of the soil is the the one that controls the transport processes of the solutions to the plant through the root mass, to the water layer or to the surface water, and absorbing the toxic chemical components makes this medium to act as a buffer and filtering.

When into the soil the mechanical filtering capacity and physicochemical buffering, the capabilities of the microbiological and biochemical transformation are exceeded, then the organic and inorganic components of the solution are transferred to soil, and hence they can then be transported in the depth or surface waters, or can be extracted by the roots of plants, affecting the entire food chain.

Ensuring the biological environment of life, natural habitat for many species, and also as a store of genes for different species of plant and animal organisms, is the third very important ecological function of the soil.

In this environment coexist many living organisms, from bacteria and fungi to meso and macrofauna.

Preserving the genetic potential from soil has a fundamental role in biological processes, so that agricultural practices be applied in a way that does not lead to degradation or destruction of this wealth.

The conventional agriculture, energy-intensive, has seriously affected the function of the soil.

The best example is the disappearance lumbricides who major role in reconstruction processes naturally the structural state as a whole, but especially the macro- and micro-structural aggregates quality, porous and having high capacity to resist destructive action of water and agricultural tools. Along with other bodies, lumbricides were affected by increased concentration of heavy metals, herbicides uncontrolled application of excessive use of mineral fertilizers or organic fertilizers liquids, intensive work of the soil significantly reducing soil and food enhancing water losses by removing or the burning of the vegetal remnants.

Thanks to the followers of the intensive modern technologies, the anthropic pressure exerted on the soil, over time, greatly increased due to increased mechanization and agricultural machinery growing larger, heavier and faster, the excessive use of highly active mineral fertilizers for immediate growth from nutrient concentration soil and stimulate the rapid development of the plants.

As the requirements of humanity became larger, the agricultural technology systems have increased and their negative effects on soil processes have become more severe.

Since the soil condition is the requirement decisive in ensuring the success the conservative agricultural technologies and environmental protection in different areas of the world and in Europe are intensified studies on its ability multifunctional precisely linked above three ecological functions, as well as its resilience capacity.

Resilience capacity of the soil is one of the most important and complex characteristics of the soil , is in fact an attribute of the soil , involving the ability to respond as an " elastic body " if it is subjected to a force , a pressure , or actions , and and to return to its original shape.

However, under certain conditions, the soil may suffer irreversible degradation processes, if "pressure" put on him is very severe and its vital processes are completely destroyed!

CONCLUSIONS

Knowledge of soil properties, namely compaction factors influencing the practice of importance as it helps finding the general physical condition of the soil (aeration, texture, structure) and the calculation of water and nutrients. Abrasive wear, soil moisture, soil texture coefficient of friction and the main factors influencing soil compaction

These processes can affect ground over time and are manmade or natural phenomena due.

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RĂCIREA MORILOR TUBULARE CU BILE PENTRU MĂCINAREA CIMENTULUI / COOLING OF BALL MILLS FOR GRINDING CEMENT

I. Diferite modalităţi de răcire a morilor de ciment / Different ways for cooling of cement mills

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REZUMAT
În lucrarea de faţă se prezintă diferite modalităţi de eliminare, prin răcire, a căldurii degajate în urma procesului de măcinare a cimentului în morile cu bile. Sunt prezentate, pentru răcirea cimentului, o serie de date necesare pentru realizarea răcirii morii (prin ventilare şi prin pulverizarea de apă în moară) şi pentru adoptarea echipamentului de desprăfuire a aerului evacuat din moară.

ABSTRACT
In this paper are presented various ways to eliminate, by cooling, the heat developed in the process of grinding cement in ball mills. Are presented, for cooling of cement, a series of data necessary for the cooling of the mill (by ventilation and by spraying water) and for the adoption of the dedusting equipment.

KEY WORDS: cement mill, mill ventilation, cement cooling, water injection.

CUVINTE CHEIE: moară de ciment, ventilarea morii, răcirea cimentului, pulverizarea de apă.

1. GENERALITĂŢI

Căldura care se dezvoltă în morile cu bile are două componente: căldura produsă prin procesul de măcinare şi căldura cu care intră clincherul în moară.

Cea mai mare parte din energia primită de moară de la motorul de acţionare al acesteia se transformă în căldură; numai circa 5% din energia primită este utilizată de către moară pentru mărunţirea materialului până la fineţea cerută. Căldura dezvoltată în timpul măcinării produce o creştere foarte mare a temperaturii în interiorul echipamentului, afectând negativ desfăşurarea procesului tehnologic, atunci când este depăşită o anumită limită.

O parte din căldura dezvoltată în moară este eliminată prin radiaţia şi convecţia tamburului morii, iar restul va produce încălzirea materialului mărunţit.

Această ultimă căldură trebuie înlăturată fie prin ventilarea interiorului morii folosind un curent de aer, fie prin răcirea materialului măcinat în interiorul morii sau în afara acesteia.

În general, în cazul morilor mari, căldura nu poate fi înlăturată numai prin ventilare, fiind necesară o răcire suplimentară, prin pulverizarea de apă în moară.

Ventilarea morii şi/sau răcirea materialului în moară sau în afara acesteia trebuie astfel realizate încât să se evite supraîncălzirea produsului rezultat. Temperatura ridicată a materialului măcinat este cauzată adesea de slaba eficienţă a procesului de măcinare, care poate fi determinată de acoperirea corpurilor de măcinare şi blindajelor tamburului cu material fin măcinat, de aglomerarea materialului măcinat şi de slaba comportare la curgere a acestuia.

Pe lângă răcirea materialului din moară, ventilarea îndeplineşte şi alte funcţiuni:
- evacuarea din moară a fracţiunilor fine;
- desprăfuirea morii (rolul acestei funcţii fiind de a evita acumularea de praf în moară).

La măcinarea materiilor prime pentru fabricarea cimentului (făinii brute), încălzirea materialului măcinat nu afectează calitatea acestuia, având chiar un efect pozitiv, uscarea lui.

Totuşi, temperatura făinii brute nu trebuie să depăşească 100^{o}C, deoarece valori mai mari ale temperaturii favorizează acoperirea bilelor şi blindajelor morii cu un strat de particule fin măcinate (la măcinarea calcarului se produce o cantitate mare de fracţiuni foarte fine, sub *2 μm*) care amortizează şocurile bilelor, afectând performanţele morii [6].

Dacă materialul măcinat este clincherul, temperatura acestuia nu trebuie să depăşească 100...105^{o}C deoarece, în caz contrar, apar o serie de fenomene negative care vor afectata atât calitatea cimentului cât şi procesul de măcinare [1, 2, 4, 5]:

- apariţia fenomenului de priză falsă a cimentului din cauza deshidratării parţiale a ghipsului, care se macină împreună cu cimentul şi care are rolul de a regla timpul de priză al acestuia;
- scăderea rezistenţei cimentului ca urmare a hidratării superficiale a particulelor lui la contactul cu vaporii de apă rezultaţi din deshidratarea ghipsului;
- creşterea tendinţei de aglomerare a particulelor fine de ciment şi aderarea lor pe corpurile de măcinare şi pe alte elemente interioare ale morii (datorită forţelor de coeziune superficială şi forţelor generate de încărcarea electrostatică);
- deteriorarea sacilor de hârtie utilizaţi pentru ambalarea cimentului.

Acoperirea bilelor şi blindajelor cu un strat de particule fine produce o reducere importantă a randamentului procesului de măcinare (de până la 30%) datorită reducerii şocurilor bilelor asupra materialului, împiedicării clasării bilelor după mărimea lor, de către blindajele autosortatoare (ajungându-se chiar şi la fenomenul de clasare inversă), reducerea ponderii măcinării prin frecare, produsă de bilele mici (din compartimentul de măcinare fină), acestea nemaivenind în contact direct unele cu altele [5, 6].

De asemenea, fenomenul de aglomerare produce - prin reducerea fluidităţii materialului pulverulent - şi alte efecte negative: scăderea eficienţei separatoarelor pneumatice, blocarea materialului în instalaţiile de transport, depozitare şi ambalare etc.

2. MODALITĂŢI DE RĂCIRE A CIMENTULUI ÎN MORILE TUBULARE CU BILE

La morile tubulare cu bile cu funţionare în circuit deschis, cimentul se răceşte, de regulă, numai prin ventilarea interiorului morii. În caz că ventilarea nu este suficientă pentru răcirea cimentului, atunci răcirea se contină prin injectarea (pulverizarea) de apă în interiorul morii.

Dacă după răcirea în interiorul morii temperatura cimentului nu are o valoare acceptabilă care să evite problemele legate de depozitarea cimentului în silozuri şi de ambalarea acestuia în saci de hârtie, cimentul se răceşte în răcitoare exterioare, plasate în afara morii.

Morile mici pot fi, de asemenea, răcite prin stropirea cu apă a suprafeţei exterioare a tamburului, însă această modalitate de răcire are dezavantajul că necesită un debit mare de apă, iar pe suprafaţa tamburului se formează cruste de oxizi şi de ciment întărit.

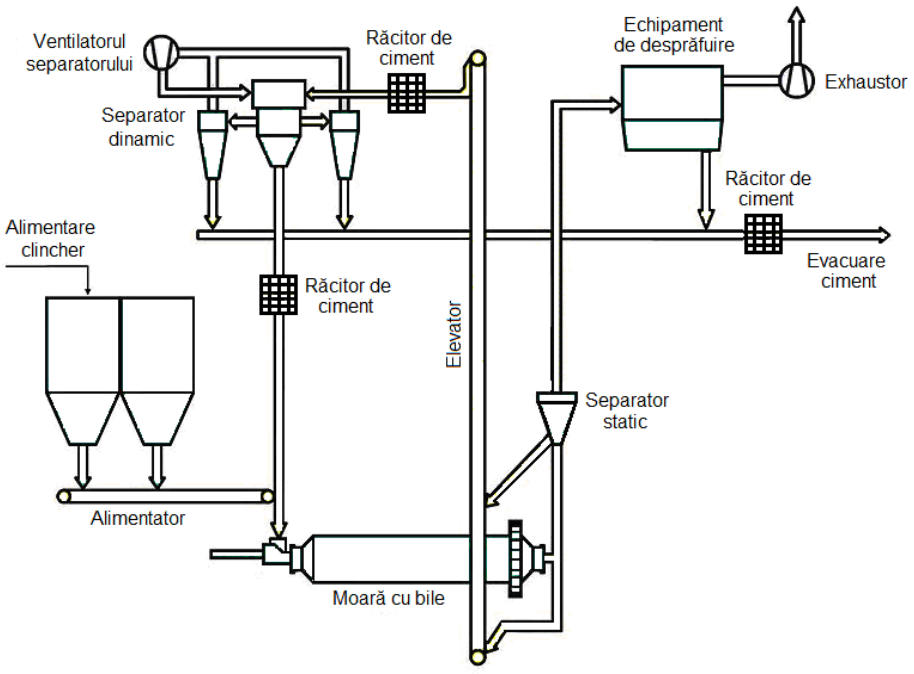

Figura 1. *Modalităţi de răcire a cimentului măcinat în morile cu circuit închis [9].*

Posibilităţile de răcire a morilor în circuit închis sunt prezentate în figura 1. În afară de răcirea cimentului în interiorul morii, prin ventilare sau/şi pulverizare de apă, acesta se poate răci şi în afara morii: în separatorul dinamic (cu aer sau cu apă), sau în răcitoare exterioare. Se pot utiliza, de asemenea, combinaţii ale acestor modalităţi de răcire, după necesităţi.

Răcitoarele de ciment exterioare se plasează fie înainte de alimentarea separatorului dinamic, fie la evacuarea grişului (fracţiunea grosieră) sau la evacuarea produsului finit din separator (fig. 1). Răcitorul pentru produsul final evacuat din separator are rolul de a reduce temperatura cimentului pentru a evita formarea de bulgări în silozurile de ciment şi de a înlesni curgerea cimentului prin instalaţiile de ambalare a acestuia.

O temperatură prea mare în circuitul de măcinare poate fi evitată prin instalarea de răcitoare atât între moară şi separator (pe alimentarea separatorului), cât şi între separator şi moară (pe evacuarea grişului din separator).

Răcirea pe alimentarea separatorului contribuie la reducerea atât a temperaturii produsului finit, cât şi a fracţiunii grosiere (grişului). Deoarece fracţiunea grosieră se recirculă în instalaţia de măcinare, acest răcitor trebuie proiectat pentru un debit de material de până la 3 ori mai mare decât debitul morii, prin urmare costul de investiţie al acestuia este mare.

O soluţie mai economicoasă constă în instalarea unui răcitor pe evacurea grişului din separator, în felul acesta temperatura grişului reducându-se cu circa 30...40 ^{0}C (căldura totală introdusă în moară fiind redusă în mod considerabil), iar cea a produsului finit cu 15...25 ^{0}C [1].

Reducerea căldurii totale introduse în moară este necesară, îndeosebi, în următoarele cazuri:

- când moara se răceşte numai prin ventilare;
- când moara se răceşte atât prin ventilare cât şi prin pulverizare de apă, însă debitul de apă injectată trebuie să fie foarte mic, pentru a nu afecta calitatea cimentului;
- când se produce ciment de înaltă fineţe, situaţie în care căldura intrată în moară odată cu grişul este adeseori mai mare decât aceea intrată cu clincherul.

Răcitoarele exterioare de ciment se realizează în două variante constructive: răcitoare verticale cu melc (pentru amestecarea şi ridicarea cimentului în răcitor) şi răcitor cu cimentul în strat fluidizat. Aceste răcitoare exterioare produc o reducere a temperaturii cimentului cu 20...40 ^{0}C [1].

2. VENTILAREA MORILOR TUBULARE CU BILE

La evacuarea din moară, aerul folosit pentru ventilare trebuie desprăfuit fie într-un filtru electrostatic, fie într-un filtru cu saci.

Practica arată că, dacă debitul ventilării şi echipamentul de desprăfuire nu sunt adoptate corect şi reglate corespunzător, pot apărea probleme considerabile atît în ceea ce priveşte funcţionarea morii, cât şi eficienţa desprăfuirii.

Debitul optim al ventilării depinde în principal de următoarele criterii:

- viteza maximă a aerului în interiorul morii;
- căldura intrată în moară cu clincherul şi căldura dezvoltată în timpul măcinării;
- temperatura punctului de rouă, impusă de echipamentul de desprăfuire.

Eficienţa optimă a măcinării depinde în mare măsură de viteza curentului de aer prin tubul morii.

Debitul maxim de aer pentru ventilarea morii depinde de:

- debitul morii şi temperatura de intrare a clincherului în moară;
- aria secţiunii transversale libere a tamburului (situată deasupra încărcăturii de bile);
- viteza de circulaţie a curentului de aer prin moară.

Viteza aerului prin tubul morii trebuie să se adopte astfel încât să se evite evacuarea din moară a particulelor de material care nu au atins fineţea de măcinare cerută. Din acest punct de vedere, viteza aerului de ventilare, raportată la secţiunea transversală liberă (de deasupra încărcăturii de bile), trebuie să fie cuprinsă între următoarele valori [1]:

v = 1,5...2,0 m/s – pentru mori în circuit închis;
v = 1,0...1,5 m/s – pentru mori în circuit deschis.

Limita superioară a vitezei se adoptă atunci când sistemul de desprăfuire este prevăzut şi cu separator static (pentru reţinerea particulelor grosiere), plasat înaintea electrofiltrului sau filtrului cu saci. În acest caz, materialul evacuat din moară este alimentat (cu un elevator cu cupe) în separatorul static, fracţiunea grosieră reţinută fiind reintrodusă în circuitul de măcinare.

După alte surse bibliografice [5, 6], viteza aerului pentru ventilarea morii raportată la secţiunea transversală liberă a tamburului acesteia (situată deasupra încărcăturii de bile) are următoarele valori:

v = 1,0....1,5 m/s - pentru morile în circuit închis;
v = 0,8....1,2 m/s - pentru morile în circuit deschis.

Uneori ventilarea se defineşte şi prin debitul specific de aer, raportat la unitatea de cantitate de produs finit (*Nm^{3}aer/kg produs finit*).

Tabelul 1. *Valori ale debitului specific de aer pentru ventilarea morilor, în funcţie de tipul echipamentului de desprăfuire [1].*

Diametrul morii, *m*	Filtre cu saci	Filtre electrostatice
	Debitul de ventilare, m^3 aer/*kg* ciment	
2,0...3,5	0,90	0,45
3,5...6,0	0,35...0,90	0,20...0,45

În mod normal, la măcinarea cimentului, debitul specific de aer de ventilare are valoarea de *0,30...0,45* Nm^3 *aer/kg ciment* [5, 6], în funcţie de tipul echipamentului utilizat pentru desprăfuirea aerului evacuat din moară (tabelele 1 şi 3).

În afara valorilor vitezei în secţiunea transversală liberă, precizate mai sus, este important ca şi în alte zone ale morii viteza să aibă anumite valori bine precizate. Acest lucru este necesar pentru a asigura uniformitatea debitului aerului de ventilare şi pentru a păstra în limite rezonabile pierderile de presiune (pierderi gazodinamice) la curgerea curentului de aer prin moară.

Astfel de valori ale vitezei sunt [6]:

- *20...25 m/s* - prin fusul tubular de intrare în moară;
- *15...20 m/s* - prin zona centrală a diafragmei dintre camere şi prin zona centrală a diafragmei de evacuare;
- *20...25 m/s* - prin fusul tubular de ieşire din moară.

Pierderile de presiune la trecerea aerului prin moară trebuie să fie cât mai reduse, pentru a înlesni curgerea aerului prin moară şi pentru a diminua consumul de energie al ventilatorului.

În mod normal, pentru o moară corect proiectată, pierderile de presiune au valorile [6]:

- *1200...1600 Pa =120...160 mm* H_2O - pentru mori de diametru mic ($D < 2,8$ *m*);
- *1500...2000 Pa = 150...200 mm* H_2O – pentru mori de diametru mediu (D = *3,0...3,8 m*);
- *1800...2500 Pa =180...250 mm* H_2O - pentru mori de diametru mare ($D > 4,0$ *m*).

La determinarea pierderii de presiune totală a instalaţiei de măcinare trebuie să se ţină seama de pierderile de presiune ale diferitelor componente ale acesteia. Pentru diferite componente ale instalaţiei de măcinare, pierderile de presiune au, orientativ, valorile [5]:

- Δp_s *= 1000 Pa =100 mm* H_2O - pierderea de presiune în separatorul static;
- Δp_c *= 800 Pa = 80 mm* H_2O - pierderea de presiune în ciclon;
- Δp_{fs} *= 1500 Pa = 150 mm* H_2O - pierderea de presiune în filtrul cu saci;
- Δp_{fe} *= 400 Pa = 40 mm* H_2O - pierderea de presiune în filtrul electrostatic;
- Δp_{con} *= 800 Pa = 80 mm* H_2O - pierderea de presiune în conducte;

Δp_d *= 200 Pa = 20 mm* H_2O - presiunea dinamică.

Exemplu de calcul

Debitul de aer de ventilaţie este determinat de relaţia [6]:

$$Q = (1-\varphi)\cdot\frac{\pi\cdot(D-2\cdot s)^2}{4}\cdot v\cdot(1+a_f)\ \ [m^3/s],$$

în care D este diametrul nominal al morii, *m*; s – grosimea blindajului, *m*; φ – gradul de umplere, *%*; v - viteza aerului de ventilaţie prin secţiunea liberă a morii, *m/s*; a_f – aerul fals, *%*.

Considerând: D *= 4,2 m*; s *= 80 mm = 0,08 m*; φ *= 30% = 0,3*; v *= 1,5 m/s*; a_f *= 10 % = 0,1*, rezultă:

$$Q = (1-\varphi)\cdot\frac{\pi\cdot(D-2\cdot s)^2}{4}\cdot v\cdot(1+a_f)=$$

$$=(1-0,3)\cdot\frac{\pi\cdot(4,2-2\cdot 0,08)^2}{4}\cdot 1,5\cdot(1+0,1)=$$

$$=14,196\,m^3/s=51107\,m^3/h$$

Se adoptă un ventilator cu debitul Q *= 55000* m^3/h. Presiunea dezvoltată de ventilator trebuie să acopere pierderea de presiune totală din instalaţia de măcinare, care depinde de componenţa acestuia. Dacă instalaţia de măcinare din acest exemplu cuprinde: moară, separator static, ciclon şi filtru cu saci, pierderea de presiune totală a acesteia, pe care trebuie să o acopere ventilatorul, este:

$$\Delta p_t=\Delta p_m+\Delta p_s+\Delta p_c+\Delta p_d+\Delta p_{con}+\Delta p_{fs}=$$

$$=2000+1000+800+200+800+1500=6300\,Pa=$$

$$=630\ mm\,H_2O\cdot$$

Alte mărimi prin care se poate caracteriza ventilarea morilor cu bile

Ventilarea morii poate fi caracterizată printr-un indicator definit de raportul dintre aria secţiunii transversale libere a tamburului şi debitul morii. Variaţia acestui indicator, în funcţie de mărimea (diametrul) morii, poate fi determinată exprimând diferite mărimi caracteristice ale morilor cu bile, în funcţie de diametrul acestora.

În acest scop se consideră următoarele date specifice majorităţii morilor pentru măcinarea cimentului [1]:

- Raportul lungime/diametru: L/D *= 3,2*;
- Gradul de umplere a tamburului cu corpuri de măcinare (bile): φ *= 30 %*;
- Turaţia relativă a morii: $\psi = n/n_{cr} = 74\%$;
- Densitatea în vrac a bilelor: ρ_b *= 4,55 t/*m^3 (bile Φ *60 mm*);
- Consumul specific de energie al morii: N_{sp} *= 32 kWh/t*.

Se determină, în funcţie de diametrul interior D al tamburului morii:

- Aria secţiunii transversale libere a tamburului morii (de deasupra încărcăturii de bile):

$$A_l = (1-\varphi)\cdot\frac{\pi\cdot D^2}{4} = (1-0{,}3)\cdot\frac{\pi}{4}\cdot D^2 = 0{,}55\cdot D^2 \ \ m^2;$$

- Puterea de acţionare a morii (pentru φ *=0,30* şi ψ *= 0,74*, *c = 7,3*) (relaţia lui Blanc) [3]:

$$N = c\cdot G\cdot\sqrt{D} =$$

$$= c\cdot\varphi\cdot\frac{\pi\cdot D^2}{4}\cdot L\cdot\rho_b\cdot\sqrt{D} = c\cdot\varphi\cdot\frac{\pi}{4}\cdot\lambda\cdot\rho_b\cdot D^{3,5} =$$

$$= 7{,}3\cdot 0{,}3\cdot\frac{\pi}{4}\cdot 3{,}2\cdot 4{,}55\cdot D^{3,5} = 25{,}04\cdot D^{3,5} \ \ kW$$

- Debitul morii:

$$Q = \frac{N}{N_{sp}} = \frac{25{,}04\cdot D^{3,5}}{32} = 0{,}78\cdot D^{3,5} \ \ t/h;$$

- Aria specifică a secţiunii transversale libere a tamburului:

$$A_{l,sp} = \frac{A_l}{Q} = \frac{0{,}55\cdot D^2}{0{,}78\cdot D^{3,5}} = \frac{0{,}705}{D^{1,5}}\ \frac{m^2}{t/h}.$$

Se stabilesc dependenţele grafice ale debitului morii, ariei secţiunii transversale libere a tamburului morii (de deasupra încărcăturii de bile) şi aria specifică a secţiunii transversale libere, raportată la debitul morii, în funcţie de diametrul tamburului (fig. 2).

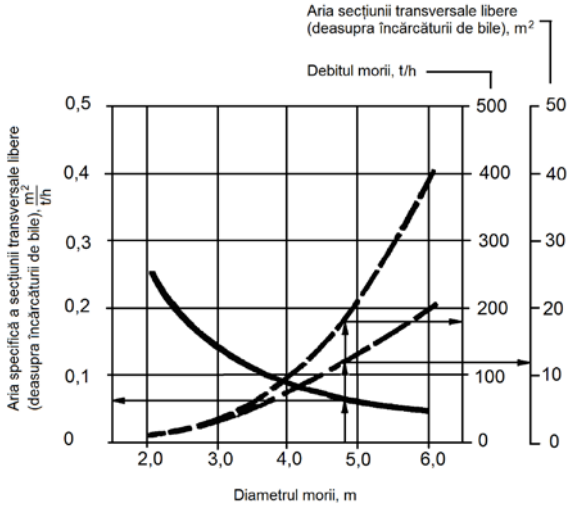

Figura 2. *Variaţia debitului, a ariei secţiunii transversale libere a tamburului şi a ariei libere specifice, în funcţie de diametrul morii [1].*

Se observă că atunci când diametrului *D* al morii creşte, puterea şi debitul acesteia cresc proporţional cu $D^{3,5}$, aria secţiunii transversale libere a tamburului - cu D^2, iar aria secţiunii transversale libere raportată la debitul morii - cu $1/D^{1,5}$.

Prin urmare, morile cu diametrul mare au, raportat la debitul (*t/h*) lor, o arie a secţiunii transversale libere ($m^2/(t/h)$) mult mai mică decât morile cu diametrul mic (fig. 2).

De exemplu, pentru moara cu diametrul interior *D =4,8 m*, rezultă (fig. 2):

$$A_l = 0{,}55\cdot D^2 = 0{,}55\cdot 4{,}8^2 = 12{,}67\,m^2;$$

$$Q = 0{,}78\cdot D^{3,5} = 0{,}78\cdot 4{,}8^{3,5} \approx 190\ t/h;$$

$$A_{l,sp} = \frac{0{,}705}{D^{1,5}} = \frac{0{,}705}{4{,}8^{1,5}} = 0{,}06\ \frac{m^2}{t/h}.$$

Dependenţa grafică a debitului specific de aer de ventilare în funcţie de diametrul morii (fig. 3) se stabileşte utilizând relaţia:

$$V_{sp} = \frac{v\cdot A_l}{Q} = \frac{0{,}55\cdot v\cdot D^2}{0{,}78\cdot D^{3,5}} = \frac{0{,}705\cdot v}{D^{1,5}}\ \frac{m^3/s}{t/h} =$$

$$= \frac{2{,}538\cdot v}{D^{1,5}}\ \ \frac{m^3}{kg}.$$

Analizând figura 3 se observă că debitul specific de aer de ventilare scade considerabil cu creşterea diametrului morii.

Nu se recomandă să se ventileze moara cu debitul maxim posibil. Debitul de aer trebuie reglat în funcţie de temperatura clincherului la intrarea în moară şi de temperatura impusă cimentului la evacuarea din moară.

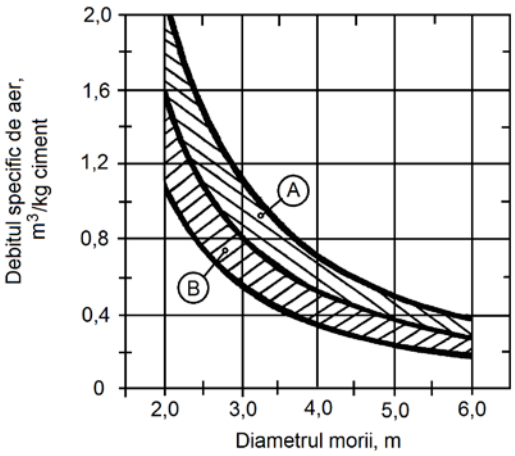

Figura 3. *Debitul specific de aer de ventilare în funcţie de diametrul morii [1, 4].*
A – moară în circuit închis (pentru v = 1,5...2,0 m/s); B – moară în circuit deschis (pentru v = 1,0...1,5 m/s).

Datorită depresiunii din instalaţia de măcinare, în aceasta se aspiră prin neetanşeităţile sistemului de evacuare a morii, aerul fals. Acest aer suplimentar supraîncarcă ventilatorul şi, dacă acesta este dimensionat fără considerarea aerului fals, ventilaţia morii poate fi diminuată.

Debitul de aer fals se evaluează în funcţie de tipul de acţionare a morii (de care depinde construcţia sistemului de evacuare a acesteia) şi se exprimă în procente din debitul aerului de ventilaţie. Debitul de aer fals poate avea următoarele valori [6]:

7,5...10 % - pentru mori cu acţionare periferică;
15...20 % - pentru mori cu acţionare centrală;
30...40 % - pentru mori cu evacuare periferică.

4. RĂCIREA CIMENTULUI PRIN PULVERIZAREA DE APĂ ÎN MOARĂ

Pulverizarea de apă se utilizează pentru reducerea temperaturii cimentului în moară până la o valoare care să prevină o serie de efecte nedorite: deshidratarea ghipsului (care produce fenomenul de priză falsă), aglomerarea cimentului şi formarea de bulgări în silozurile de depozitare, scăderea rezistenţei cimentului şi reducerea fluidităţii acestuia etc.

Clincherul cu conţinut ridicat de C_3A (aluminat tricalcic ($3CaO \cdot Al_2O_3$)) sau cu conţinut ridicat de alcalii sunt mai sensibile faţă de apa pulverizată (produce reducerea rezistenţei şi priza rapidă a cimentului) [1].

În acest caz, este indicat ca cimentul să fie răcit în răcitoare exterioare.

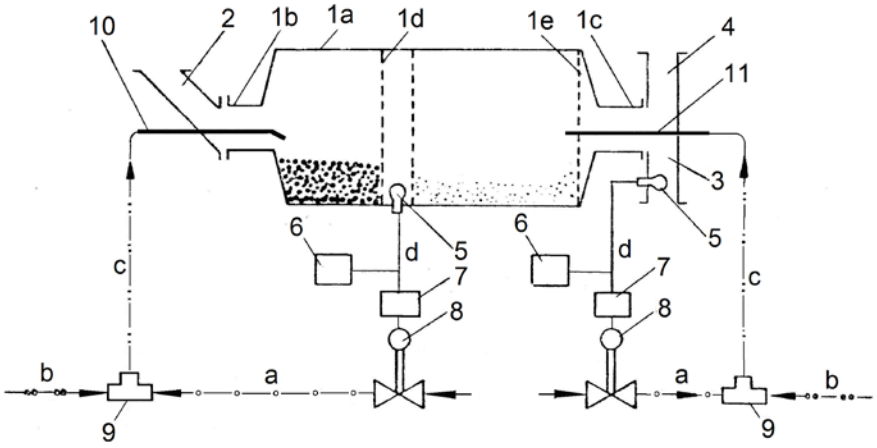

Figura 4. *Schema instalaţiei de răcire prin pulverizarea de apă în ambele camere ale unei mori pentru măcinarea cimentului, cu reglarea debitului de apă în funcţie de temperatura materialului [4].*

1a – tamburul morii; 1b – fus tubular de alimentare; 1c – fus tubular de evacuare; 1d – perete despărţitor dublu; 1e – grătar de evacuare; 2 – pâlnie de alimentare; 3 . pâlnie de evacuare; 4 – racord de desprăfuire; 5 – traductor de temperatură; 6 – aparat înregistrator de temperatură; 7 – regulator; 8 – ventil acţionat de către un servomecanism; 9 – cameră pentru amestecarea apei şi aerului comprimat; 10 – lance de pulverizare a apei în prima cameră; 11 – lance pentru pulverizarea apei în camera a doua; a – circuit de apă; b – circuit de aer comprimat; c – circuit pentru amestec de apă şi aer comprimat; d – circuite de măsură şi comandă.

Pulverizarea de apă se utilizează îndeosebi în cazul morilor mari, pentru a elimina din ciment căldura care nu a putut fi eliminată prin ventilarea morii.

Apa poate fi injectată în primul sau/şi în al doilea compartiment al morii (fig. 4), în echicurent sau în contracurent.

Injectarea apei în echicurent conduce la o reducere continuă a temperaturii cimentului în lungul axei morii; se evită astfel vârful de temperatură care apare la injectarea apei în contracurent. Din acest motiv, chiar dacă conducta de alimentare a apei se montează cu dificultate în tubul morii, injectarea în echicurent este preferată, actualmente, celei în contracurent.

Pulverizarea apei se produce prin trecerea acesteia şi a aerului comprimat care realizează pulverizarea printr-un ajutaj obişnuit, presiunea apei având valoarea de circa *5...6 bari*, iar cea a aerului de circa *1...2 bari* [1]. Aerul comprimat contribuie atât la pulverizarea apei, cât şi la desfundarea ajutajului de praful de ciment care pătrunde în el atunci când nu este folosit.

Acest sistem de joasă presiune, deşi a fost primul sistem de pulverizare implementat, este încă folosit în multe fabrici de ciment. Dezavantajul acestui sistem de joasă presiune constă în faptul că, atunci când aerul comprimat se întrerupe, pulverizarea apei nu se mai face sub formă de ceaţă, formându-se picături mari de apă.

Pentru a evita această deficienţă, noile sisteme de pulverizare se proiectează pentru presiuni mari ale apei, de *6...10 bari* [1], care realizează pulverizarea fină a apei, fără să mai fie nevoie de prezenţa aerului comprimat. Totuşi, pentru a preveni formarea depozitelor de praf în ajutajul de pulverizare a apei, se foloseşte şi aer, cu presiunea de *0,05...0,1 bari*, care se introduce în ajutaj printr-o conductă separată [1].

Pentru proiectarea sistemelor de injectare a apei în mori se pot utiliza datele din tabelul 2.

Tabelul 2. *Valori ale debitului şi presiunii folosite pentru proiectarea sistemelor de injectare a apei în mori [1].*

Caracteristici ale apei şi aerului	Injecţie de înaltă presiune (de ex. Polysius)	Injecţie de joasă presiune (de ex. F.L.Shmidt)
Presiunea apei, *bari*	8...10	1,5...2,0
Debitul apei	v. tabelul 3	v. tabelul 3
Presiunea aerului, *bari*	0,05...0,07	5...6
Debitul aerului, m^3*aer/kg apă*	0,07	0,05

Pulverizarea apei în primul compartiment se face direct pe clincher sau pe încărcătura de bile pentru a preveni udarea diafragmei care, dacă este umezită, ar putea să se înfunde. Tubul de injectare a apei este fixat pe sistemul de alimentare a morii cu material. Apa se alimentează în compartimentul morii printr-un tub interior, iar prin tubul exterior (concentric cu cel interior) se alimentează aerul pentru curăţirea ajutajului.

Dacă temperatura clincherului este foarte mare (*>150* ^0C), atunci în primul compartiment se va pulveriza un debit mare de apă (*>35%*). Dacă temperatura clincherului este redusă (*< 80* ^0C), atunci în primul compartiment nu se va mai pulveriza apă [1].

În al doilea compartiment al morii apa se va pulveriza astfel încât picăturile fine de apă să nu umezească diafragma de evacuare, pentru a nu o înfunda. Tubul de injectare a apei se fixează direct pe dispozitivul de evacuare a morii, rotind împreună cu acesta.

Experienţa arată că debitul de apă injectată în compartimentul al doilea se menţine constant, deoarece temperatura clincherului se uniformizează deja prin reglarea debitului apei pulverizate în primul compartiment al morii.

Pentru alimentarea apei în funcţie de temperatura din moară trebuie instalat un sistem automat de control, rolul acestuia fiind de a corela cele două elemente contrdictorii: calitatea cimentului şi eficienţa desprăfuirii morii. Astfel, pentru a asigura calitatea cimentului trebuie să se regleze în mod corespunzător temperatura acestuia, iar pentru a realiza o buna eficienţă a desprăfuirii trebuie să se controleze punctul de rouă al aerului de ventilaţie din moară.

Sistemul de control trebuie să îndeplinească, de asemenea, şi rolul unui element de siguranţă, adică să nu permită injectarea apei dacă:

- moara nu funcţionează;
- suflanta de aer nu este în funcţiune;
- temperatura cimentului este mai mică de *95...100* ^0C.

Debitul necesar de apă injectată depinde de o serie de factori: temperatura clincherului, umiditatea ghipsului, fineţea de măcinare a cimentului, debitul şi viteza aerului prin moară etc. şi trebuie modificat corespunzător condiţiilor concrete de funcţionare a morii.

În funcţie de tipul echipamentului de desprăfuire utilizat, se pot folosi pentru debitul de aer de ventilare şi pentru debitul de apă pulverizată valorile din tabelul 3.

Tabelul 3. *Valori ale debitului debitul de aer de ventilare şi ale debitul de apă pulverizată, pentru diferite echipamente folosite pentru desprăfuire [1].*

Tipul desprăfuitorului	Debitul de aer de ventilare	Debitul de apă
Filtru cu saci	0,35...0,90 m^3 *aer/kg cim.*	*max.* 50*g apă/*m^3 *aer*
Filtru electrostatic	0,20...0,45 m^3 *aer/kg cim.*	1...4% din debitul morii

Valori mai precise ale debitelor de aer de ventilare şi de apă pulverizată se obţin prin realizarea bilanţului termic al morii.

5. ASPECTE PRIVIND DESPRĂFUIREA AERULUI EVACUAT DIN INSTALAŢIA DE MĂCINARE

Deoarece aerul folosit pentru ventilare trebuie desprăfuit înainte de evacuarea lui din instalaţia de măcinare, punctul de rouă al acestuia trebuie să aibă o valoare care să corespundă tipului de echipament de desprăfuire utlizat.

Dacă pentru desprăfuire se utilizează filtrul electrostatic, atunci pentru a se obţine o eficienţă convenabilă a desprăfuirii, trebuie să se lucreze cu un punct de rouă ridicat (adică debit de aer de ventilaţie mic şi debit mare de apă pulverizată).

Dacă pentru desprăfuire se utilizează filtrul cu saci, atunci este de preferat să se lucreze cu punct de rouă scăzut (adică debit de aer de ventilaţie mare şi debit mic de apă pulverizată).

Stabilirea debitului aerului de ventilaţie trebuie să se facă ţinând seama însă şi de capacitatea echipamentului de desprăfuire. Astfel, o creştere a debitului ventilării poate fi benefică numai dacă echipamentul de desprăfuire poate funcţiona eficient în condiţiile noului debit mărit.

Filtrele cu saci se folosesc pentru desprăfuirea morilor mici, cu diametrul de până la *3,5 m*, morile mari fiind echipate cu filtre electrostatice. La o funcţionare normală a instalaţiei de măcinare, eficienţa desprăfuirii filtrelor electrostatice nu ridică probleme deosebite.

Totuşi, dacă în moară se alimentează clincher cu temperatura redusă, eficienţa filtrelor electrostatice scăzând foarte mult ca urmare a reducerii debitului de apă pulverizată, apar emisii

necontrolate de praf, care nu sunt acceptate de autorităţile de mediu [1].

De aceea, filtrele cu saci, mai sigure în ceea ce priveşte scăpările necontrolate de praf, au început să înlocuiască filtrele electrostatice (mai puţin sigure din acest punct de vedere) şi în cazul morilor mari. Filtrele cu saci sunt însă sensibile la puncte de rouă ridicate (condensarea vaporilor de apă), care determină reducerea eficienţei funcţionării lor.

Prin urmare, la adoptarea echipamentelor de desprăfuire, trebuie să se acorde o atenţie deosebită mai multor factori: sensibilităţii echipamentului de desprăfuire la fluctuaţia punctului de rouă; debitului de apă pulverizată; condiţiilor de operare a instalaţiei de măcinare; costului de investiţie al echipamentului de desprăfuire.

Pentru a asigura reţinerea eficientă a prafului în filtrele electrostatice, rezistivitatea electrică a prafului trebuie să aibă valori în domeniul $1 \cdot 10^4 \ldots 1 \cdot 10^{11}$ *Ω·cm*; prafurile care apar în cadrul fabricilor de ciment au valori cuprinse între aceste limite.

Prafurile cu valori ale rezistivităţii în afara acestor limite sunt reţinute cu dificultate în filtrele electrostatice, această situaţie putând fi evitată prin reglarea corespunzătoare a valorilor temperaturii şi umidităţii aerului [7].

Temperatura şi umiditatea aerului influenţează în mare măsură eficienţa electrofiltrului, rezistivitatea electrică a prafului mărindu-se cu creşterea temperaturii şi micşorându-se cu creşterea umidităţii aerului.

Valori mari ale eficienţei desprăfuirii în filtrele electrostatice se realizează dacă temperatura aerului evacuat din instalaţiile de măcinare este apropiată valorii corespunzătoare punctului de rouă [7].

Prin urmare, la morile cu răcire prin pulverizare de apă, factorul care limitează debitul de aer desprăfuit este punctul de rouă. La filtrele cu saci, în mod normal, punctul de rouă nu trebuie să depăşească $50\ ^0C$ [1]. La filtrele electrostatice, pentru a se obţine o eficienţă de desprăfuire normală, valoarea minimă a punctului de rouă trebuie să depăşească $50\ ^0C$ [1].

În figura 5 este prezentată grafic dependenţa debitului specific de aer desprăfuit, în funcţie de diametrul morii, pentru filtre cu saci şi electrofiltre.

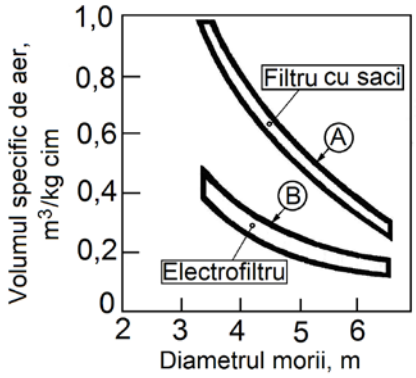

Figura 5. *Debitul specific de aer desprăfuit, în funcţie de diametrul morii, pentru filtre cu saci şi electrofiltre [4].*
A – curba pentru punctul de rouă maxim;
B – curba pentru punctul de rouă minim.

Din figura 5 se observă că filtrele cu saci pot înlocui filtrele electrostatice pentru desprăfuirea morilor mari. Se poate concluziona că debitul optim de ventilare a morii depinde nu numai de mărimea morii şi de răcirea necesară acesteia, ci şi de echipamentul de desprăfuire utlizat.

Costurile de investiţie ale echipamentelor de desprăfuire care echipează morile mari au cam acelaşi ordin de mărime atât pentru filtrele cu saci, cât şi pentru cele electrostatice, filtrele cu saci având costuri ceva mai mici. În cazul morilor mici mici, filtrele electrostatice sunt mult mai scumpe decât decât filtrele cu saci de mărime similară [1].

Deşi costul de investiţie al filtrelor cu saci este mai redus decât cel al electrofiltrelor, ele au un consum specific de energie ridicat (presiune mare a aerului) şi costuri mari de mentenanţă. Practica arată că este bine ca înainte de echipamentul de despăfuire (filtru cu saci sau electrostatic) să se plaseze, pentru reţinerea particulelor grosiere, un separator static cu fante reglabile.

Experienţa arată de asemenea că, atunci când se utilizează adaosuri de măcinare (substanţe tensioactive: 1,2-propandiol, acid acetic, trietanolamină, lignosulfonat etc.) care, adăugate cimentului în proporţie de *0,01…0,03 %*, reduc fenomenul de aglomerare şi de aderare a particulelor fine pe suprafaţa corpurilor de măcinare şi a blindajelor morii şi îmbunătăţesc proprietăţile de curgere ale cimentului măcinat [4, 8], eficienţa de desprăfuire, atât a filtrelor electrostatice cât şi a filtrelor cu saci, se reduce. Pentru a compensa această reducere a eficienţei de desprăfuire, suprafaţa activă a acestor filtre trebuie mărită.

Astfel, atunci când se utilizează adaosuri de măcinare, suprafaţa activă a filtrelor electrostatice trebuie mărită cu circa *10...15%* [1].

În cazul filtrelor cu saci, pentru dimensionarea tehnologică a acestora, atunci când se utilizează sau nu adaosuri de măcinare, se pot folosi valorile încărcării specifice prezentate în tabelul 4.

Tabelul 4. *Valori ale încărcării specifice ale filtrelor cu saci [1].*

Regenerarea suprafeţei filtrante	Încărcarea specifică a filtrului, m^3 *aer/*m^2 *supr.filtrantă·h*	
	Fără adaosuri de măcinare	Cu adaosuri de măcinare
Mecanică	80...100	60...80
Cu jet de aer	120...140	100...120

6. RĂCIREA CIMENTULUI ÎN AFARA MORII

Răcirea cimentului în separatorul dinamic

Răcirea cimentului în separator (fig. 1) se poate face prin introducerea de aer proaspăt în separatorul dinamic (când temperatura cimentului se reduce cu aproximativ *15...25* ^0C) sau prin introducerea de apă în mantaua de răcire din jurul acestuia (când temperatura cimentului se reduce cu circa *30...40* ^0C, debitul de apă având valori de circa *0,2...0,3* m^3 *apă/t de ciment*) [1].

Răcirea prin introducerea de aer în separator poate afecta însă performanţele separatorului şi poate mări costurile de operare datorită debitului mai mare de aer care trebuie desprăfuit.

Răcirea separatorului cu apă se face prin introducerea acesteia într-o mantaua de răcire care îmbracă partea inferioară, conică, a separatorului.

Dezavantajul major al acestei modalităţi de răcire constă în faptul că, prin formarea de cruste pe peretele separatorului, se reduce foarte mult eficienţa răcirii. Formarea de cruste poate fi diminuată dacă răcirea nu se realizează prin manta de răcire ci prin pulverizarea directă a apei pe suprafaţa exterioară a separatorului.

Răcirea cimentului în răcitoare plasate în afara morii

Răcitoarele de ciment din afara morii se plasează în instalaţia de măcinare fie înainte de alimentarea separatorului dinamic, fie la evacuarea fracţiunii grosiere (grişului) sau a produsului finit din acesta (fig. 1). Răcitorul pentru produsul finit are rolul de a reduce temperatura cimentului pentru a evita aglomerarea lui, cu formare de bulgări, în silozurile de depozitare şi de a înlesni curgerea cimentului prin instalaţiile de ambalare a acestuia.

Reducerea temperaturii cimentului în circuitul de măcinare se poate face prin instalarea de răcitoare atât între moară şi separatorul dinamic (pe alimentarea separatorului), cât şi între separator şi moară (pe evacuarea grişului din separator).

Răcirea pe alimentarea separatorului contribuie atât la reducerea temperaturii produsului finit, cât şi a grişului. Acest răcitor trebuie proiectat pentru un debit de material de până la *3* ori mai mare decât debitul morii, prin urmare costul de investiţie al acestuia este mare.

O soluţie mai economicoasă constă în instalarea unui răcitor pe evacurea grişului din separator. Temperatura produsului finit poate fi redusă, în acest mod, cu *10...20* ^0C, iar cea a grişului cu *30...40* ^0C [1]. Căldura totală intrată în moară va fi, prin urmare, redusă în mod considerabil.

7. CONCLUZII

La măcinarea cimentului în morile cu bile se degajă o mare cantitate de căldură care influenţează negativ atât calitatea cimentului rezultat, cât şi eficienţa procesului de măcinare.

În morile mici temperatura cimentului poate fi menţinută în limite acceptabile prin ventilarea cu aer a interiorului morii.

La morile mari însă, căldura nu poate fi înlăturată complet numai prin ventilarea morii cu aer, ci este nevoie de o răcire suplimentară prin pulverizarea de apă în moară, debitele de aer de ventilare şi de apă pulverizată depinzând în pricipal de mărimea morii şi de temperatura clincherului introdus în moară.

Dacă nici răcirea prin ventilare şi pulverizare de apă în interiorul morii nu este suficientă, atunci se procedează şi la răcirea cimentului în răcitoare adecvate, plasate în afara morii, precum şi la răcirea tubului morii la exteriorul acestuia.

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RĂCIREA MORILOR TUBULARE CU BILE PENTRU MĂCINAREA CIMENTULUI / COOLING OF BALL MILLS FOR GRINDING CEMENT

II. Bilanţul termic al morii de ciment / Heat balance of the cement mill

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REZUMAT
În lucrare sunt prezentate datele necesare pentru realizarea bilanţului termic al morii de ciment, în scopul determinării debitului de aer de ventilare şi a celui de apă pulverizată, pentru răcirea cimentului în moară până la o valoare a temperaturii care să nu afecteze calitatea cimentului şi eficienţa procesului de măcinare. De modalitatea de răcire depinde, prin valoarea punctului de rouă al aerului evacuat din moară, stabilirea echipamentului pentru desprăfuirea acestuia.

ABSTRACT
In this paper are presented the data necessary for the achievement of thermal balance of cement mill for determining the air flow of ventilation and water spray to cool the cement mill up to a temperature that will not affect the quality of the cement and grinding process efficiency. Method of cooling determines, through the dew point of the exhaust air from the mill, the type of the dedusting equipment.

KEY WORDS: cement mill, mill ventilation, cement cooling, water injection.

CUVINTE CHEIE: moară de ciment, ventilarea morii, răcirea cimentului, pulverizarea de apă.

1. GENERALITĂŢI

În morile cu bile pentru ciment se dezvoltă o mare cantitate de căldură, atât ca urmare a procesului de măcinare, cât şi ca urmare a temperaturii cu care intră clincherul în moară.

O mare parte din energia primită de moară de la motorul ei de acţionare (circa *95 %*) se transformă, în urma procesului de măcinare, în căldură, care, acumulându-se în ciment, produce încălzirea puternică a acestuia. Dacă temperatura cimentului în moară depăşeşte o anumită limită (*100...105 ^{0}C)*, sunt afectate negativ atât calitatea cimentului obţinut, cât şi desfăşurarea procesului de măcinare, din cauza apariţiei următoarelor fenomene [1, 2, 4, 5]:

- deshidratarea parţială a ghipsului care se introduce în ciment pentru reglarea timpului de priză al acestuia;
- priză falsă a cimentului, determinată de deshidratarea ghipsului;
- scăderea rezistenţei cimentului ca urmare a hidratării superficiale a particulelor lui la contactul cu vaporii de apă rezultaţi din deshidratarea ghipsului;
- creşterea tendinţei de aglomerare a particulelor fine de ciment şi aderarea lor pe corpurile de măcinare şi pe alte elemente interioare ale morii (datorită forţelor de coeziune superficială şi forţelor generate de încărcarea electrostatică);
- reducerea proprietăţilor de curgere a cimentului pulverulent.

Acoperirea bilelor şi blindajelor morii cu un strat de particule fine de ciment produce o scădere importantă a randamentului procesului de măcinare (de până la *30 %*), determinată de: reducerea şocurilor bilelor asupra materialului; împiedicarea clasării bilelor după mărimea lor, de către blindajele autosortatoare; reducerea ponderii măcinării prin frecare produsă de bilele mici (din compartimentul

de măcinare fină), deoarece acestea nu mai ajung în contact direct unele cu altele etc. [5, 6].

O parte din căldura dezvoltată în moară se pierde prin radiaţia şi convecţia tamburului morii, iar restul, care produce încălzirea cimentului, trebuie înlăturată prin răcirea morii. Modalităţile de răcire a morilor cu bile depind de cantitatea de căldură dezvoltată în procesul de măcinare, care, la rândul ei, depinde de mărimea morii şi de temperatura cu care clincherul este alimentat în moară.

La morile mici şi la temperaturi reduse de intrare a clincherului în moară este suficientă răcirea prin ventilarea morii (trecerea unui curent de aer prin interiorul acesteia). La morile mari şi la temperaturi ridicate ale clincherului la intrarea în moară, răcirea prin ventilare nu mai este suficientă şi trebuie suplimentată cu o răcire prin pulverizare (injectare) de apă în interiorul morii.

Debitele de aer de ventilaţie (m^3 *aer/h*) şi de apă pulverizată (*kg apă/h*) se determină fie pe baza consumurilor specifice rezultate din experienţa utilizării morilor cu bile (v. partea I a lucrării), fie, cu mult mai multă precizie, realizând bilanţul termic al morii.

2.CALCULUL BILANŢULUI TERMIC AL MORILOR CU BILE PENTRU MĂCINAREA CIMENTULUI

a. Răcirea morii prin ventilare

Debitul de aer necesar pentru ventilarea morii depinde de temperatura clincherului la intrarea în moară şi se determină în urma realizării bilanţului termic al instalaţiei de măcinare care, pentru moara care funcţionează în circuit închis, se realizează conform schemei din figura 1.

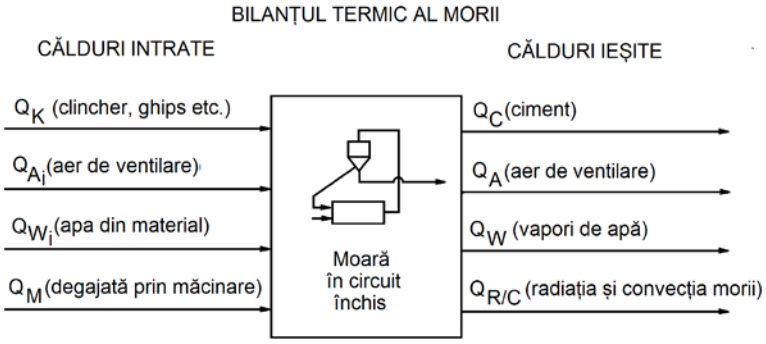

Figura. 1. *Schema bilanţului termic al morii [1].*

Dacă se consideră că aerul de ventilaţie şi apa din materialul alimentat în moară se introduc în bilanţul termic la temperatura mediului ambiant, atunci căldurile intrate cu acestea, fiind foarte mici, se pot neglija.

Pentru măcinarea cimentului portland normal (consumul specific de energie la măcinare de *33 kWh/t* şi fineţea de măcinare a cimentului de *300* m^2/kg (*3000* cm^2/g)), conturul pe care se realizează bilanţul este cuprins între alimentarea clincherului supus măcinării şi evacuarea produsului finit (fig. 1). Temperatura produsului finit, la ieşirea din separatorul dinamic, trebuie să fie sub valoarea limită de *100* ^0C.

Se poate întâmpla însă, ca în cursul procesului de măcinare să apară vârfuri de temperatură mai mari decât această valoare limită, care influenţează negativ calitatea cimentului obţinut. Aceste vârfuri de temperatură pot să apară la măcinarea în morile tubulare, care lucrează în circuit închis, cu sarcină de recirculare foarte mare (mori scurte sau mori pentru cimenturi cu fineţe de măcinare foarte mare).

Uneori bilanţul termic se poate realiza separat: pentru tubul morii şi pentru separatorul dinamic, în bilanţul scris pentru tubul morii apărând o nouă căldură intrată, cea cu care grişul iese din separatorul dinamic.

Pentru a înlesni analiza bilanţului termic, atât căldurile intrate în conturul bilanţului cât şi cele ieşite din acesta se scriu pentru unitatea de cantitate de produs finit (*1 kg de ciment*).

La producerea cimentului portland normal, căldurile intrate în conturul bilanţului (fig. 1) sunt: căldura produsă prin măcinarea clincherului, (Q_M), direct proporţională cu puterea *N* a motorului de acţionare a morii şi căldura intrată cu clincherul (Q_K), direct proporţională cu temperatura acestuia.

Căldurile intrate sunt determinate de relaţiile:

- Căldura degajată prin măcinare [1, 3]:
- $$Q_M = \frac{\eta \cdot N}{Q} \quad \frac{kJ}{kg} \qquad (1)$$
- unde *N* este puterea motorului de acţionare a morii, *kW*; η – randamentul acţionării morii, *%*; *Q* – debitul morii, *kg/s*;
- Căldura intrată cu clincherul:
- $$Q_K = c_{pK} \cdot (t_K - t_0) \quad \frac{kJ}{kg}$$

(2)

unde c_{pK} este căldura specifică a clincherului, *kJ/kg* ^0C; t_K – temperatura cu care intră clincherul în moară, ^0C; t_0 – temperatura mediului ambiant, ^0C.

Căldura specifică a clincherului se determină cu relaţia [1]:

$$c_{pK} = 0{,}00046 \cdot t_K + 0{,}733 \quad \text{kJ/kg } {}^0\text{C}$$

unde t_K – temperatura cu care intră clincherul în moară, ^0C.

Căldurile ieşite din conturul bilanţului (fig. 1) sunt: căldura conţinută de cimentul evacuat (Q_C), căldura pierdută prin radiaţia şi convecţia tamburului morii ($Q_{R/C}$), căldura pentru evaporarea apei (Q_W).

Căldurile ieşite sunt determinate de relaţiile:

- Căldura ieşită cu cimentul măcinat:
- $Q_C = c_{pC} \cdot (t_C - t_0) \quad \frac{kJ}{kg}$;

(3)

- unde $c_{pC} = c_{pK}$ este căldura specifică a cimentului, *kJ/kg* ^0C; t_C – temperatura cimentului în moară, ^0C; t_0 – temperatura mediului ambiant, ^0C.
- Căldura pierdută prin radiaţia şi convecţia componentelor instalaţiei de măcinare depinde de aria suprefeţei exterioare şi de temperatura acestora.

Pentru a simplifica calculele se ia în consideraţie numai aria exterioară a tubului morii şi temperatura acesteia. De aria şi temperatura suprafeţelor celorlalte componente ale instalaţiei de măcinare se ţine seama prin introducerea în calcul a unui factor de transfer de căldură (*k*). Considerând că, în medie, temperatura învelişului morii este de *80...90* ^0C, căldura pierdută prin radiaţia şi convecţia componentelor instalaţiei de măcinare se determină cu relaţia [1]:

$$Q_{R/C} = \frac{S \cdot k}{Q} \quad \frac{kJ}{kg} \tag{4}$$

unde aria suprafeţei exterioare a morii este definită de expresia:

$$S = 2 \cdot \frac{\pi \cdot D^2}{4} + \pi \cdot D \cdot L \ , \quad m^2 \tag{5}$$

(*D* – diametrul exterior al tamburului morii, *m*; *L* – lungimea acestia, *m*); *Q* – debitul morii, *kg/s*; *k* - factorul de transfer termic (tabelul 1).

Tabelul 1. *Valori ale factorului de transfer termic [1].*

Tipul morii	Diametrul tamburului morii, m	
	Φ < 3,5	Φ > 3,5
	Valori *k, kJ/m²·s =kW/ m²*	
Moară în circuit deschis	1,11	
Moară în circuit închis	2,22	3,33

Relaţia (4) poate fi pusă sub forma [1]:

$$Q_{R/C} = \left(\frac{D}{2} + L\right) \cdot \frac{\pi \cdot D \cdot k}{Q} \quad \frac{kJ}{kg} \tag{6}$$

unde *D* – diametrul nominal al tamburului morii, *m*; *L* – lungimea tamburului, *m*; *Q*– debitul morii, *kg/s*; *k* – factorul de transfer termic, *kW/ m²*.

Pentru determinarea căldurii pierdute prin radiaţia şi convecţia tamburului morii se poate utiliza şi relaţia [4]:

$$Q_{R/C} = \frac{\alpha \cdot S \cdot (t_m - t_a)}{Q} \quad kJ/kg \tag{7}$$

unde:

α - coeficientul de transfer termic, determinat de relaţia [4]:

$$\alpha = \left(6{,}16 + 6{,}95 \cdot \sqrt{D}\right) \cdot 10^{-3} \quad kJ/m^2 \cdot s \cdot {}^0C \ ; \tag{8}$$

D – diametrul morii, *m*;

S - aria suprafeţei exterioare a morii, determinată de relaţia (5), m^2;

t_m = *80...90* ^0C – temperatura medie a mantalei morii;

t_a = *20* ^0C – temperatura mediului ambiant;

Q - debitul morii, *kg/s*.

-Căldura ieşită cu aerul de ventilaţie evacuat din moară:

$$Q_A = \frac{c_{pA} \cdot V_A \cdot (t_A - t_0)}{Q} \quad \frac{kJ}{kg} \tag{9}$$

unde V_a este debitul volumic al aerului de ventilare, Nm^3/s; c_{pA} = *1,3 kJ/ Nm³* ^0C – căldura specifică a aerului ; t_A – temperatura aerului de ventilare la ieşirea din moară, ^0C; *Q* - debitul morii, *kg/s*.

-Căldura consumată pentru evaporarea apei conţinută de materialul alimentat în moară se determină cu relaţia:

$$Q_W = r \cdot W \quad \frac{kJ}{kg} \tag{10}$$

unde *W* este cantitatea de apă provenită din umiditatea materialului alimentat în moară, *kg apă/kg cim*; *r = 2500 kJ/kg apă* – căldura de vaporizare a apei.

Cantitatea de apă adusă de materialul alimentat în moară:

$$W = V_{W\,mat} = u \cdot Q \ \ kg/s \tag{11}$$

unde *u* este umiditatea materialului alimentat în moară, *%*; *Q* – debitul morii, *kg/s*.

Din ecuaţia de bilanţ termic se poate determina debitul de aer necesar ventilării morii:

$$V_A = \frac{Q \cdot [(Q_M + Q_K) - (Q_C + Q_{R/C} + Q_W)]}{c_{pA} \cdot (t_A - t_0)} \quad Nm^3/s \tag{12}$$

Dacă utilizarea ventilaţiei cu debitul maxim de aer (corespunzător limitei superioare a domeniului de viteze prescris pentru tipul respectiv de moară) şi evaporarea apei din material nu este suficientă pentru răcirea cimentului până la temperatura cerută, atunci trebuie să se apeleze şi la răcirea suplimentară prin pulverizarea de apă în interiorul morii. În acest caz, debitul de apă intrată în moară va fi $W = V_{Wp} + V_{Wmat}$, unde V_{Wp} este debitul de apă pulverizată pentru răcire, iar V_{Wmat} este apa intrată cu materialul alimentat în moară.

După realizarea bilanţului termic este necesar să se determine temperatura punctului de rouă a aerului evacuat din moară, în funcţie de care se stabileşte echipamentul de desprăfuire a acestuia (pentru valori $\tau < 45^0C$ ale punctului de rouă, desprăfuirea morii se realizează cu filtre cu saci, iar pentru valori $\tau > 45^0C$, cu filtre electrostatice) [1].

b. Răcirea suplimentară morii prin pulverizare de apă

După stabilirea debitului V_A de aer de ventilaţie, astfel încât viteza aerului să fie în limitele prescrise, şi determinarea căldurii Q_A, evacuate din moară prin aerul de ventilaţie evacuat, se poate determina debitul de apă necesar pentru răcirea suplimentară prin pulverizare de apă în moară.

În acest caz, debitul de apă care prin evaporarea în moară realizează răcirea suplimentară a acesteia (apa care trebuie pulverizată + apa conţinută de materialul alimentat în moară) este determinat de relaţia:

$$W = \frac{(Q_M + Q_K) - (Q_C + Q_{R/C} + Q_A)}{r} \quad kg\ apă/kg\ cim \cdot \tag{13}$$

Conţinutul de umiditate a aerului evacuat din moară se determină cu relaţia:

$$W^* = \frac{W \cdot Q}{V_A} \quad \frac{kg\ apă}{m^3\ aer}, \tag{14}$$

iar conţinutul de umiditate a aerului evacuat din moară, raportat la *kg* de aer uscat, cu relaţia:

$$W_g^* = \frac{W^*}{\rho_a} \quad \frac{kg\ apă}{kg\ aer} \tag{15}$$

unde $\rho_a = 1{,}293\ kg/m^3$ este densitatea aerului în condiţiile stării normale.

Temperatura punctului de rouă al aerului se determină utilizând diagrama din figura 2.

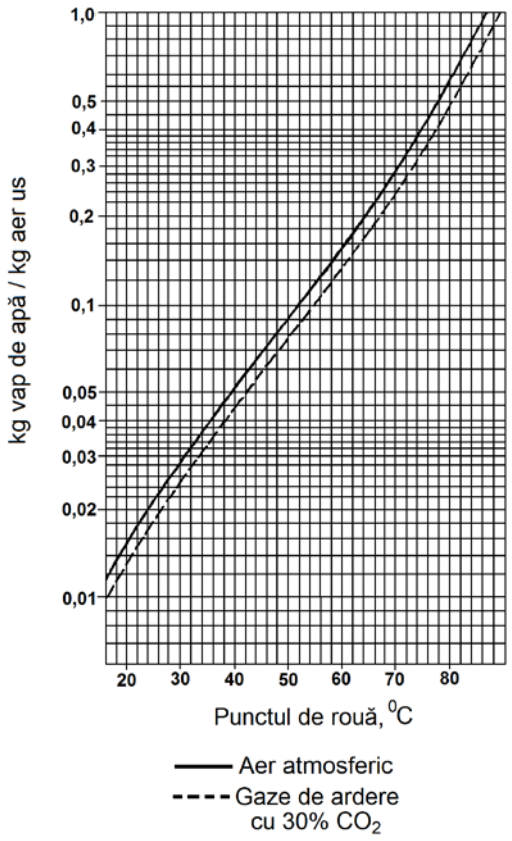

Figura 2. *Diagramă pentru determinarea punctului de rouă [1].*

Dacă temperatura punctului de rouă are valori $\tau < 45^0C$, se pot folosi pentru desprăfuirea aerului evacuat din moară filtre cu saci, iar dacă are valori $\tau > 45^0C$, filtre electrostatice [1].

Pentru a vedea influenţa mărimii morii asupra modului în care trebuie realizată răcirea ei, s-a realizat bilanţul termic pentru mori cu diferite diametre. În calculul bilanţului termic s-au mai utilizat următoarele date, specifice majorităţii morilor pentru măcinarea cimentului [1]:

- Raportul lungime/diametru: $L/D = 3{,}2$;
- Gradul de umplere a tamburului cu corpuri de măcinare (bile): $\varphi = 30\ \%$;
- Turaţia relativă a morii: $\psi = n/n_{cr} = 74\%$;
- Densitatea în vrac a bilelor: $\rho_b = 4{,}55\ t/m^3$ (bile Φ *60 mm*);
- Consumul specific de energie al morii: $N_{sp} = 32\ kWh/t$.

Se determină, în funcţie de diametrul interior *D* al tamburului morii:

- Aria secţiunii transversale libere a tamburului morii (de deasupra încărcăturii de bile):

$$A_l = (1-\varphi) \cdot \frac{\pi \cdot D^2}{4} = (1-0{,}3) \cdot \frac{\pi}{4} \cdot D^2 = 0{,}55 \cdot D^2\ m^2;$$

- Puterea de acţionare a morii (pentru $\varphi = 0{,}30$ şi $\psi = 0{,}74$, $c = 7{,}3$) (relaţia lui Blanc) [3]:

$$N = c \cdot G \cdot \sqrt{D} =$$

$$= c \cdot \varphi \cdot \frac{\pi \cdot D^2}{4} \cdot L \cdot \rho_b \cdot \sqrt{D} = c \cdot \varphi \cdot \frac{\pi}{4} \cdot \lambda \cdot \rho_b \cdot D^{3,5} =$$

$$= 7,3 \cdot 0,3 \cdot \frac{\pi}{4} \cdot 3,2 \cdot 4,55 \cdot D^{3,5} = 25,04 \cdot D^{3,5} \ kW$$

- Debitul morii:

$$Q = \frac{N}{N_{sp}} = \frac{25,04 \cdot D^{3,5}}{32} = 0,78 \cdot D^{3,5} \ t/h;$$

- Viteza maximă a aerului prin moară: *2 m/s*;
- Temperatura clincherului la intrarea în moară şi a cimentului la ieşirea din moară: *100 ^0C*;
- Temperatura aerului de ventilare la ieşirea din moară: *100 ^0C*.

Bilanţul termic s-a realizat pentru moara răcită numai prin ventilare.

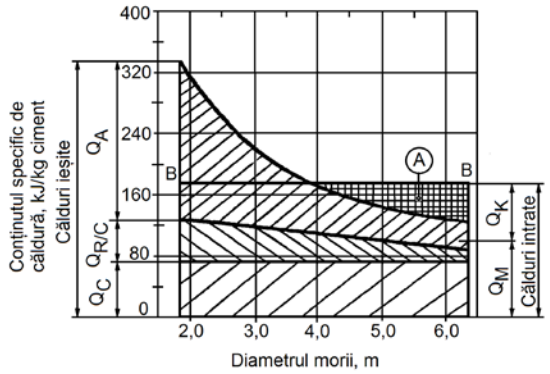

Figura 3. *Căldurile intrate în moară şi căldurile ieşite din moară, în funcţie de diametrul morii. Zona A trebuie acoperită prin răcire suplimentară, cu apă pulverizată sau cu răcitoare exterioare [1].*

Cu căldurile intrate şi căldurile ieşite, calculate pentru mori de diferite diametre, s-a realizat diagrama din figura 3.

Analizând această diagramă, se constată următoarele:

- Suma căldurilor intrate depinde numai de temperatura clincherului, fiind constantă în raport cu diametrul morii;
- Căldura ieşită cu aerul de ventilaţie descreşte foarte mult cu creşterea diametrului morii (variind direct proporţional cu *$1/D^{1,5}$*);
- Căldura pierdută prin radiaţia şi convecţia tamburului descreşte uşor cu creşterea diametrului morii.

Dacă prin ventilaţia morii temperatura cimentului nu scade până la valoarea cerută, atunci se procedează la răcirea suplimentară a acesteia prin pulverizarea de apă în interiorul ei sau, în cazul morilor în circuit închis, folosind răcitoare exterioare pentru ciment.

Pentru temperatura clincherului la intrarea în moară de *100 ^0C*, morile cu diametrul mai mare de *4 m* necesită răcirea suplimentară a cimentului (zona *A* din figura 3).

Dacă temperatura clincherului creşte, de exemplu, către valoarea de *150 ^0C*, atunci şi morile de diametru mic vor avea nevoie de răcire suplimentară (prin mărirea temperaturii clincherului, segmentul de dreaptă *B-B* se deplasează spre în sus, paralel cu el însuşi, producând extinderea zonei *A* spre domeniul diametrelor mai mici de *4 m* (fig. 3)).

3.EXEMPLU DE CALCUL

Se va realiza calculul pentru răcirea morii de ciment cu următoarele caracteristici [1]:

- Diametrul nominal al tamburului morii: *D = 4,2 m*;
- Lungimea tamburului morii: *L = 14 m*;
- Grosimea blindajelor: *s = 75 mm*;
- Densitatea în vrac a bilelor: *ρ_b = 4,55 t/m^3* (bile *Φ 60*);
- Gradul de umplere: *φ = 30 %*;
- Turaţia relativă: $\psi = n/n_{cr} = 74\%$;
- Consumul specific de energie (pentru ciment cu finețea de măcinare de *350 m^2/kg*): *N_{sp} =33 kWh/t* (fig. 4)
- Randamentul acţionării: *η = 95 %*;
- Viteza maximă a aerului în moară: *v = 2 m/s*;
- Temperatura clincherului: *t_K =150 ^0C*;
- Temperatura cimentului: *t_C =100 ^0C*;
- Temperatura aerului la ieşirea din moară: *t_A =100 ^0C*;
- Temperatura mediului ambiant: *t_0 =20 ^0C*.

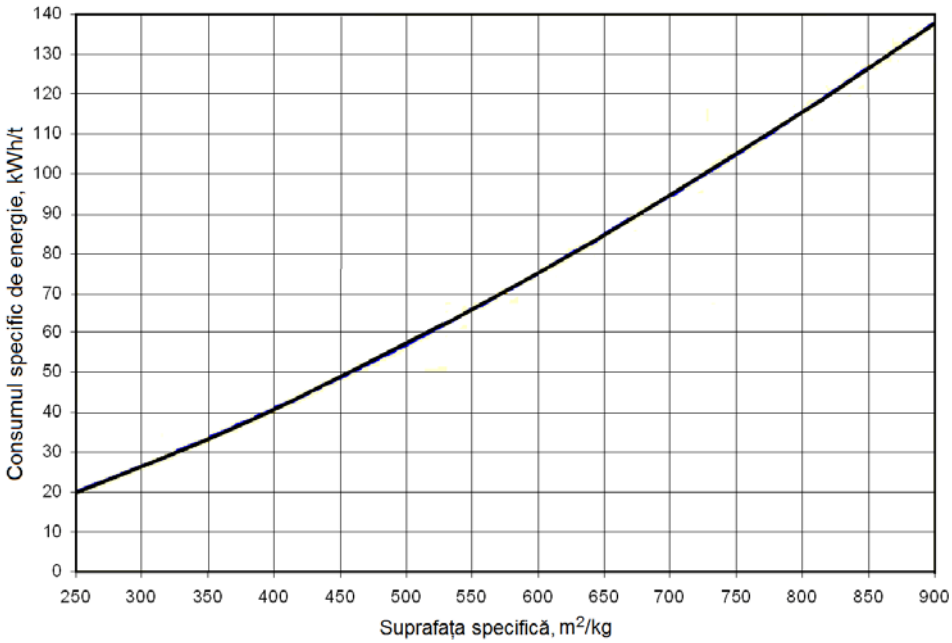

Figura 4. *Consumul specific de energie al morilor de ciment, în funcţie de finețea de măcinare a cimentului [7].*

Moara având diametrul $D = 4{,}2\ m$ se va răci atât prin ventilare cât şi prin pulverizarea de apă în interiorul ei (fig. 3).

Se determină:

- Diametrul interior (liber) al morii: $D_i = D - 2 \cdot s = 4{,}2 - 2 \cdot 0{,}075 = 4{,}05\ m$;

- Raportul: $\lambda = \frac{L}{D} = \frac{14}{4{,}2} = 3{,}33$;

- Puterea morii (pentru $\varphi = 0{,}30$ şi $\psi = 0{,}74$, $c = 7{,}3$) (relaţia lui Blanc):

$$N = c \cdot G \cdot \sqrt{D_i} =$$

$$= c \cdot \varphi \cdot \frac{\pi \cdot D^2}{4} \cdot L \cdot \rho_b \cdot \sqrt{D_i} = c \cdot \varphi \cdot \frac{\pi}{4} \cdot \lambda \cdot \rho_b \cdot D_i^{3,5} =$$

$$= 7{,}3 \cdot 0{,}3 \cdot \frac{\pi}{4} \cdot 3{,}33 \cdot 4{,}55 \cdot D_i^{3,5} = 26{,}06 \cdot D_i^{3,5}\ kW$$

$$N = 26{,}06 \cdot D_i^{3,5} = 26{,}06 \cdot 4{,}05^{3,5} = 3484\ kW\ ;$$

- Se adoptă un motor electric cu puterea: $N = 3500\ kW$;

- Debitul morii:

$$Q = \frac{N}{N_{sp}} = \frac{3500}{33} = 106\ t/h = 29{,}45\ kg/s \cdot$$

- Compoziţia materialului alimentat în moară, temperatura şi umiditatea componentelor acestuia, precum şi temperatura şi umiditatea amestecului sunt prezentate în tabelul 2.

Tabelul 2. *Compoziţia materialului alimentat în moară, temperatura şi umiditatea componentelor acestuia, precum şi temperatura şi umiditatea amestecului.*

Materiale alimentate în moară	Proporţia fiecărui material, %	Umiditatea la intrare a fiecărui material, %	Umiditatea adusă în amestec de fiecare material, %	Temperatura la intrare a fiecărui material, °C	Temperatura amestecului de materiale, °C
Clincher	85	0	0	150	0,85·150 = 127,5
Ghips	5	2	0,05·2 = 0,1	20	0,05·20 = 1,0
Calcar	10	5	0,10·5 = 0,5	20	0,10·20 = 2,0
Total	100	0,6	0,1+0,5 = 0,6	105	127,5+1+2=130,5

Cantitatea de apă adusă de materialele alimentate în moară:

$$W_{W\,mat} = u \cdot Q \;\; kg/s$$

unde u este umiditatea amestecului de materiale alimentat în moară, %; Q – debitul morii, *kg/s*.

- Cantitatea de apă adusă de materialele alimentate în moară:

$$W_{W\,mat} = u \cdot Q = \frac{0,6}{100} \cdot \frac{106000}{3600} = 0,176 \;\; kg/s = 636\, kg/h$$

- Temperatura amestecului de clincher, ghips şi calcar introdus în moară:

$$t_K^* = p_K \cdot t_K + p_G \cdot t_G + p_C \cdot t_C =$$

$$= 0,85 \cdot 150 + 0,05 \cdot 20 + 0,10 \cdot 20 = 130,5\, ^0C$$

unde p_K, p_G, p_C sunt respectiv proporţiile în amestec ale clincherului, ghipsului şi calcarului, iar t_K, t_G, t_C – temperaturile acestora (tabelul 2).

- Debitul maxim de ventilare (la temperatura de *100 ^0C*):

$$V_A = (1-\varphi) \cdot \frac{\pi \cdot (D - 2 \cdot s)^2}{4} \cdot v =$$

$$= (1-0,3) \cdot \frac{\pi \cdot (4,2 - 2 \cdot 0,075)^2}{4} \cdot 2 = 18,0\, m^3/s \approx$$

$$\approx 65000\, m^3/h$$

- Debitul de aer vehiculat prin moară, ţinând seama de aerul fals aspirat prin neetanşeităţile sistemului de evacuare a morii:

$$V_{A\max} = V_A \cdot (1 + a_f) = 65000 \cdot (1 + 0,15) = 74750\, m^3/h$$

unde s-a considerat că aerul fals reprezintă *a = 15%* din debitul de aer vehiculat prin moară.

- Debitul de aer de ventilaţie, corespunzător stării normale

$$V_{AN} = V_A \cdot \frac{T_N}{T} = 18,0 \cdot \frac{273}{273+100} = 13,2 \;\; Nm^3/s \approx .$$

$$\approx 47500 \;\; Nm^3/h$$

- Posibilitatea de a realiza debitul de ventilare depinde de tipul echipamentului de desprăfuire folosit şi de temperatura punctului de rouă. Temperatura punctului de rouă trebuie să aibă valorile:

  - $\tau < 45\, ^0C$ - pentru filtre cu saci;
  - $\tau > 45\, ^0C$ - pentru filtre electrostatice.

Pentru determinarea punctului de rouă trebuie realizat bilanţul termic al morii.

Bilanţul termic al morii

Prin bilanţul termic al morii se va determina debitul de aer de ventilare şi debitul de apă pulverizată necesare răcirii acesteia.

Călduri intrate

- Căldura degajată prin măcinarea cimentului:

$$Q_M = \frac{\eta \cdot N}{Q} = \frac{0,95 \cdot 3500}{29,45} = 112,9\, \frac{kJ}{kg};$$

- Căldura specifică a amestecului de clincher, ghips şi calcar:

$$c_{pK} = 0,00046 \cdot t_K^* + 0,733 = 0,00046 \cdot 130,5 + 0,733 =$$

$$= 0,793 \;\; \text{kJ/kg } ^0\text{C}$$

- Căldura intrată cu amestecul de clincher, ghips şi calcar alimentat în moară:

$$Q_K = c_{pK} \cdot (t_K - t_0) = 0,793 \cdot (130,5 - 20) = 87,6\, \frac{kJ}{kg}$$

- Totalul căldurilor intrate în moară:

$$Q_M + Q_K = 112,9 + 87,6 = 200,5\; kJ/kg\,.$$

Călduri ieşite

- Căldura ieşită cu cimentul măcinat:

$$Q_C = c_{pC} \cdot (t_C - t_0) = 0,779 \cdot (100 - 20) = 62,3\, \frac{kJ}{kg}$$

unde căldura specifică a cimentului:

$$c_{pC} = 0,00046 \cdot t_C + 0,733 = 0,00046 \cdot 100 + 0,733 =$$

$$= 0,779\, \text{kJ/kg } ^0\text{C}$$

- Căldura pierdută prin radiaţie şi convecţie:

$$Q_{R/C} = \frac{S \cdot k}{Q} = \frac{212,5 \cdot 3,33}{29,45} = 24,0\, \frac{kJ}{kg}$$

unde aria suprafeţei exterioare a morii are valoarea:

$$S = 2 \cdot \frac{\pi \cdot D^2}{4} + \pi \cdot D \cdot L = 2 \cdot \frac{\pi \cdot 4,2^2}{4} + \pi \cdot 4,2 \cdot 14 =$$

$$= 212,5\, m^2$$

iar factorul de transfer termic valoarea *k = 3,33 kW/m^2* (v. tabelul 1, pentru moara în circuit închis cu $\Phi > 3,5$ *m*).

- Căldura ieşită cu aerul de ventilaţie:

$$Q_A = \frac{c_{pA} \cdot V_A \cdot (t_A - t_0)}{Q} = \frac{1,3 \cdot 13,2 \cdot (100 - 20)}{29,45} =$$

$$= 46,6\, \frac{kJ}{kg}$$

unde $c_{pA} = 1,3\; kJ/Nm^3\, ^0C$.

- Căldura consumată pentru evaporarea apei (pulverizată + apa din materialul alimentat în moară):

$$Q_W = (Q_M + Q_K) - (Q_C + Q_{R/C} + Q_A) =$$

$$= (112,8 + 87,6) - (62,3 + 24,0 + 46,6) = 67,5\, \frac{kJ}{kg}$$

Totalul căldurilor ieite din moară:

$$(Q_C + Q_{R/C} + Q_A + Q_W) = (62,3 + 24,0 + 46,6 + 67,5) =$$

$$= 200,5\, \frac{kJ}{kg}$$

Punctul de rouă

- Cantitea de apă evaporată (v. relaţia (10):

$$W = \frac{Q_W}{r} = \frac{67,5}{2500} = 0,027\, \frac{kg\; apă}{kg\; ciment} = 27,0\, \frac{kg\; apă}{t\; ciment}$$

- Debitul de apă evaporată:

$$V_W = W \cdot Q = 0,027 \cdot 29,45 = 0,795\, kg/s =$$

$$= 2860\, kg/h = 2860\, l/h$$

- Cantitatea de apă datorită umidităţii materialului alimentat în moară:

$V_{W\,mat} = u \cdot Q = \frac{0,6}{100} \cdot 29,45 = 0,176\ kg/s = 636\,kg/h$

- Consumul de apă pentru pulverizare:

$V_{Wp} = V_W - V_{Wmat} = 2860 - 636 = 2224\ l/h$

- Conţinutul de umiditate a aerului evacuat din moară:

$$W^* = \frac{W \cdot Q}{V_A} = \frac{0,027 \cdot 29,45}{18,0} = 0,044\ \frac{kg\ apă}{m^3\ aer};$$

- Conţinutul de umiditate a aerului evacuat din moară, raportat la *kg* de aer uscat:

$$W_g^* = \frac{W^*}{\rho_a} = \frac{0,044}{1,293} = 0,034\ \frac{kg\ apă}{kg\ aer}$$

unde ρ_a *=1,293 kg/m*^{3} este densitatea aerului în condiţiile stării normale.

- Temperatura punctului de rouă:

Din figura 2, pentru valoarea conţinutul de umiditate $W_g^* = 0,034\ \frac{kg\ apă}{kg\ aer}$, rezultă temperatura punctului de rouă $\tau = 33\ ^0C$.

Această valoare a temperaturii punctului de rouă este potrivită pentru a folosi filtrul cu saci ($\tau = 33 < 45^0C$) ca echipament de desprăfuire a aerului evacuat din moară, însă este prea mică pentru utilizarea în acest scop a filtrului electrostatic (la care trebuie $\tau > 45^0C$).

Bilanţul termic al morii desprăfuite cu filtru electrostatic

Pentru ca filtrul electrostatic să poată fi folosit trebuie ca debitele de aer ventilaţie şi de apă de pulverizare să fie modificate în mod corespunzător. Pentru utilizarea filtrului electrostatic, ar trebui ca debitul specific al aerului de ventilare să aibă valoarea $v_{sp} = 0,40\ m^3$ *aer/kg ciment* (v. din partea I a lucrării: tabelul 1- pentru morile în circuit închis, cu $\Phi > 3,5\ m$ şi tabelul 3 - pentru morile desprăfuite cu filtru electrostatic).

Se determină:

- Debitul de aer de ventilare, la temperatura de *100* ^0C, în situaţia în care debitul specific are valoarea: $v_{sp} = 0,40\ m^3$ *aer/kg ciment*:

$V_A = v_{sp} \cdot Q = 0,4 \cdot 29,45 = 11,78\,m^3 aer/s \approx$

$\approx 42400\,m^3 aer/h$

- Debitul de aer de ventilare corespunzător stării normale:

$$V_{A\,N} = V_A \cdot \frac{T_N}{T} = 11,78 \cdot \frac{273}{273+100} = 8,6\,Nm^3/s \approx$$

$\approx 31000\ Nm^3/h$

- Debitul de aer vehiculat prin moară, ţinând seama de aerul fals aspirat prin neetanşeităţile sistemului de evacuare a morii:

$V_{A\max} = V_A \cdot (1 + a_f) = 42400 \cdot (1 + 0,15) = 48760\,m^3/h$

unde s-a considerat că aerul fals reprezintă *a = 15%* din debitul de aer vehiculat prin moară.

- Se verifică viteza aerului prin moară:

$$v = \frac{V_A}{(1-\varphi) \cdot \frac{\pi \cdot (D - 2 \cdot s)^2}{4}} =$$

$$= \frac{11,78}{(1-0,3) \cdot \frac{\pi \cdot (4,2 - 2 \cdot 0,075)^2}{4}} = 1,30\ m/s$$

Această valoare a vitezei se înscrie în limitele prescrise pentru morile în circuit închis [5, 6].

- Căldura ieşită cu aerul de ventilaţie:

$$Q_{A1} = \frac{c_{pA} \cdot V_A \cdot (t_A - t_0)}{Q} = \frac{1,3 \cdot 8,6 \cdot (100 - 20)}{29,45} = 30,3\ \frac{kJ}{kg}$$

- Căldura consumată pentru evaporarea apei (pulverizate + apa datorită umidităţii materialului alimentat în moară):

$Q_{W1} = (Q_M + Q_K) - (Q_C + Q_{R/C} + Q_{A1}) =$

$= (112,8 + 87,6) - (62,3 + 24,0 + 30,3) = 83,8\ \frac{kJ}{kg}$

- Cantitea de apă evaporată:

$$W_1 = \frac{Q_{W1}}{r} = \frac{83,8}{2500} = 0,0335 \frac{kg\ apă}{kg\ ciment} = 33,5\ \frac{kg\ apă}{t\ ciment}$$

- Consumul de apă:

$V_{W1} = W_1 \cdot Q = 0,0335 \cdot 29,45 = 0,99\,kg/s =$;

$= 3551\,kg/h = 3551\ l/h$

- Consumul de apă pentru pulverizare:

$V_{Wp1} = V_{W1} - V_{Wmat} = 3551 - 636 = 2915\ l/h$;

- Conţinutul de umiditate a aerului evacuat din moară:

$$W_1^* = \frac{W_1 \cdot Q}{V_A} = \frac{0,0335 \cdot 29,45}{8,6} = 0,115\ \frac{kg\ apă}{m^3\ aer};$$

- Conţinutul de umiditate a aerului evacuat din moară, raportat la *kg* de aer uscat:

$$W_{g1}^* = \frac{W_1^*}{\rho_a} = \frac{0,115}{1,293} = 0,089\ \frac{kg\ apă}{kg\ aer};$$

- Utilizând diagrama din figura 2 rezultă, pentru $W_{g1}^* = 0,089\ \frac{kg\ apă}{kg\ aer}$, valoarea temperaturii punctului de rouă $\tau = 50\ ^0C$.

În concluzie, pentru debitele de aer de ventilare + apă de pulverizare de:

$-V_A + V_W = 65000\,m^3\,aer/h + 2224\,kg\,apă/h$ - se utilizează pentru desprăfuire *filtrul cu saci*;

$-V_A + V_W = 42400\,m^3\,aer/h + 2915\,kg\,apă/h$ - se utilizează pentru desprăfuire *filtrul electrostatic*.

Calculul debitului de apă pulverizată pentru diferite valori ale temperaturii clincherului

Atunci când clincherul alimentat în moară are diferite temperaturi, căldura consumată pentru evaporarea apei pulverizate în cazul când desprăfuirea se face cu filtrul electrostatic (moara

cu $\Phi > 3,5\ m$, debitul specific al aerului de ventilare $v_{sp} = 0,4\ m^3$ *aer/kg ciment*) se determină cu relaţia:

$$Q_W = (Q_M + Q_K) - (Q_C + Q_{R/C} + Q_A) =$$
$$= (112,9 + Q_K) - (62,3 + 24,0 + 30,3) = Q_K - 3,7$$

Căldura adusă de amestecul de clincher, ghips şi calcar alimentat în moară se determină, pentru diferite temperaturi ale clincherului, cu relaţia:

$$Q_K = c_{pK} \cdot (t_K^* - t_0)\ \frac{kJ}{kg}$$

în care:

$$t_K^* = p_K \cdot t_K + p_G \cdot t_G + p_C \cdot t_C =$$
$$= 0,85 \cdot t_K + 0,05 \cdot 20 + 0,10 \cdot 20 = 0,85 \cdot t_K + 3\ {}^0C$$

(v. tabelul 2)).

Consumul de apă pentru pulverizare se determină cu relaţia:

$$V_{Wp} = \frac{Q_W \cdot Q}{r} - V_{Wmat} = \frac{3600 \cdot Q_W \cdot 29,45}{2500} - 636 =$$
$$= 42,4 \cdot Q_W - 636\ \frac{l}{h}$$

Calculul debitului de apă pulverizată se realizează pentru următoarele valori ale temperaturii clincherului:

$t_K = 150^0 C$; $t_K = 125^0 C$;

$t_K = 100^0 C$; $t_K = 75^0 C$,

rezultatele calculului fiind prezentate în tabelul 3.

Tabelul 3. *Rezultatele calculului.*

t_K	Q_K, kJ/kg	Q_W, kJ/kg	V_{Wp}, l/h
150^0C	87,6	83,9	2915
125^0C	69,9	56,2	1747
100^0C	52,6	48,9	1438
75^0C	38,6	32,0	721

Analizând datele din tabelul 3, se observă că păstrând condiţiile în care se realizează ventilarea morii ($v_{sp} = 0,40\ m^3$ *aer/kg ciment*), debitul de apă pulverizată, necesar răcirii cimentului până la temperatura de *100 ^0C* , se reduce considerabil pe măsură ce scade temperatura cu care clincherul se alimentează în moară.

4. CONCLUZII

Pentru morile mici (cu diametrul $D < 4,0\ m$), în care se macină clincher cu temperatura la intrare relativ redusă (sub *100 ^0C*), răcirea cimentului până la temperatura maximă admisă de *100 ^0C* se poate realiza numai prin ventilare şi prin evaporarea umidităţii conţinută de diferitele adaosuri (ghips, zgură, calcar etc.) care se macină împreună cu clincherul de ciment.

În cazul morilor mari (cu $D > 4,0$) şi temperatura clincherului la intrare mare (de până la *150 ^0C*), această modalitate de răcire este insuficientă şi trebuie să se recurgă şi la răcirea prin pulverizarea de apă în moară.

Modalitatea de răcire a morii, prin ventilarea morii sau/şi prin pulverizarea de apă în interiorul acesteia, influenţează, prin temperatura punctului de rouă al aerului evacuat din moară, tipul echipamentului utilizat pentru desprăfuirea acestuia (filtru cu saci sau filtru electrostatic).

În cazul folosirii filtrului cu saci, pentru obţinerea unei eficienţe ridicate a acestuia, este de preferat să se lucreze cu un punct de rouă scăzut (*<45^0C*), adică cu debit de aer de ventilaţie mare şi debit mic de apă pulverizată.

Dacă însă pentru desprăfuire se utilizează filtrul electrostatic, atunci se obţine o eficienţă convenabilă a desprăfuirii dacă se lucrează cu un punct de rouă ridicat (*>45^0C*), adică cu debit de aer de ventilaţie mic şi debit mare de apă pulverizată.

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EXPERIMENTAL RESEARCHES CONCERNING THE MEASURING OF FLOW RATES IN INDUSTRIAL EQUIPMENTS

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ABSTRACT
Measurements of amount and flux of different media (liquid or gaseous) are very often done in laboratories or in industry. If the amount of flowing media is small, energy, velocity and pressure caused by the flowing are small, too. Thus, for small amounts of the flowing media it cannot be used classic flow meters (rotameters, anemometers, vibratory flow meters etc.). Application of constriction flow meters requires relatively large contractions causing suitable large pressure changes and it is not always acceptable in technological processes. If a technological process requires automated measurements at a low pressure drop and the flow varies in time, it is necessary to find other measuring methods. In this paper, the author proposes a solution enabling automated measurements and causing low pressure drops.

KEYWORDS: Industrial equipment, flow rate, low pressure.

1. INTRODUCTION

Measurements of amount and flux of different media (liquid or gaseous) are very often done in laboratories and in industry. For example, in the case of gaseous media, the gas volume is a function of pressure and temperature, so the measured volume is usually reduced to normal conditions (273.15 K, 0.1013 MPa). Gas volume measurement resolves itself to determination of the tank volume. There are different gases, so different methods and measuring instruments are applied, [1], [5].

Application of constriction flow meters requires relatively large contractions causing suitable large pressure changes and it is not always acceptable in technological processes. If a technological process requires automated measurements and a low pressure drop, and the flow is not constant but varies at time, it is necessary to find other measuring methods, [7].

In this paper, the author proposes a solution enabling automated measurements and causing low pressure drops.

2. EXPERIMENTAL FLOW METER STRUCTURE

The flow meter structure is shown in Fig. 1.

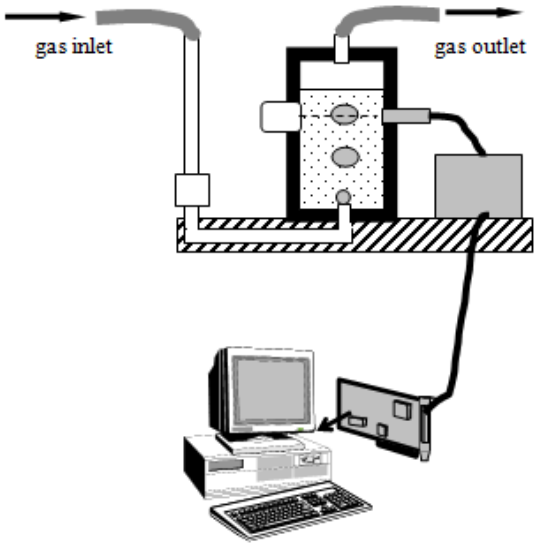

Fig. 1. *Flow meter structure*

The gas is delivered to the nozzle 2 mounted at the bottom of the measuring tank *1* containing a liquid. The check valve *3* protects against the liquid overflow and suction in the case of negative pressure in the measuring system. The gas from the nozzle is present in the liquid as bubbles. If a nozzle diameter is suitably chosen, we can obtain bubbles of regular shapes, flowing out at constant time intervals.

This is a base for measurements of the bubbles volume. Those measurements include scanning the tested section and detection of the gas bubble presence. The tested section is subjected to a coherent light beam, emitted by the source *4*.

When the light beam meets a gas bubble, it divides into some components and, as a consequence, the light beam weakens and the weakening is received by the wave-guide detector *5*. In the measuring converter *6*, light signals from the detector are changed into an electric signal of TTL standard.

In the optical method, a tested section is subjected to a homogeneous light beam and next intensity of the light passing through the liquid with the moving bubbles is detected (Fig.2).

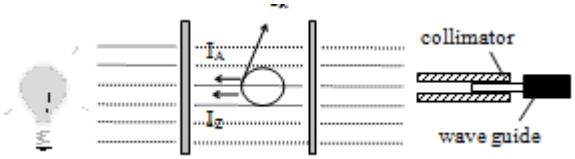

Fig. 2. *Distribution of components of light intensity*

The light emitted from its source passes through the column filled with a liquid and is partly absorbed by the it.

Decrease of intensity of the light beam after the bubble meeting is determined from the following equation:

$$E = \log \frac{I_0}{I} = \log \frac{I + I_R + I_Z + I_A}{I} \qquad (1),$$

where:

I_0 – beam intensity emitted by the source;
I – beam intensity received by the detector;
I_R – intensity of the beam dissipated by a bubble;
I_Z - intensity of the beam reflected from a bubble;
I_A – intensity of the beam absorbed by a bubble.

The presented measuring method allows to determine a bubble shape on the basis of detection of the luminous flux in the visual field of the detector. Decrease of the light intensity of the ray passing through the liquid below the limit value informs us about that fact. The data obtained from measurements are in a binary form. Reconstruction of a bubble shape is possible as a result of application of the algorithm for image reconstruction.

A light source is a fibre light bulb located in the centre of the concave mirror with a set of correcting lens (Fig.3). The bulb should be cylindrical, its length should be more than a detector length. Such a shape enables to obtain uniform light beam intensity along the lightened section. Location of the bulb *1* in the mirror focus *2* provides obtaining parallel light rays in vertical direction. For better directing the beam in horizontal direction, a series of mini lens *3* was applied.

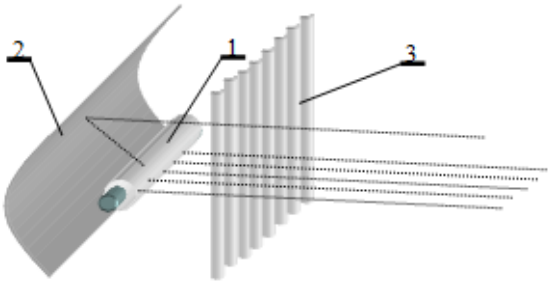

Fig. 3. *Light source*

Volume of the flowing gas bubbles is determined in a numerical way, with use of a suitable algorithm for reconstruction of bubble shape. While the reconstruction, a bubble shape is approximated by a series of cylinders (Fig. 4) [2]. Bubble shapes are determined by volume determination by cylinders d_z in height.

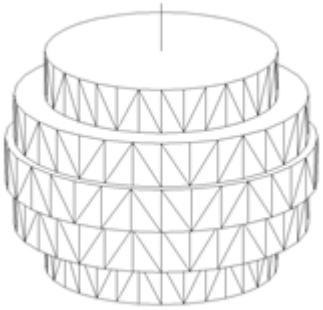

Fig. 4. *Approximation of a bubble shape*

3. THEORETICAL MODELING

Calculations of bubble volume include summation of volumes of cylinders included into one bubble. The equation for volume takes the following form:

$$V_w = \sum_{i=1}^{n-1} V_i = \frac{d_z \pi}{4} \sum_{i=1}^{n-1} d_{(i)}{}^2 \qquad (2),$$

where: V_i - constituent volume of one slice;
$d_{(i)}$ – diameters of the cylinder of the i-th slice;

d_z - slice height;
n - a number of slices forming a bubble.

Determination of the displacement d_z between particular ellipses includes calculation of a way travelled by a bubble between successive measurements. The way is dependent on the bubble motion rate and the sampling time, according to the equation

$$d_z = w_n t_p \quad (3),$$

where:
t_p – sampling time;
w_n – bubble rate.

The bubble movement rate is determined from analysis of courses of the measuring signals coming from suitable optical probes located in the upper and bottom layers of the detector. The rates are determined on the basis of calculations of the mean time of the bubble passage.

$$w_s = \frac{s}{n_Z t_p} \quad (4),$$

where:
n_Z – mean number of the clock strokes.

4. ANALYSIS OF THE GAS BUBBLE FORMING

In the presented flow meter, the measuring accuracy is strongly influenced by a suitable selection of the nozzle diameter, from which the bubbles are getting away. In this case, a measuring range and a measuring error should be taken into account, [3]. It is also assumed that the volume flowing through the pipe causes increase of the bubble volume. Any forces connected with the gas compressibility are neglected in the considered model (Fig.5).

Thus, the equation for the bubble diameter takes the following form:

$$d = \sqrt[3]{\frac{6\ \sigma\ d_0}{g\ (\rho_C - \rho_G)} + \frac{\rho_G}{(\rho_C - \rho_G)} \frac{{d_0}^2}{2g} v} \quad (5),$$

where:
ρ_C – liquid density;
ρ_G – gas density;
d_o – hole diameter;
g – acceleration of gravity;
v – velocity of the gas flow from the nozzle;
σ – coefficient of the liquid surface tension.

This model is valid for dynamic formation of bubbles, however, the flow out velocity must be rather small because it cannot cause bubble deformation.

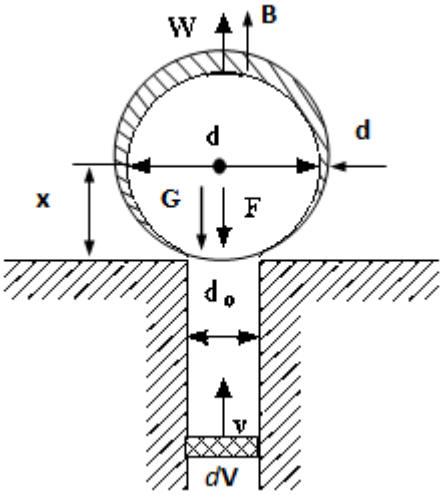

Fig. 5. *Bubble formation in an unrestricted flow*

5. ANALYSIS OF THE GAS BUBBLE MOVEMENT

A shape of the gas bubble moving in a liquid changes all the time because the moving bubble is subjected to the forces causing its deformations (Fig.6). It is a result of continuous changes of pressure distribution inside the bubble. Changes of a bubble shape directly influences velocity of its movement in the liquid.

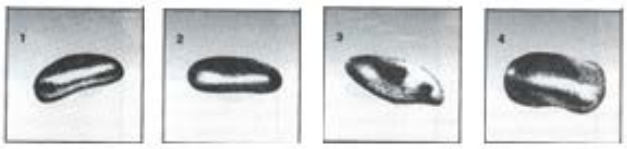

Fig. 6. *Deformations the bubble on moving, [6]*

Movement of a spherical bubble in an immovable liquid after covering a distance becomes approximately uniform. It is caused by equilibrium of forces acting on the bubble (Fig.7). A gas bubble moving in the liquid is subjected to two main forces. One of them is the hydrostatic lift force *W*, it is directed upward and its value is according the Archimedes principle. The other force is directed downward and it is the resisting force, it acts oppositely to the bubble movement direction. This force is dependent only on velocity and it counteracts to the hydrostatic lift force. Deformations of the bubble shape are mainly caused by the resisting forces

of the bubble maven. On the other hand, this force depends only on the bubble movement rate and the resistance coefficient.

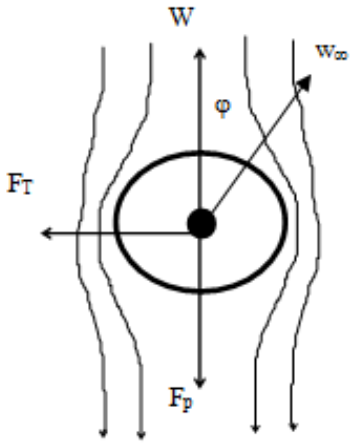

Fig. 7. *Distribution of forces acting on a bubble*

Movement of a spherical gas bubble in an immovable liquid after a certain way becomes approximately uniform. It is caused by equilibrium of forces acting on the bubble. The gas bubble moving in the liquid is subjected to two basic forces. One of them is the uplift pressure force W, directed upward and value agrees with the Archimedes rule. Neglecting the bubble weight, we can express it as:

$$W = \rho_C g \frac{1}{6} \pi d^3 \qquad (6)$$

The other force acting on the bubble is the resisting force, opposite to its motion direction. It depends only on velocity and it counteracts the uplift pressure force. Bubble shape deformations are mainly caused by the resisting forces of the bubble movement. This force depends the bubble velocity and the resistance coefficient. Fig. 8 shows relation the resistance coefficient C_D and the criterion Reynolds number:

$$\mathrm{Re} = \frac{w_\infty d \rho_C}{\mu_C} \qquad (7),$$

where:

w_∞ – velocity of bubble;

μ_C – dynamical coefficient of liquid viscosity.

Velocity of the moving bubbles can be determined from:

$$w_\infty = \sqrt{\frac{2g}{C_D} \frac{(\rho_C - \rho_G)}{\rho_C} \frac{V}{A}} \qquad (8),$$

where:

C_D – resistance coefficient;

A – cross-section area of the bubble;

V – bubble volume.

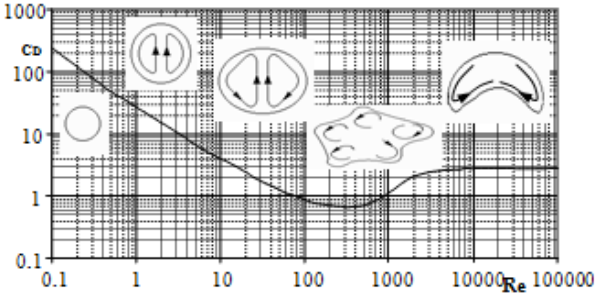

Fig. 8. *Dependence of resistance coefficient on bubble shape*

Basing on analysis of the bubble movement we can select a suitable liquid for the flow meter. The Tadaka criterial number can be assumed as a criterion for selection. Its value should not exceed 5.5 [2, 3]. The Tadaka number can be defined as:

$$Ta = \mathrm{Re}\, M^{0,23} \qquad (9),$$

where:

Re – Reynolds number;

M – Morton number.

$$M = \frac{g \mu_C^4 (\rho_C - \rho_G)}{\rho_C^2 \sigma^3} \qquad (10)$$

6. EXPERIMENTAL RESULTS

During the tests, a constant gas flux was delivered from a diffusion pump. Its value was precisely determined. Next, the flow was measured with the flow meter. Fig. 9 shows a comparison of the test results.

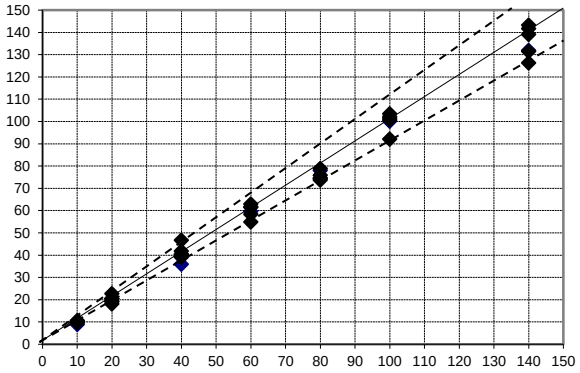

Fig. 9. *Dependences between measured and applied flows*

Six measurements were done for each flow value so it is possible to estimate the measurement uncertainty. The measuring points were approximated

by a straight line. The broken line shows a deviation ± 10%.

Fig. 10 presents the distribution of measurement uncertainty versus the flow. From the presented characteristics it appears that uncertainty is included within the range of 10% measuring values in all the measuring interval, [4].

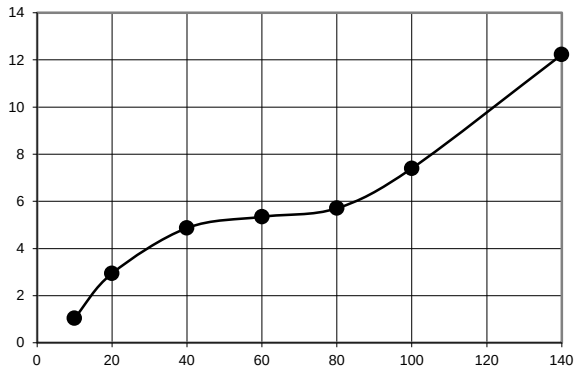

Fig. 10. *Dependencies between uncertainty and flow*

7. CONCLUSIONS

The presented method enables to measure very small flows under a low drop of the gas pressure. The measuring range is about some m^3/h. It is dependent on a flow meter structure.

For a model flow meter the measuring uncertainty from the confidence interval 95% is included into 10% measured value. We can obtain decrease of the measuring uncertainty using a detector of less resolution and a light source of better convergence – for instance a laser with a set of semi transmitting mirrors.

The proposed solution was applied for measurements of gas emitted from moulding sands while drying where it satisfies the assumed requirements.

ACKNOWLEDGEMENT

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MECHANICAL TESTING OF ELECTRONIC PRINTED CIRCUIT BOARDS AND SOLDERING ALLOYS

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Abstract
According to electronic technology theory, the electronic connection must satisfy electrical, thermal and mechanical functionalities. Is known that the resistance and mechanical integrity of the electronic assembly (composed from: printed circuit boards (PCB), devices/ electronic components and electronic component installation on printed circuit boards), is provided by the mechanical function.
The goal of the present paper is to describe some mechanical aspects regarding the behaviour of copper layer deposit on the PCB and of the soldering alloys deposit on the copper – PCB assembly used in electronic technology and also we want to determine the abrasion coefficient of those In order to highlight the mechanical characteristics of tested boards in correlation with different rigid support, there were performed some mechanical tests using a dedicated stand. The tested PCB's is CEM (Composite epoxy material) with deposited copper, and the soldering alloy was a lead free one SAC305.
Friction forces between sliding surfaces arise due to complex mechanisms and lead to mathematical models which are highly nonlinear, discontinuous and nonsmooth.
The novelty of the present paper is given by the materials that are tested and by the fact that this type of mechanical testing was never used in electronic technology, although the subject under discussion has major importance for mechanical integrity of electronic assemblies.

Keywords: *soldering alloys, printed circuit boards, adhesion, CEM(Composite epoxy material).*

1. INTRODUCTION

According to electronic technology theory, the electronic connection must satisfy electrical, thermal and mechanical functionalities. The subject of the present paper is given by the mechanical attachment of electronic assembly.

Is known that the resistance and mechanical integrity of the electronic assembly (composed from: printed circuit boards (PCB), devices/ electronic components and electronic component installation on printed circuit boards), is provided by the mechanical function. [1]

We want to observe some mechanical aspects regarding the behaviour of copper layer deposit on the PCB and of the soldering alloys deposit on the copper – PCB assembly used in electronic technology at low and very low sliding speeds.

The tested printed board (PCB's) is one of the most frequent and common substrates, with a relatively low-cost, CEM (Composite epoxy material) with copper deposited and the soldering alloy is the lead free solder paste, SAC305 (96.5%Sn/3.0%Ag/0.5%Cu).

CEM is a composite epoxy material typically made of woven glass fabric surfaces and non-woven glass core combined with epoxy resin.

Copper is the most used non ferrous metal and the sheet of copper, in general used to cover PCB's has thickness between 5 and 100 μm. The common thickness is 35μm, small thicknesses may not provide sufficient resistance and the biggest are not economic. [2]

The trybological tests were made on an installation used for friction and wear study at low and very low sliding speeds.

This paper aims to determine abrasion coefficient and friction coefficient of deposited copper on the rigid support and of the soldering alloy SAC305.

2. TECHNICAL REQUIREMENTS

The results of the previous work [1] and the description of the experiment are highlighted below.

In the previous work [1], the mechanical tests were made by applying a force of 20N with a sliding speed equal with 0.5 mm/s on the layer of copper deposited on rigid support CEM and on the soldering alloy SAC 305 deposited on the rigid substrates. As an indenter we used a use a steel diamond cone with tip angle of 60 ° and a radius of 12.5 μm.

Was used an UMT Micro-Scratch Equipment. The schematic of the setup used in this study is shown below. It can provide rotational translational or reciprocating motions with speeds ranging from 0.1 μm/s up to 10 m/s.

The load is applied to the sample by the carriage using F_z for a close-loop feed-back mechanism for stability and accuracy and can be kept constant or linearly increasing from as low as 0.05 g to as high as 1000 N.

Friction force (F_x), normal load (F_z), penetration deepness and friction coefficient are measured and recorded at a total sampling rate of 20k Hz.

Wear depth electric capacitance and digital camera are also readily available. The configuration below is an example of one of many possible combinations of friction/load sensor lower drive specimen holder and specimens. [3]

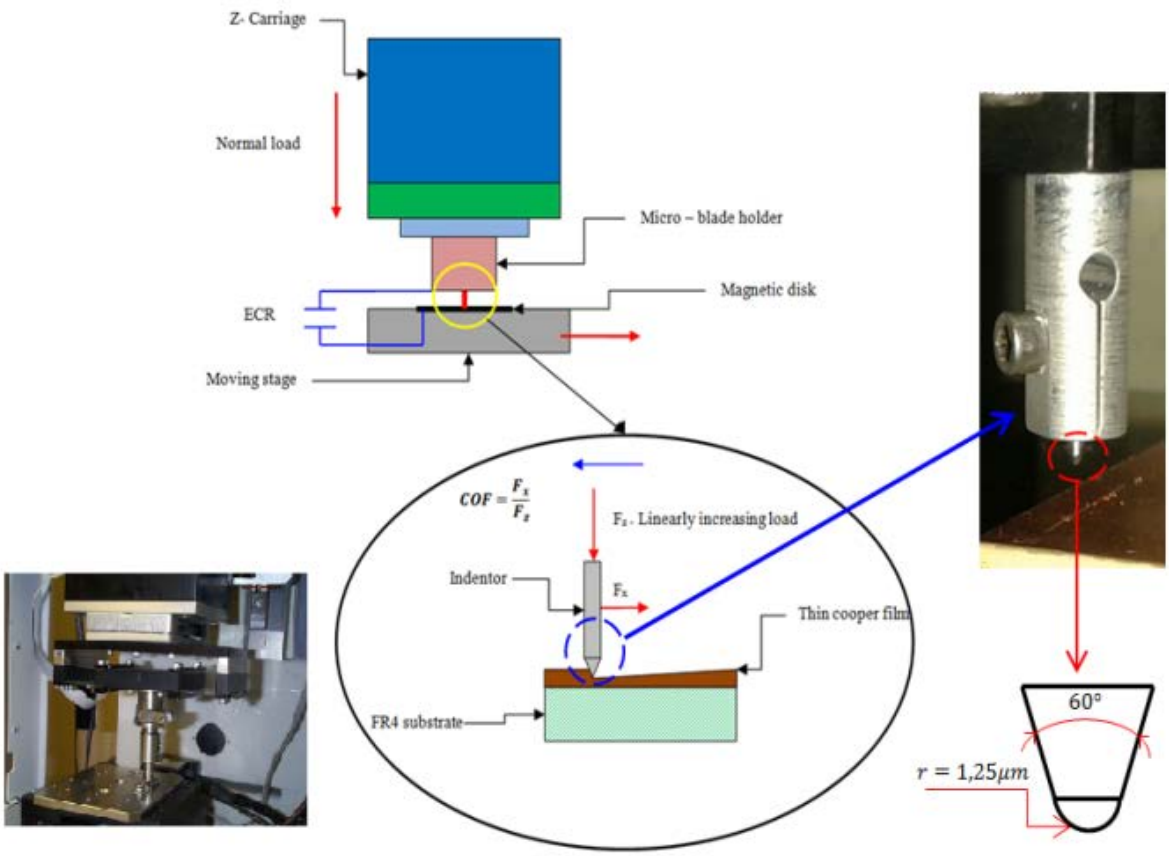

Figure 1. *Functional scheme for Micro-scratch test equipment*

The results are captured with the help of acquisition system they may be viewed, analyzed and interpreted by using the control unit. After the micro-scratch test profilometry of the sample was determinate with the help of SJ301 (Mitutoyo, Japan) profilometer the same one we used for our experiment too (Figure 5).

Optical inspection was made with a video system Leica (Condor 70-3 – share test equipment). [1]
The profilometry result are presented in Figure 2.

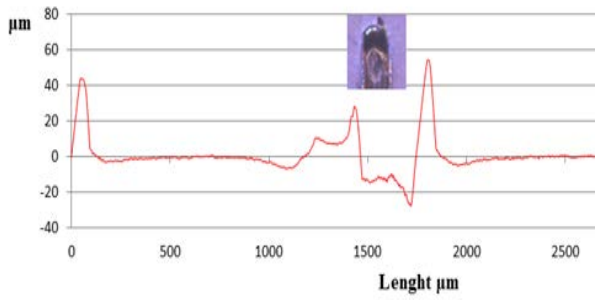

Figure 2. *CEM profilometry*

In Table 1 we find the results of the abrasivity factor for the rigid support CEM with deposited copper for one scratch.

Table 1. *Geometrical form of scratch wear and abrasivity factor*

Material	A_1 [µm^2]	A_2 [µm^2]	A_v [µm^2]	f_{ab}
CEM- Copper				
End	2845.85	3275.619	-4104.0	-0.491
Middle	1020.4	11716.2	-2184.9	-0.003
Start	628.569	866.223	-697.62	-1.142

For the experiment of this paper we utilized an installation used for friction and wear study at low and very low sliding speeds (Figure 3).

The schematic of the setup used in this study is shown below. It can provide motions with speeds ranging from 0 up to 15 mm/min.

The load is constant values from 10 to 150 N.

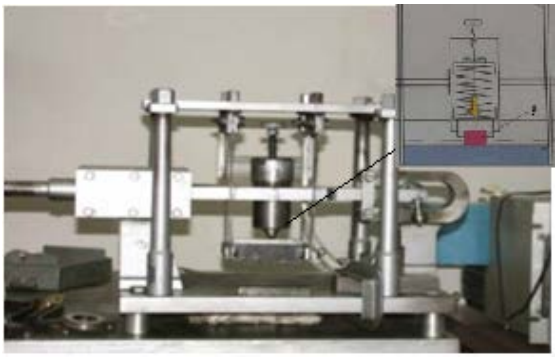

Figure 3. *Installation used for friction and wear study at low and very low sliding speeds*

The friction and wear test depends on measuring the amount of deformation caused when the indenter 1 is pressed in to the surface with a fixed force and the sliding movement .

The disadvantage is that that although hardness of material depends on the plastic properties, the stress-strain relation cannot be obtained. [4]

The experiment consists in a progressive scratch with a length of 35 mm, the indenter will move with a speed of 0.032 mm/s. As an indenter we used a steel cone with a spherical top. The geometry of this intender is characterized by the radius r=0.1 mm and the angle f=120˚(Figure 4).

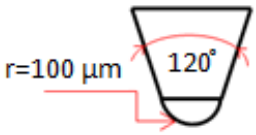

Figure 4. *The geometry of the cone*

Test samples were cleaned with isopropyl alcohol for removing the oxides deposited on the surface of the copper layer.

The profilometry result are presented in Figure 6 and Figure 7.

Figure 5.*Profilometer SJ301*

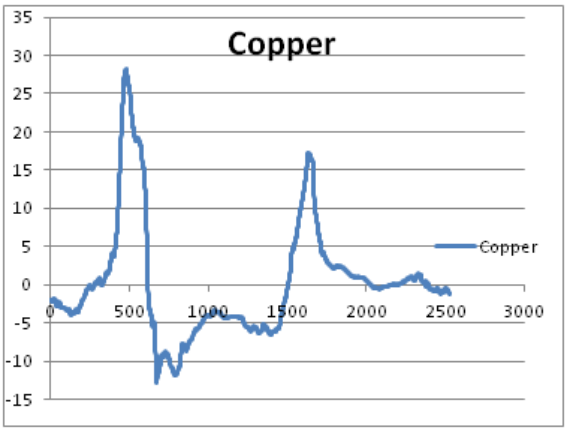

Figure 6. *Copper profilometry deposited on the rigid support CEM*

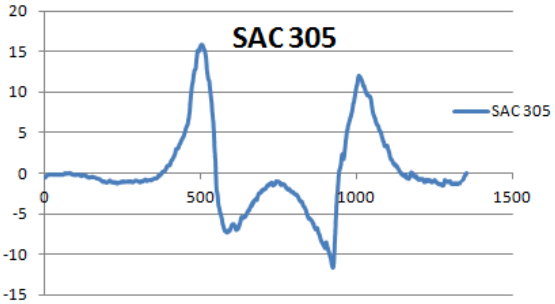

Figure 7. *SAC 305 profilometry*

As result of micro-scratching test, the surface of the samples has deformed near the contact area between indenter con and rigid surface of the sample. Observing the deformation and by using the profilograms presented above the abrasion factor was determinate as being the ratio of the

volume of material displaced in the process and the volume the scratch path. This method was developed by Zum Gahr for scratch profiles in ductile metals [5]. Is define the abrasion factor as:

$$f_{ab} = 1 - \frac{A_1 + A_2}{|A_v|}. \quad (1)$$

where A_1 and A_2 are the structurated surfaces areas situated above the initial axis of the undistorted surface and A_v is the area of the deformated surface structurated under the initial axis Figure 8.

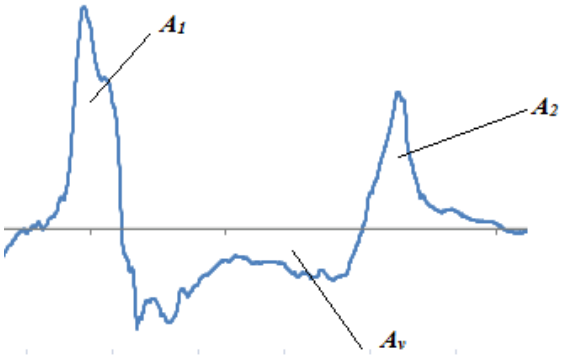

Figure 8. *Abrasion model*

The values obtanied with (1) and the results of the profilometer are presented in the tabel below.

Table 2. *Values of the abrasion factor on the samples.*

Material	A_1 [µm^2]	A_2 [µm^2]	A_v [µm^2]	f_{ab}
CEM- Copper	1990.24	1277.426	-2682.6	-0.2186
SAC 305	1225.56	1120.98	-1830.0	-0.282

The form of the scratch indicates a ductile behavior because the cone has connected with a sphere on top, the initial deformations were elastic, then plastic. After the move of the top of the cone on the contact surface, the contact surface elastic deformations are cancelled, resulting a jump on the bottom of the scratch. On this phenomenon, we will work a theoretical model in a next paper.

The friction coefficient variation at low speeds is exemplify in Figure 9 for the rigid support CEM with soldering alloy deposited SAC 305.

In Figure 9 we can notice a fast stabilization of the friction coefficient, highlighting that at drive speed 0.032 mm/s and normal force 20 N, the phenomenon of stick-slip does not exist.

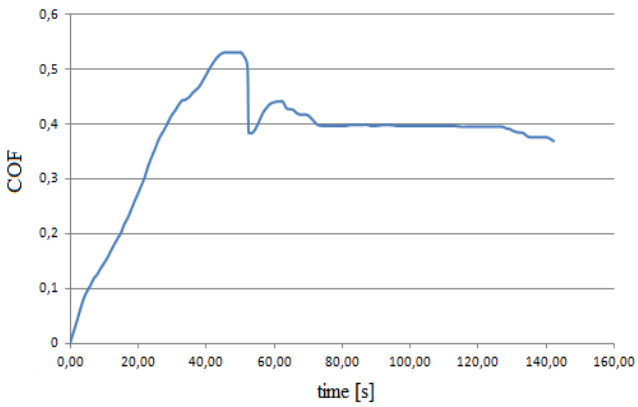

Figure 9. *The value of the friction coefficient in time*

3. CONCLUSION

We can see from the profile interpretation that near the indenter, the material deforms. When cone went left behind borders of material, which leads to the idea that the material is ductile.

If we observe the values from Table 2, we can see that the abrasion factor has subunit values, $f_{ab}<1$. Ductile materials have that characteristic. If we have a material with a hardness above then the abrasion factor also increase.

The value of the abrasion factor (negative) indicates the plastic deformation of the layer with density reduction. This phenomenon of plastic deformation can be explained on the basis of the theory of flow lines Hencky-von Mises.

As we can see from the profilgrams, both sides of the scratch are asymmetrical.

The phenomenon of deformation of the copper layer in the presence of slip includes slipping movement relative .

Material deformed and given to one side denotes a behaviour ductile.

Material removed increasing the volume in the process of dumping.

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INCREASING THE PERFORMANCES OF SMALL AND MEDIUM-SIZED ENTERPRISES THROUGH EXPORT STRATEGIES

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ABSTRACT
The internationalization of business tends to become a condition of existence for every company, regardless the size or field in which it operates. Given that the national market is at its saturation level and cannot provide optimal conditions for national companies operating out only on the lands where they were founded, more and more of them are looking over their own borders in search of external space to ensure their environment for doing business.

KEYWORDS: Export, export planning, payment and finance.

1. INTRODUCTION

Carrying out of activity beyond the existence of a national market located on the level of saturation is one of the motivations underlying the decision of internationalization. It might say that the only motivation for which the companies decide to internationalize is the desire of obtaining large amount of profit. This is not contested, but among the motivations of the company in deciding internationalization are added other motivations. A company decides to internationalize either by displaying its will to enter into the process of internationalization, or because the company finds itself in order to survive on the market to begin the process of internationalization. In the first case we refer to the proactive motivations and in the second case, the motivations are part of the reactive.

Once fixed the motivations of internationalization, every company will opt for internationalization strategy which best reflects the company and its characteristics while providing a maximum level of benefits and minimal risks. This stage becomes one of the utmost importance to the company considering that the strategy of internationalization is the basis on which it will compose the entire international activity of the company.

2. PLANNING FOREIGN TRADE OPERATIONS

If a product is successful in the domestic market, there is likely to be successful also in foreign markets. However, a detailed analysis of its external potential is required. The company can start by researching which is the demand for similar products in the target markets, and the need to adapt or improve the product. In order to succeed, it is needed a strong and long-term commitment of management to recover the cost of entry into the foreign market, due to the changes, publicity, and the given by building a network of agents / distributors. Companies that already operate in the internal market should consider developing export markets by allocating financial and personnel resources or by resorting the local experts.

To achieve proper planning of exports, it is necessary to go through a number of steps: Checking the preparation stage of export - export audit, selecting the export market, export marketing plan and its implementation.

3. EXPORT AUDIT

Export audit involves the realization of two main operations through which it is highlighted the situation of the company that is to export and the market in which it is set to expand.

Therefore to achieve an effective export company auditing is necessary both to identify strengths and

weaknesses and the audit that identifies market opportunities and threats. In other words, the first activity is to provide the most accurate and real SWOT analysis of the present situation.

4. THE SELECTION OF MARKETS

To select foreign markets to which the company intends to expand, preliminary activities should be: product classification, identifying the markets most sustained growth rate for the product, identifying the most accessible markets, also consulting other exporters on those markets preferably as they are not direct competitors because they can distort reality in order to create certain advantages.

The analysis of proximity, social political climate, economic climate, cultural, technological standards and climatic conditions in that country, it is imperative to correct channeling of production and of selected markets for the exporting company. It is very important that all these issues to be compatible with the product that the company exports to be successful because inconsistency can lead to a major failure which can unbalance the company even in internal market where it operates.

5. MAIN WAYS OF EXPORT

In economic reality, companies involve in the development of international operations, initially through this first forms of export. For small and medium companies export achievement across national borders may be the only embodiment of the process of internationalization, given the limited resources and low risk aversion. Entrepreneurs have two ways to export they can apply and who can choose according to the company's profile and financial resources at their disposal. These types of exports are direct exports and indirect exports.

Direct export aims full involvement of the company in the marketing of products abroad, while indirect export involves making business through agents which means that the company is not directly involved in the international process.

6. DIRECT EXPORT

It occurs when a company exports on the international market based on their own efforts, without recourse to an intermediary. This type of export may be preferred when export volumes are high, the market share is high or when the goods exported are classified in a special category and are not suitable for export by the intermediaries on the market.

DIRECT EXPORTS	
ADVANTAGES	DISADVANTAGES
- It offers to the producers the opportunity to participate in acquiring the commercial profit - Producers are kept in direct contact with the market; - It gives opportunities to promote products, brand name; - The producer may adopt a long-term policy and participate in determining the export; - The exporter may benefit from export incentives; - It provides a better control of the export transaction and marketing mix.	- Marketing costs are high; - The specific risks of foreign trade activity directly impacts the company; - It is necessary to establish certain services or compartments shaped by international activities; - It requires skilled personnel in the international market; - Lack of good export strategy leads to a low degree of market penetration; - There is a risk that managers focus mainly on export, to the detriment of production

7. INDIRECT EXPORT

It involves the use of intermediaries to transpose the product in the country to be exported. It is used for companies that have few resources to penetrate the international market, being one of the easiest and cheapest ways to penetrate a foreign market. Companies use this method to obtain a benefit in terms of opportunities that may arise without substantial costs or to sell excess production resulting from existing production capacities higher than required.

Advantages	Disadvantages
- No investment needed; - Do not involve the use of resources; - Costs are reduced - No market or political risky; - Can be obtained large market share; - The company does not need its own export organization.	- Knowledge of foreign market is zero; - Do not allow control over the marketing mix, especially on intermediaries; - The results are based on the interests of intermediaries; - Sometimes marketing activity bring low incomes.

(Source: Danciu, Victor, "International Marketing. From traditional to global", Economic Publishing, Bucharest, 2001).

8. PAYMENT AND FUNDING IN EXPORT OPERATIONS

Exports of goods, products and services are of particular importance in a country's economy because they provide intake of convertible currency, with the largest contribution to balance the payments. Therefore, taking into account Constantin Anghelache author's conception, organization and holding of own capital in exporting enterprises, it is essential for carrying out activities of effective foreign trade. Since obtaining this capital is difficult and may take, in some cases, it is required closer collaboration between a funding body (commercial banks) and exporter, [1].

Because each export has different characteristics, different costs, different export ways, each exporter has the opportunity to choose from a range of financing techniques, the most suitable for its ability to repay or for the time period for which loan is contracted.

International Payments can be made in advance, the exporter receiving the money before delivering the goods, on delivery of goods in installments, the first represents an advance for goods to be delivered or for the bill.

As shown by the Romanian Centre for Foreign Trade, there are numerous ways to pay for exports, the most important being: documentary credit (letter of credit), payment order, documentary collection, payment by bank transfer, [2].

Documentary letter of credit is a written commitment, taken by a bank to make payments on behalf of the importer to exporter, in return for the presentation of documents certifying that the goods are still under exporter property and documents are in line with what is noted in the letter of credit.

The parties involved in this operation are: importer (calls his bank to open a letter of credit), the issuing bank (the importer's bank), notifying bank (exporter's bank), the exporter or beneficiary, [3].

The payment order is a payment method by which directly communicate the exporter and the importer by sending financial documents (bills of exchange and checks) and commercial documents (invoice, bill of lading). It is represented by disposition given by the importer to his bank, to pay a sum of money corresponding to deliveries of goods to settle the obligation that it has towards exporter.

Collections of documentary are initiated by the exporter, which transmits documents to the bank, along with instructions on receipt of the money corresponding to the value of goods shipped. Exporter's bank follows these instructions and then sends the documents to the importer's bank that notify him of the presence of documents. The importer is required to pay the equivalent value of the goods to get into possession of the documents. This sum of money is sent to exporter's bank, who shall notify him that he can receive the money, [4].

Export financing is a problem faced by most companies that orient their business to foreign markets. Their financial resources come from two sources, namely: own resources and funds raised (bank financing and various borrowings).

Pre-financing loans of export, are intended for the operating period, between product delivery and getting their corresponding amount of money from the importer. To continue carrying out the production activity, importers require a credit for pre-order to succeed to cover the payments for raw materials, materials, production process related expenses (salaries, fuel, energy). Since this type of loan is granted for a short period of time, it can be contracted in lei currency and in foreign currency for a period not exceeding 12 months.

Post funding loans are represented by export credits, that author Ioan Popa, classifies them into several types of loans: advances on goods documents (credits are awarded to exporters on the basis of certain documents to demonstrate the existence of goods which are ready for export), advances in foreign currency (exporters are given both as a method of financing and as a cover in case of currency risk, based on claims that they present), bank advances through the assignment of receivables (advances provided to exporters to supplement funds for production activities and delivering the goods for export, by assigning claims that they have to importers), [5].

The last of the techniques of short-term financing is factoring, which is a mechanism to obtain financing on the sale of bills that have a maturity of around 180 days. In this case, a factor (commercial bank) is in possession of invoices which the adherent (exporter) provide on the basis of a contract between the two parties. The factor undertakes to pay the initial 80% of those bills, and the remaining 20% to be paid when the importer pays the goods, [6].

Factoring is used to finance current activities to cover credit risk or to recover the assigned debts.
Therefore, export operations, requires a complex research activity of the best options for export, to identify possible partners and to outline the main objectives that the exporters establish. It should also be identified variables that can influence the workflow to find effective solutions to possible obstacles.

CONCLUSIONS

The internationalization process is increasingly more present in the current economic environment, business become international business under the influence of economic factors.

The internationalization process is as a condition of existence for companies. More broadly, the company decides to internationalize thanks to several factors, although there is a tendency to say that the only motivation for company to internationalize is obtaining a higher level of profit.

As there is no single motivation of internationalization, so there is no single strategy of internationalization, because each company has its identifying characteristics and its objectives.

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RESEARCH ON THE ROMANIAN BUSINESS CONCERNS ON WASTE ELECTRICAL AND ELECTRONIC EQUIPMENT AGAINST ENVIRONMENTAL AND ECO-INNOVATION ISSUES

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ABSTRACT
Research on the Romanian business environment concerns on Waste Electrical and Electronic Equipment against environmental and eco-innovation issues were made by developing a questionnaire for enterprises. The questionnaire is adressed to the companies questions on problematic theme of electrical and electronic equipment waste and eco – innovation; it has been carried out an investigation for distributing the questionnaire. Once collected, the information were processed and after their received replies, it was the finalisation, the analysis and the drafting of conclusions regarding the Romanian business position and requirements towards the WEEE issues (waste electrical and electronic equipment) and eco - innovation. The main idea is to increase the organizational competitiveness of Romanian companies that are operating in this area, also to increase the degree of involvement of these entities in promoting eco-innovation for green economy development.

KEYWORDS: Electrical and Electronic Equipment Waste, eco – innovation, enterprise, questionnaire

CUVINTE CHEIE: deșeuri de echipamente electrice și electronice, eco-inovare, întreprindere, chestionar

1. INTRODUCTION

The contemporary society has the necessity to analyse the business requirements about the need for the achievement and the effective use of a virtual hub for eco-innovation to increase the competitiveness in recycling waste electrical and electronic equipment (Contract no. 320/2014, PN-II-PT-PCCA-2013 4-1400), [1], [2].

To obtain relevant information was drawn up a list of companies representing the business environment in Romania, which included all types (micro, small, medium and large), which are active in electrical and electronic equipment or having activities related to this area. In order to obtain this information it was necessary to search existing information from websites of the companies, for a more precise determination of their classification in the range of products and services or related activities directly related to the WEEE, [3], [4].

The questionnaire adress to the companies included questions on problematic theme of electrical and electronic equipment waste and eco – innovation; it has been carried out an investigation for distributing the questionnaire. Once collected, the information were processed and after their received replies, it was the finalisation, the analysis and the drafting of conclusions regarding the Romanian business position and requirements towards the WEEE issues (waste electrical and electronic equipment) and to eco – innovation, [5].

2. DRAWING UP THE LIST OF COMPANIES REPRESENTING THE ROMANIAN BUSINESS ENVIRONMENT WORKING IN THE WEEE AREA

The list of companies intended to interview all type of respondents belong to micro, small, medium and large companies, having activities directly related to WEEE production, distribution and recycling or

working in areas related to this field. Documentation for choosing companies was done by consulting the databases of the National Institute for Small and Medium Enterprises (INIMM) and the Chamber of Commerce and Industry of Bucharest (CCIB), [6], [7].
Consultation of information from the companies websites was made for a more precise determination of the classification of products and services in WEEE surveyed companies. List conducted for disseminating questionnaires in order to conduct the survey includes a total of 658 companies:
☐ Companies operating in the field of computers and computer technology
☐Companies operating in the field of audio equipment
☐ Companies working in the field of auto service equipment
☐ Companies with activities in ecology domain
☐ Companies with activities in Electrical and luminaires domain
☐Companies with activities in appliances
☐Companies with activities in electrical installations
☐ Companies with activities in electrical engineering and automations
☐ Companies operating in the field of refrigeration systems
☐ Companies working in the area of toys
☐ Companies working in waste recycling
☐ Companies operating in the field of tools and construction equipment, [5].

3. THE ACHIEVING, THE DISTRIBUTION AND THE INVESTIGATION BASED ON COMPANIES QUESTIONNAIRE

The achievement of the questionnaire intended to show the behavior analysis and the business requirements against the Romanian Electrical and Electronic Equipment Waste (WEEE) and the eco-innovation. The questionnaire included:
- general questions about the company:
- details about the company, specifying the activity domain and the number of employees, its positioning in the category of producers / distributors / recyclers of EEE products;
- the firm certifications, its degree of experience in the field of WEEE and eco – innovation, the concerns related to these directions, if there are problems in business activity related to environmental performance and also if it has experience in developing solutions in eco - innovation;
- questions showing the degree of interest in WEEE management and the usefulness of a virtual hub for eco-innovation for increasing the WEEE management competitiveness and the eco - innovation:
- interest in a company's domain specific problems (legislation, recycling, environmental impact, waste management policies, training, user behavior, informal sector, etc.);
- expected results from accessing a virtual hub for eco-innovation to increase the competitiveness in recycling waste electrical and electronic equipment and possible useful tools;
- financial availability to using the hub.

The questionnaire consisted of 20 questions and it was sent by the email address of each company in the list, being accessible for any education level of the respondent; the responses have been centralized by the working team of SC ICTCM SA. The survey conducted by distributing the questionnaire was made in October 2014 to the specialists from 658 Romanian firms, which were selected from the above presented groups.

4. INFORMATION PROCESSING OF REPLIES FROM THE RECEIVED QUESTIONNAIRES

After sending questionnaires to 658 firms there were returned messages from 283 addresses (it meens that companies are no longer working in the field, they were disbanded or they changed their activity profile, still existing in the 2010 database). 375 valid addresses only 37 firms have responded, it means 9.86% response rate to the questionnaire - a rate similar to the average rate of response to surveys in Romania (approx. 10%), [8].

5. COMPLETION, ANALYSIS AND DRAFTING CONCLUSIONS REGARDING THE ROMANIAN BUSINESS POSITION

After analyzing the obtained information from firms responses there can be observed the following aspects:
• The analysis of *Business Information* shows the respondents proportion, the firms classification by product categories and the companies role in the WEEE management, as follows (Table 1):

Table 1. *The analysis of Business Information*

The company activity in the field	*The role in the WEEE management*	*% of all respondents*
Companies working in the field of computers and computing equipment	EEE products manufacturer	16,22

Companies working in audio equipment field	EEE products retailer	2.70
Companies working in the auto service equipment field	EEE products distributor	5.41
Companies working in the ecological field	EEE products manufacturer, EEE products distributor	8.11
Companies with activities in Electrical and luminaires domain	EEE products manufacturer, EEE products distributor	5.41
Companies with activities in appliances	EEE products manufacturer, EEE products distributor	13.51
Companies with activities in electrical installations	EEE products manufacturer, EEE products distributor, EEE products recyclers	10.81
Companies with activities in electrical engineering and automations	EEE products manufacturer, EEE products distributor	13.51
Companies operating in the field of refrigeration systems	EEE products distributor, EEE products recyclers	5.41
Companies working in the area of toys	EEE products distributor	2.70
Companies working in waste recycling	EEE products recyclers	8.11
Companies operating in the field of tools and construction equipment	EEE products distributor, EEE products recyclers	8.11

There is a higher percentage of responses from companies operating in the field of computers and computer technology, home appliances, electrical engineering and automations, showing greater interest in the investigated issue. That fact is due to the competition in these areas of interest or better trainning of the specialists in the field, because in most cases the questionnaires were completed by the executive staff with responsibility for WEEE firm solving issues.

Analyzing the entity respondents by the firm number of employees – we have received answers to sent questionnaires from micro enterprises (8.11%), from small enterprises (40.54%), from some medium companies (40.54%) and from large enterprises (10.81%). This shows the same seriousness and interest of small and medium sized firms to be present in a competitive market, focusing on received information that can contribute to the companies growth. The micro-enterprises, considering also the manager competences, joins quite well WEEE issues, while large firms, being secure on their clients and their turnover, don't have always a prompt answer to surveys.

6. CONCLUSIONS

Considering the WEEE management, there is a wide range of companies with activities in areas involving the existence of waste electrical and electronic equipment. It is important to specify that a firm can be found simultaneously in several situations:

- Manufacturer and distributor of electrical and electronic equipment;
- Manufacturer, distributor and recycler of electrical and electronic equipment;
- Distributor and recycler of electrical and electronic equipment.

Thus, from all companies that responded to the survey, 67.57% are producers of electrical and electronic equipment, 75.68% are distributors of electrical and electronic equipment and a percentage of 32.43% are electrical and electronic equipment recyclers. It shows the fact that present society is mainly focused on consumption, proof being the high proportion of companies distributing electrical and electronic equipment. Analyzing the situation of the Companies from the field of waste electrical and electronic equipment having certifications and a strategy on environmental issues, there are some conclusions:

- 66.67% of responding micro enterprises, 73,33% of responding small and medium companies 100% and 100% of large firms were active in the WEEE field - a percentage very encouraging for all types of analyzed companies.
- 66.67% of micro - enterprises and 86.67% of small businesses have ISO 9001 and ISO 14001 certifications, as 100% of medium and large companies; in addition, a percentage of 13.33% of small firms has OHSAS 18001 certification. This fact reflects a good management and a responsible policy over the certification for all companies, regardless the size.

- 33.33% of responding micro-enterprises, 100% of small, medium and large enterprises have a strategy on environmental issues, their implementation is differentiated as follows:
  - Micro -enterprizes emphasized on employees training concerning the company strategy, their financial resources being quite limited.
  - In small companies, 57.80% of them put into practice the implementation of an environmental management system (EMAS, ISO 14001, ISO 9001 integrated with OHSAS 18001 and other standards and specific codes and categories of company services), 13.33% of them made the implementation of an integrated system regarding the environment (ISO 14001), the quality (9001), health and work security (OHSAS 18001) and 28.87% of them had other environmental management.
  - For medium size companies there was conducted the employees familiarization with environmental issues and their awareness, the employees training on company strategy, environmental responsability drawing for the employees and the implementation of a management system (EMAS, ISO 14001, integrated with ISO 9001, OHSAS 18001 and other standards and specific codes and categories of company services). (It is obvious that the size company increasing there will be established specific duties and responsibilities for the environment responsible position).
  - For large size companies it is done the employees training on company strategy, linked to popularization campaigns: intranet, posters, magazines, internal publications, trainings, internal newsletters, company portal, website, sustainability report Posters, leaflets, flyers, emails, briefing. Also in this case they are drawn environmental responsibility to the employees and it is done the management system implementation (EMAS, ISO 14001, integrated with ISO 9001, OHSAS 18001 and other standards and codes specific to the activity and company service categories).
- For the case of 80% of micro-enterprises and 76% of small businesses there are problems caused by financial resources lack, which blocks the company to improve its environmental performance. There are also limited situations (6.67% of medium-sized companies), where there are issues against the environmental improving related to legislative problems.

Analysing the eco-innovation situation of the surveyed companies, 66.67% of micro - enterprises have no concerns in this area, only a small proportion is dedicated to this segment, the size of entities and the financial possibilities are very low. Among small firms - 40% of them have concerns in eco - innovation, the percent is rising to 53,33% for medium enterprises and 75% for large enterprises.

It is justified, the higer the company, the higer financial resources were be involved to succeed on the market, on competitive environment, with green and innovative products, as a guarantee of success. Therefore medium and large companies have developed eco - innovative solutions in their activities, while micro - enterprises and small firms had less conditions and opportunities to develop.

ACKNOWLEDGMENT

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GENERATING MACHINING SEQUENCES DURING DESIGN PHASE BASED ON CONSTRUCTIVE-TECHNOLOGICAL FEATURES - PART I

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REZUMAT

Dezvoltarea integrată a produselor în contextul ingineriei simultane impune luarea în considerare încă din faza de proiectare a aspectelor de fabricaţie. În acest scop informaţiile furnizate de un sistem CAD trebuie să conţină, pe lângă informaţiile geometrice, informaţii tehnologice, de precizie, de material etc. Într-un mediu integrat CAD/CAPP/ CAM aceste informaţii trebuie să poată fi transmise, accesate şi preluate automat din toate etapele. Din acest punct de vedere modelarea bazată pe entităţi (Design by Features) facilitează integrarea proiectării cu activităţile din aval iar entitatea este mediul de transmitere a informaţiei între CAD, CAPP şi CAM. În prezenta lucrare este prezentată definirea şi utilizarea entităţilor constructiv-tehnologice simple şi complexe cu rol esenţial în proiectarea tehnologică şi fabricaţie. Aceste entităţi sunt conţinute în biblioteca sistemului software dezvoltat şi sunt clasificate în trei categorii: exterioare, interioare şi speciale.

ABSTRACT

Integrated development of products in the context of concurrent engineering requires taking into consideration during the design stage of manufacturing issues. For this purpose the part model provided by a CAD system must contain, in addition to the geometrical data, information used in process planning and manufacturing such as precision, materials, machine-tools, etc. In an integrated CAD/CAPP/CAM environment all this information must be transmitted, accessed and automatically retrieved from all stages. From this point of view Design by Features facilitates the integration of design with the downstream activities and the feature is the medium of information transmission between CAD, CAPP and CAM. In this paper, definition and use of simple and complex constructive-technological features in process planning are presented. These features are contained in the system software library and they are classified in three categories: external, internal and specific features.

KEYWORDS: feature-based design, constructive-technological features, CAD/CAPP/CAM, process planning, concurrent engineering, manufacturing features

CUVINTE CHEIE: proiectare bazată pe entităţi, entităţi constructiv-tehnologice, CAD/CAPP/CAM, proiectare tehnologică, inginerie concurentă, entități de fabricație

1. INTRODUCTION

Concurrent engineering states that critical process planning and manufacturing issues should be considered early in design stage in order to reduce the number of design iterations [1].

The essential idea of this concept is to put the majority of effort in the product design stage to analyze the factors which might affect subsequent production processes, and hence save overall product development time [1-3]. For such approach, the CAD systems should provide a model of product that besides the geometric information must contain additional information for process planning and manufacturing.

Although CAD/CAM systems were significantly developed a designer would complete the entire design of product before passing to downstream stages as process planning and manufacturing [4]. They do not allow establishing the technological sequences for features or for a portion of the part before its 3D model to be completed.

Feature-based design has received much attention be-cause the features are considered the connection elements between CAD, CAPP and CAM systems [1, 5-7]. In this category, constructive-technological features are key elements which allow a integrated approach of the design, process planning and manufacturing activities. As for feature concept, researchers have own way in using this term, especially depending on the context, without reaching any consensus. Although it is widely accepted necessity of using the features, either referred to feature-based design, feature recognition or feature extraction there is not yet a clear classification [5, 7].

In this paper, the methodology of generation and use of simple and complex constructive-technological features with essential role in process planning and manufacturing is presented. The main purpose of the paper is to demonstrate the importance of these types of features by establishing the machining sequences during the design phase, before the part to be fully completed from constructive point of view. These types of features underlying an integrated software system which allows concurrent approach of the design, process planning and manufacturing tasks for the parts of gear wheels family. Also, the system can be used for modelling the parts in whose geometries are identified the features contained in its library. The software system is developed in DCL and Visual LISP programming environments.

2. LITERATURE REVIEW

2.1. FEATURES TYPES

In design and manufacture engineering there are different ways of using the feature concept. Although there were a number of attempts for classification of entities (CAM-I in 1986), no standard has been adopted in this regard by the community of researchers.

Pratt and Wilson developed a scheme for the CAM-I [1,5] which was adopted by the Form Feature Informational Model - FFIM of Product Data Exchange Specification (PDES). In PDES features are classified as follows: passages, depressions, protrusions, transitions, areas and deformations (operations for modifying the shape). Cunningham and Dixon (1988) classified features, depending on their role in the design, in static and dynamic features [5]. In 1991, Pratt classified features in: manufacturing features, design features, analysis features, tolerance and control features, assembly features and features of general form [1].

In IPDM (Intelligent Product Design and Manufacturing) system [13] features are classified in two categories: macro functional features and micro form features. Shah and Mantyla (1995) classified the features as follows [5, 8]: *form features* - describe regions of nominal geometry; *tolerance features* - deviations from the nominal shape/size/position; *assembly features* - describe assembly connections, surfaces interaction; *functional features* - sets of characteristics related to a specific function; *material features* - describe the material structure, heat treatment etc.

The feature taxonomy [7] of FAPPS (Feature-based Automatic Process Planning System) consists of depressions and protrusions in atomic features. Xu & Hinduja [7,9] classify machining features into four classes: hole/pocket, through-hole, open pocket/slot/step and free feature. Gao and Haung [7,10] simply define primitive features as sur-face, boss, pocket, hole, through slot, non-through slot, notch and step. Kang & all [7] proposed a logical classification scheme for multi-axis machining features based on the manufacturing processes for the features.

STEP (Standard for the Exchange of Product Model Data) classifies manufacturing features in machining feature, transition feature, compound feature and replicate feature [11]. Machining feature identifies a volume of material that shall be removed to obtain the final part geometry from the initial stock. Transition feature is a transition area between two surfaces (chamfer, fillet and edge round).

It can be noted that have been developed various classification systems of the features and still there are different opinions regarding their classification and definition. In the literature, the features considered to be the most used are defined as follows:

- Form feature: they did not contain any semantic meaning apart from the ability to identify themselves through the corresponding shape [12];
- Manufacturing feature: they are shapes which represent volumes of materials that shall be removed from a part by machining or shall result from machining [11]. One of the most used manufacturing features is machining feature;
- Precision features (including tolerances and surface roughness): describe additional geometric characteristics of an existing geometric model or form features [2, 8].

It can be seen that depending on the application and the functions of the developed product there are different semantics that can be connected to the geometry. Therefore, the features must be customized depending on the application and the functions of the developed product.

2.2 FEATURE-BASED DESIGN APPROACHES

In the literature, feature-based design is essentially grouped into three approaches [1,5]: *Automatic Features Recognition, Design by Features and Human Assisted Feature Recognition.*

In the *Human Assisted Feature Recognition* approach, the designer interacts with the CAD model to define a feature by picking up entities from the part drawing [5, 13-15]. In the Automatic Features Recognition systems, the features are recognized from a part designed in a CAD system [2, 5, 7]. In Design by features, the designer creates the model of the part using both Boolean operations and inserting the feature in the desired position. In this approach the model of the part is directly built with features already defined in a library. The libraries can be predefined or user defined. This method provides to computer aided design more relevant and also facilitates the integration of CAD and CAM [1, 5, 16].

Design by features uses two methods: synthesis by features and destructive modelling with features. In synthesis by features each feature is defined by a number of individual parameters. Synthesis method generates a model by adding the protrusion features and subtracting the depression features. As for destructive modelling with features method, one single operation is available, namely, the subtraction. The features are subtracting in order they will be machined in reality and the machining features are derived simultaneously [1, 17]. The advantage of design by feature method, besides the fact it eliminates the need of recognizing the features of the part, is that, subsequently, are available all feature data for its machining. Although the geometry of the parts is described at high level and the libraries with features can help to fast building the parts [1, 19, 20] it must be established which features should be included in a library, because is not possible to create a library to include all features.

Various design systems based on features have begun to be developed since 80s. Shah and Rogers (1988) developed an expert system for modelling the form features that supports the user in defining of this type of features. Chang (1989) proposed a feature-based design and process planning system using a solid modeller [1, 17]. De Martino18 introduced a method of recognition and update of the features after each feature-based design operation. Lee and Kim [17] used an incremental approach to extract the machining features from a feature-based design. Schulz and Schuster [4, 17, 19] developed and implemented the FINDES (Feature INtegrated DEsign System) system to design the prismatic parts using the design by feature methodology. The system has two modules one for constructive design and the other for process planning. Tseng (1999) presented a modular modelling approach by strengthening the technical support provided to the designer. Bidarra and Bronsvoort (2000) proposed a semantic feature modelling system to defining and maintaining the semantics of the feature during all the modelling operations [1, 17].

It is obvious that design by features facilitates integration with CAPP and CAM. To optimize process planning, its approach is needed since the CAD phase, before the part to be finished from constructive point of view. This approach is facilitated by the design using features which must contain all the necessary data both in process planning and manufacturing.

3. GENERATING SIMPLE AND COMPLEX CONSTRUCTIVE-TECHNOLOGICAL FEATURES

To integrate design activity with downstream stages the features must include technological information in addition to geometrical information. Therefore, constructive-technological feature is an essential element which allows integrated approach of design activity (CAD), process planning (CAPP) and manufacturing (CAM).

In the developed system, form feature contains only information for describing the nominal shape (dimensions) and its position in relation to a certain reference point (Fig. 1). It is called constructive/geometric feature.

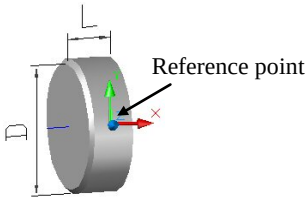


***Figure 1**: Constructive/geometric feature*

The feature which, besides describing the nominal shape, contains information relating to dimensional and geometrical deviations, surface roughness as well a set of attributes: material characteristics, heat treatment, machine-tools, cutting tools, machining processes, is a constructive-technological feature (Fig. 2). Therefore, a constructive-technological feature must contain: a constructive feature, a precision feature (i.e. precision parameters: dimensional and geometrical deviations, roughness) and a set of machining processes, machine-tools, cutting tools specific to feature type.

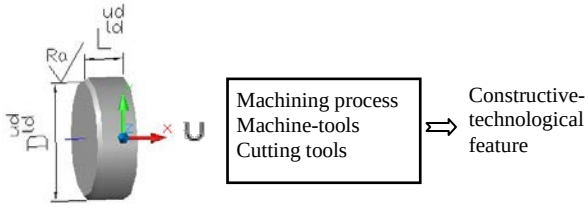


***Figure 2**: Simple constructive-technological feature*

Simple constructive-technological feature (CTFs) is the feature obtained by combining a constructive feature, a precision feature and a set of machining processes, machine-tools and cutting tools, for which can be generated a machining/technological sequence independent of the other features sequences.

Complex constructive-technological feature (CTFc) is an entity that contains several simple features of the same type or different types, which can be grouped so that to enable establishing precedence relationships between the simple features and has role in grouping machining methods in sequences/operations. Like CTFs it has an essential role in process planning (CAPP) and manufacturing (CAM).

3.1 DEFINING OF SIMPLE CONSTRUCTIVE-TECHNOLOGICAL FEATURES

The features contained in the software system are grouped in three categories: external (Fig. 3), internal (Fig. 4) and specific (Fig. 5) features.

Type		Feature sketch with precision and dimensional parameters	3D Model
Cylindrical			
Taper			
Gear teeth	Straight spur		
	Straight bevel		
Groove			
Spline			

***Figure 3**: External constructive-technological features*

Each category, in its turn, consists of several features types. For modelling the parts is applied synthesis by features method and by combining different types of features can be obtained complex parts such as shafts, spline shafts, gear shafts, spur gears, double spur gears, bevel gears, and, also, other types of parts. This paper will refer to spur gear with straight teeth.

The geometrical (diameters, lengths, angles, etc.) and non-geometrical information (tolerance and roughness) which defines a feature are introduced by means of customized dialogue boxes. Therefore, in the developed system, a part is made of several types of features. It can be described by the following:

$$\text{Part} = \{f_1, f_2, \ldots f_i, \ldots\} \quad (1)$$

In this expression, f_i is a feature of the part.

The expression means that a part is made of a set of features and each entity has some parameters.

Type		Feature sketch with precision and dimensional parameters	3D Model
Cylindrical			
Taper			
Spline	Straight profile		
	Involute profile		
Keyway			
Groove			

***Figure 4**: Internal constructive-technological features*

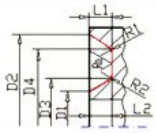
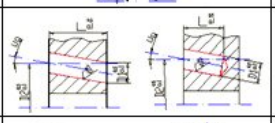
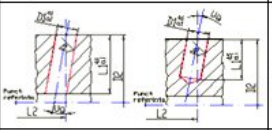
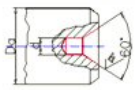
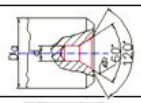
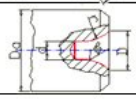
Type		Feature sketch with precision and dimensional parameters	3D Model
Face grooving	General		
	Circular		
Hole	Axial		
	Radial		
Center hole	Type A		
	Type B		
	Type R		

***Figure 5**: Specific constructive-technological features*

For process planning and manufacturing purposes, the feature parameters of a part are geometrical dimension, tolerances and roughness. Subsequently, the feature is given by:

$$f_i = f_i(p_1, p_2, \ldots p_i, \ldots) \quad (2)$$

where p_j is a parameter of the entity f_i.

Depending on the user input data into dialog boxes (Fig. 12), as well as the coordinates of reference point P0 (Fig. 6), firstly, is made 2D representation of the feature and subsequently, based on 2D drawing, the 3D representation (Fig. 7). Figure 6 shows the calculation of point coordinates that define the external cylindrical feature placed on the left side of reference point, P0.

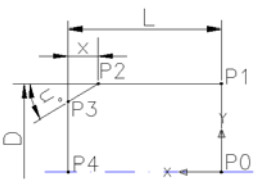


***Figure 6**: Defining external cylindrical feature*

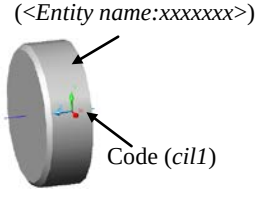


***Figure 7**: 3D model and feature coding.*

Between precision parameters (dimensional deviations, and roughness) of the feature surfaces must be a close correlation. The system checks the correctness of combination of values and warns the user when the combination is technologically impossible.

The software system, after graphical representation of each feature, automatically allocates an identification alphanumeric *code*. The code (*codei*) consists of letters - *code* - which is a combination of the first characters from the name of the feature and - *i* - a number that can receive two values: 1 or 2. Number 1 or 2 has double meaning, namely: a) the feature is generated on the left (1) or right (2) side of reference point - *pref* (Fig. 8); b) the feature is positioned on the left or right side of gear teeth feature (Fig. 8).

For example, the external cylindrical feature that is positioned on the left side of the reference point, receive the identification code *cil1* as shown in figure 8 (a). In Table 1, a few of the codes associated to features in relation to the reference point are presented.

Because the developed CAD system runs under AutoCAD design environment, each CTFs will have associated, automatically by AutoCAD, an *entity name* (Fig. 7) and an Auto LISP associated list that contains the characteristic data of the feature. For each constructive-technological feature, after graphical representation, are saved in the system database both the identification code and all geometrical and non-geometrical data.

Table 1 Feature codes

Feature type	Reference point	
	Left	Right
	Identification code	
External cylindrical	cil1	cil2
External taper	con1	con2
Spur gear teeth	dan1	dan2
Bevel gear teeth	danc1	danc2
External groove	dege1	dege2
External spline	canext1	canext2
Internal cylindrical	cili1	cili2
Internal taper	coni1	coni2

For storing of all the feature data is used the mechanism of *extended data* attached to Auto LISP associated lists using DXF *codes*. Therefore, the constructive- technological features can be identify from any program of CAD, CAPP and CAM systems by means of the identification code (*codei*) and entity name assigned by AutoCAD. Also, all necessary data can be accessed and used from any program and any time.

The mechanism of the extended data gives some major advantages such as the extended data are integrated in the AutoCAD database. They are saved and loaded at the same time with the part model.

3.2 GENERATING OF COMPLEX CONSTRUCTIVE-TECHNOLOGICAL FEATURES

For each CTFs, during CAD phase, can be established the processing technological sequence (machining methods, cutting parameters, machining time, processing cost estimation) independently of technological sequences of the other features.

If the part configuration contains several features of the same type or different types (e.g. external/internal cylindrical, external/internal taper, external/internal groove, center hole) whose manufacturing processes are dependent, they must be grouped so that a maximum number of features, or surfaces of them, to be processed in the same clamping of the part. They become complex constructive- technological features (CTFc).

Grouping CTFs in CTFc is imposed, on the one hand, by generation the variants of technological process with maximum productivity, and the other hand due to restriction regarding position and machining order of the features. Therefore, it is necessary identifying the simple constructive-technological features (CTFs) which have to be grouped such that to be generated a machining/technological sequence for the obtained CTFc.

For this purpose, the part geometry is divided into significant portions (Fig. 8) namely: left external, right external and interior. Grouping the part surfaces into significant portions was based on the consideration that all the parts of the spur gears family have a central portion.

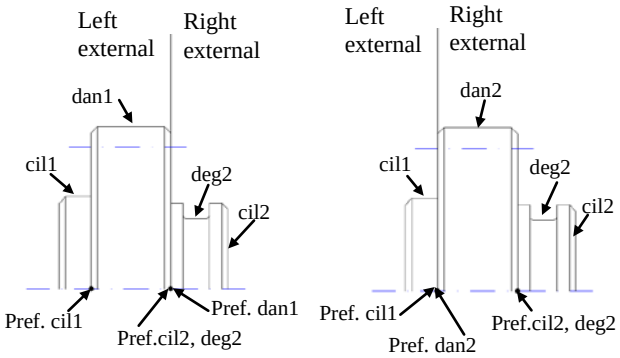


***Figure 8**: Significant portions*

The central part of the spur gears is the gear teeth feature. In relation to this portion is specified the placement position of the other features (left or right).

Regarding CTFs of spur gear teeth type whenever will be identified in the database, the CAD system, automatically, will attach a fictive external cylindrical feature which carrying the gear teeth feature. This fictive feature will "take over" in its description certain characteristics of the gear teeth feature such as chamfering, roughness and dimensional deviations.

For gear teeth feature to establish of which significant portion belongs is applied the following rule:

If (gear teeth code = *dan1)*
then associate the fictive cylindrical feature to “left external“ significant portion
else associate the fictive cylindrical feature to “right external“ significant portion

For example, if on the left external side (Fig. 8) of the part are identified two external cylindrical features (CTFs external cylindrical - *cil1* and fictive external cylindrical feature attached to the gear teeth feature - *dan1*), then they are grouped and treated as a complex feature (CTFc). They can be machined in one clamping of the part (in the same operation). This feature is considered, in the activity of ordering of the processing operations, as one. The same rule is also applied to features on the right external side: CTFs of groove type - *deg2* and CTFs cylindrical - *cil2.*

4. CONCLUSION

In this paper the design methodology by simple constructive-technological features as well as the need of their grouping in complex constructive-technological features, is presented. Grouping CTFs into CTFc is imposed both the need of generating variants of technological process with maximum productivity and due to restrictions regarding the reciprocal position and order of machining the features. CTFs are grouped in CTFc such that a maximum number of features/surfaces to be machined in a single clamping of the part with minimum number of setups.

In the second part of current paper the methodology of selecting the manufacturing methods, as well as their coding are presented. Also, by case study carried out the generation of machining sequences during CAD phase is demonstrated.

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GENERATING MACHINING SEQUENCES DURING DESIGN PHASE BASED ON CONSTRUCTIVE-TECHNOLOGICAL FEATURES - PART II

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REZUMAT

Utilizarea entităţilor constructiv-tehnologice face posibilă, încă din faza de proiectare (CAD), generarea secvenţei de prelucrare cu toţi parametrii asociaţi, cum ar fi metodele şi parametrii de prelucrare, timpul şi costurile de prelucrare, fişiere CNC etc. Această abordare permite detectarea încă din faza de proiectare a diferitelor tipuri de probleme oferind proiectanţlor posibilitatea de a le corecta încă din această etapă. Pentru a demonstra rolul lor esenţial în proiectarea tehnologică şi fabricaţie, în această parte a lucrării se prezintă metodologia de selectare a metodelor de fabricaţie dintre cele asociate entităţilor, codificarea acestora, precum şi generarea secvenţelor de prelucrare încă din faza CAD, înainte ca piesa sa fie complet definită din punct de vedere constructiv.

ABSTRACT

Using constructive-technological features makes possible, since the early design stage (CAD), generation of the machining sequence with all associated parameters such as machining methods, cutting parameters, machining time and cost, CNC file etc. This approach allows detection of various types of problems at the design stage and designer has the opportunity to correct them. To demonstrate their essential role in process planning and manufacturing, in this part of the paper is presented the methodology of selecting the manufacturing methods of ones that are associated to features, their coding as well as generation of the machining sequences during CAD phase, before the part to be completely defined from geometrical point of view.

KEYWORDS: constructive-technological features, CAD, CAPP, CAM, process planning, manufacturing features

CUVINTE CHEIE: entităţi constructiv-tehnologice, CAD, CAPP, CAM, proiectare tehnologică, entităţi de fabricaţie

1. INTRODUCTION

To optimize process planning, its approach is needed since the CAD phase, before the part to be finished from constructive point of view. This approach is facilitated by using features in the design (CAD) phase. These features must contain all the necessary data both in process planning and manufacturing [2, 3, 5].

To integrate design activity with downstream stages the features must include technological information in addition to geometrical information. From this point of view, constructive-technological feature has an essential role, because it allows integrated approach of design activity (CAD), process planning (CAPP) and manufacturing (CAM) [1, 4].

The main purpose of the paper is to demonstrate the importance of these types of features by establishing the machining sequences during the design phase, before the part to be fully completed from constructive point of view. Constructive-technological features were presented in the first part of the paper and they are contained in an integrated software system which allows concurrent approach of the design, process planning and manufacturing tasks for the parts of gear wheels family.

2. SELECTING PROCESSING METHODS ATTACHED TO FEATURES

Each simple constructive-technological feature has attached several processing methods which can be used in its machining. It is known that each method provides a certain economical class of precision and roughness. Consequently, of these methods will be selected those which provide the precision level imposed on the entity surfaces (precision class and roughness).

The workflow of selection the machining methods is shown in figure 1 where *d* is the machining dimension, *ud* - upper deviation, *ld* - lower deviation, *tpc*, *rac* - precision level and roughness provided by the method, *tpf*, *rug* - precision level and roughness imposed to the surface. In the selection process are used several important programmes developed in AutoLISP language with the following meaning: *attach_proc* - is a subprogram that attaches and encodes the processing methods related to CTFs;

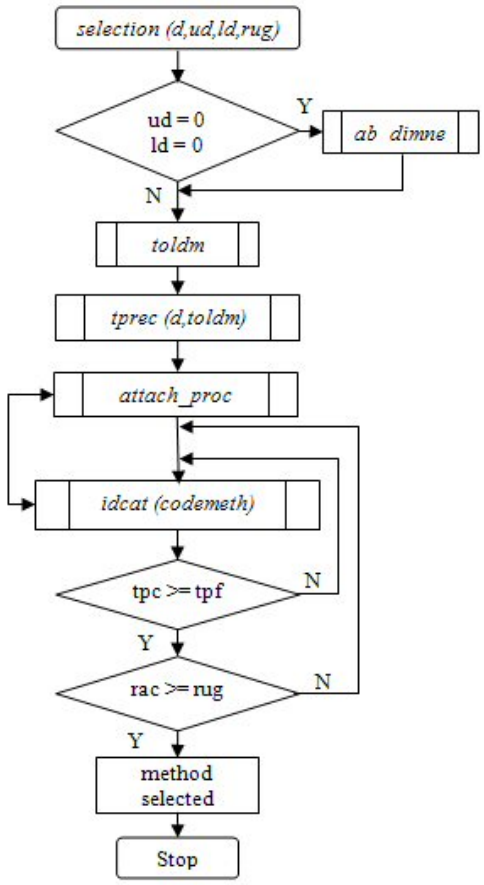

***Figure 1**: Workflow of selection machining methods*

toldm - is a subprogram that calculates the tolerance of the dimension; *ab_dimnet* - a subprogram that is dedicated to determine the deviations for dimensions without tolerance (according to the ISO standard); *idcat* - is a specialized program which identifies the class of precision and roughness provided by a processing method; *tprec* - is a program that determines the basic precision class of the dimension.

After selecting the processing method, the total precision coefficient that must be obtained after machining of each surface of a feature, is calculated. In this purpose, the following relation is used [4]:

$$K_{tot} = T_{sf} / T_p, \quad (1)$$

where T_{sf} is stock tolerance and T_p is dimensional tolerance for a given surface.

The value of the total precision coefficient is achieved by combining of different processing methods on the different machine-tools, as follows:

$$K_{int} = k_1 \cdot k_2 \cdot k_3 \cdot \ldots \cdot k_n, \quad (2)$$

where K_{int} is the intermediate precision coefficient, n is the number of processing methods needed for achieving the required precision of the surface and k_n is the precision coefficient of the method.

The precision coefficient of the selected method is calculated according to equation:

$$K_n = T_{pp} / T_{pc} \quad (3)$$

where T_{pp} is the tolerance assured by the previous machining method and T_{pc} is tolerance assured by the current method.

Number of machining methods required in obtaining a surface is established according to the following rule:

If $k_{int} \geq k_{tot}$
then, the surface can be processing through the n methods
else, it is added other processing methods.

Once processing methods were selected, in the next stage they are grouped and sequenced obtaining variants of machining sequence (Fig. 9). Subsequently, for each machining method is calculated cutting depth, number of passes, cutting parameters, machining time and cost (Fig. 10).

3. CODING OF SELECTED MANUFACTURING METHODS

The processing methods which were selected for machining a CTFs or CTFc receive a code with significance given in Table 1.

Coding, on the one hand, facilitates their display in the dialog boxes designed to establish the technological sequences (Fig. 7, b) and, on the other hand, allows to be done the correlation between the

displayed method code and the code assigned to the surface and displayed on the feature sketch (Fig. 7, c).

Table 1. *Coding of processing methods*

Method code: "method" "codes" "i" "codep"			
Meaning			
method	codes	i	codep
- method name: turning, grinding, chamfering, grooving etc.	- machining surface type: C- cylindrical F - facing T - chamfer	i= 1…n is the number of feature of the same type from a significant portion	- machining type: d- roughing sf - semi-finishing rd- rough grinding rf- finish grinding etc.
Example: Turning F2d means: roughing facing turning for the second feature from a certain significant portion			

4. CASE STUDY

Figure 2 shows the part which will be designed using the simple constructive-technological features presented in the first part of the paper.

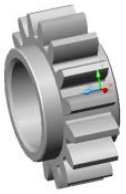

Figure 2*: Part designed*

In figure 3, the dialog box to enter the geometric and non-geometric data of teeth feature, is shown. After 3D modelling the ECTs of gear type (Fig. 4), being a feature of those process planning does not depend on the others, for this can be selected the machining procedures and grouped in machining variants.

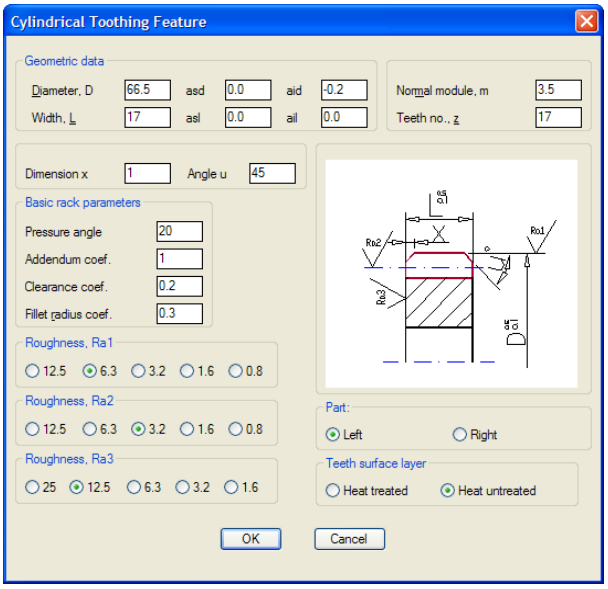

Figure 3*: Dialog box for parameters of straight cylindrical gear teeth feature*

Figure 4*: 3D spur gear teeth feature*

If the user does not want to generate technological sequence in this stage, it can be done at any time during or after constructive design. Because the generation of the machining sequence for this feature is very complex it will be the subject of a future work.

In the next step, in an intermediate phase of constructive design, is generated an external cylindrical feature on the left side of the gear teeth feature as shown in figure 6 (a). In figure 5, the dialog box to enter the data required to generate cylindrical feature, is presented.

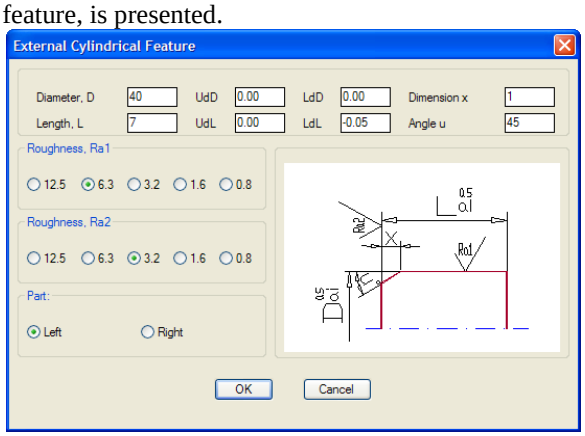

Figure 5*: Dialog box for simple external cylindrical feature*

The CAD software system is designed so that whenever it is changed the type of entity (external, internal or special) and its position related to the central entity (gear teeth feature), it will ask the user if he finished the portion of the part, which he has previously worked. If the answer is affirmative, then go into action the CAPP module for establishing the processing sequence. If the answer is negative, then the user may continue constructive design of the part.
Therefore, after attaching an external cylindrical feature on the right side of the gear teeth feature, shown in figure 6 (b), the system, automatically, asks the user if the left side is finished. If the answer is *yes*, then can be established the processing sequence for the left significant portion.

(a) (b)

***Figure 6**: Representation of external cylindrical features*

For this purpose, is automatically displayed a dialog box (Fig. 10), initially with all fields blank, by means of are performed the following:

1. By selecting the key *Display* are identified and coding all features from the left significant portion and then displayed in the *Left Features* list (Fig. 7, a).

It can be noted that, although was generated only a cylindrical feature, the system identified two external cylindrical features because for the feature of gear teeth type is automatically attached a fictive cylindrical feature (*Ent_cil1*).

2. Selecting each feature from the list *Left Features*, the machining methods will be selected from the database and then displayed in the *Machining Methods* list (Fig. 8; Fig. 7, b).

For selected feature, in the field *Preview* (Fig. 7, c) the 2D sketch with the current geometric and non-geometric parameters as well as the surface codes is displayed.

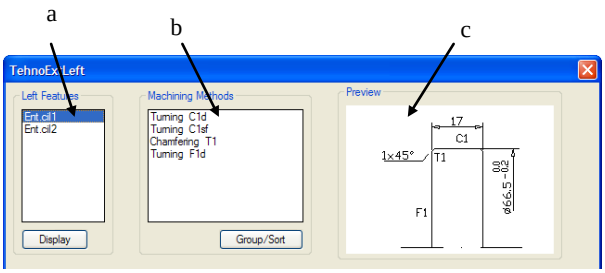

***Figure 7**: Displaying features, processing methods and sketch related to fictive external cylindrical feature attached to gear teeth feature*

These codes are used in coding the machining methods displayed in the *Machining Methods* list, too. After selecting the feature coded by *Ent_cil2*, in the fields mention above are displayed the machining methods and sketch for CTFs of external cylindrical type (Fig. 8).

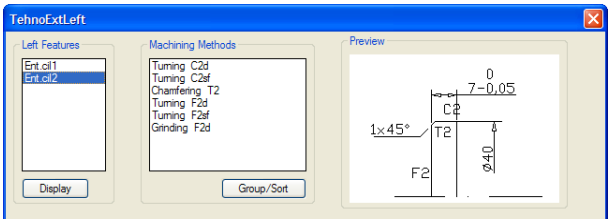

***Figure 8**: Displaying machining methods and sketch for external cylindrical feature*

3. Grouping and ordering the machining methods. By successive selecting of the button *Group/Sort* (Fig. 9) the machining methods are grouped and reordered. In this way are generated variants of machining sequences for the left significant portion of the part.

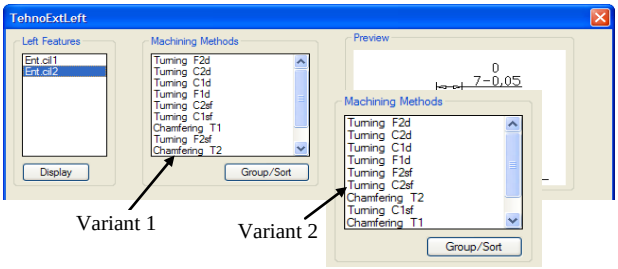

***Figure 9**: Variants of machining sequences*

To establish the variants of machining sequences applies a complex algorithm where are taking into account more criteria, such as the criteria of access to a surface, machining continuity criteria, criteria of reducing the number of clamping etc. Also, more constraints are imposed.

For example, the finishing/semi-finishing turning is made after roughing turning, the chamfering after machining of the base entity, gear teeth feature is always processed after the fictive external cylindrical feature etc.

4. Establishing the machining/technological sequence (Fig. 10). For each machining method selected from the list *Machining Methods*, the machining allowances, the number of passes, cutting parameters (*Cutting Data* section), machining time and estimated cost, are calculated (*Economic estimation* section). All these calculations are performed after selecting, from the system database, the machine-tool, cutting tool (*Choose MT, TDV* button) and entering the data required for machining cost calculation (*Cost calculation data* button).

5. Manufacturing analysis from the point of view of machining time and estimated cost. If the results displayed (mainly the time and cost) cannot be accepted, then can be change certain parameters (e.g. machine-tool or cutting tool). Otherwise, all data selected or calculated are saved for each method of the machining sequence. For this purpose are, also, used the extended data assigned to Visual LISP associated lists. Also, in this intermediate design stage, for machining/technological sequence displayed in the list *Machining methods* can be generated CNC file by selecting the button *Write NC file* (Fig. 10). This file can be used in various tests and evaluation such as verifying the tool paths, the strategies used etc.

Obtaining the final process plan and CNC files takes place after were established the machining sequences for all CTFs, CTFc and/or significant portion of the part and all related machining methods are regrouped and reordered in final operations.

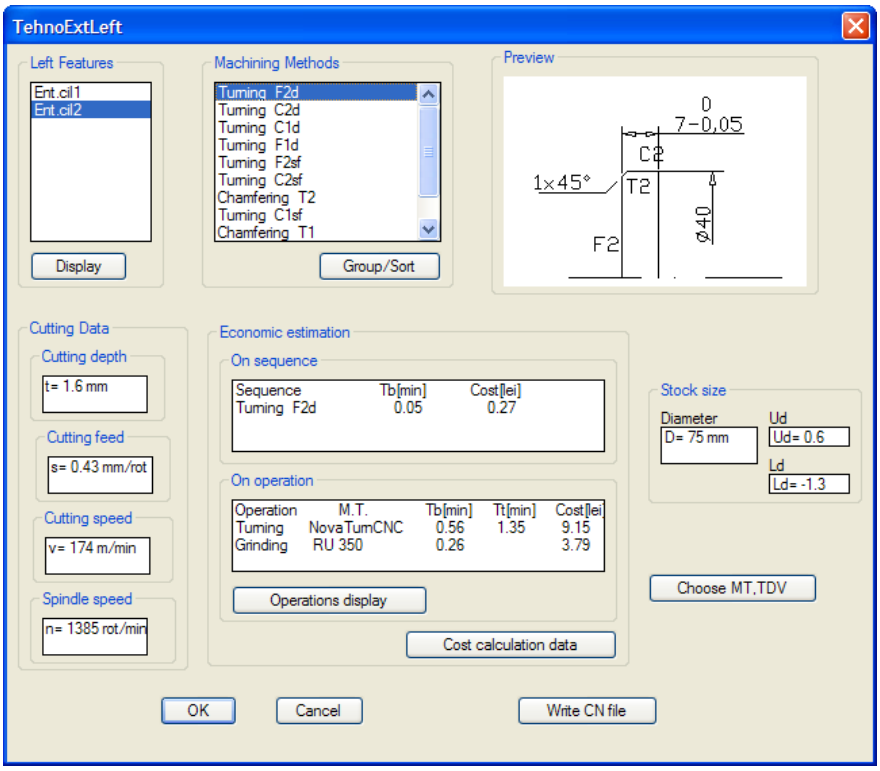

***Figure 10**: Establishing machining sequence for Left External side*

5. CONCLUSION

Designing by constructive-technological features makes possible, since the early design stage, establishing the processing sequences with all associated parameters inclusive manufacturing analysis from machining time and estimated cost point of view. Also, designers, using constructive-technological features in designing a product, can notice an unnecessary requirement for the precision of a feature due to its high manufacturing cost, so that certain unnecessarily downstream manufacturing expenses can be reduced.

In future papers will be presented details regarding the manufacturability analysis of simple and complex features, in the early stages of design as well as the use of them in CAM phase.

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