1. CONSIDERATIONS ON THE WASTE SHREDDING

1.1. Theoretical approach

According to Waste Management Act "Waste" means any substance, object or part of the object of which the owner (holder) discards or intends to dispose. Depending on their origin waste is classified into several categories (Directive 75/442EEC):

- Household waste;
- Industrial waste;
- Hazardous waste;
- Construction waste;
- Ferrous and non-ferrous metals;
- Widespread waste.

According to Waste Management Act under the concept “Waste management” we understand all activities on gathering, transportation, utilization, deactivation, including the fulfillment control over operations and activities performed after the closure of the platforms on which are situated the equipments for treating wastes. Priorities of the European strategy for waste management the Fifth Program of EU, accepted by the member states in 1993, called “Towards stability”. The program puts comparatively more distant targets and defines more general approaches such as: maintaining a high “quality life”; ensuring longteim access to natural resources; avoiding damages on the environment; perception as stable the development which satisfies the presents needs, without restricting the possibilities for future generations to meet their necessities.

Municipal wastes are the biggest problem facing humanity. Researchers seek the most effective methods of waste-processing and turning them into raw materials, the compost and heat or electricity (green energy).

After their composition, the waste containing it in appreciable quantities materials (metals, paper, glass, cloth), that can be recovery directly as a raw material. Collection, storage and recouping separate such materials for the national economy, can be considered as a secondary source of raw materials.

From the point of view of storage (neutralization) of waste, this process can be considered as a prior measure, because the result consists in a reduction of waste quantity that must be evacuated in the ecological storage.

For the processing and recovery of waste directly used as raw materials, have created business suited for this purpose. Main business of the establishments is the recovery of some types of waste like scrap iron, waste paper, leather, textiles, etc.

In the residential districts of different cities, was created points for the collection of waste from the population. In industrial areas it was created deposits and workstations for the collection and storage of waste.

An estimate of the quantity and proportion of the waste types produced in Romania at the level of 2011 year is presented in table 1 [11].

Morphological composition: 4 Groups: Scraps (10-20%, Organic part (65-70%), Combustible part (8-10%), Ballast 6-8%). Morphological structure of individual countries generate widely. Depends on the geographical climatic conditions. Morphological composition of MSW to Bulgaria is on Table 1.2. [13].

A considerable part of the waste acquired, provide from the collection of the public. Only a portion of collected waste sub-assemblies can be recovered directly.

Some wastes contain several types of materials and their quality is variable, there are dirty, etc. Form the most basic of the processing is sorting after kinds of materials and by quality. After sorting the types of materials are cleaning of foreign parts and filth.

The quantity and proportion of the waste types produced in Romania Table 1.2.

Waste types	[t]	[%]
Scrap iron	370909	70,4
Non ferrous waste	24273	4,6
paper and plastic	72935	13,8
Textile	29603	5,6
Buildings waste	15174	2,9
Glass waste	14412	2,7

Morphological composition of MSW to Bulgaria Table 1.3

Morphological composition, %	Location (10x3 citizen)						
	До 50	50-100	100-150	150-250	Над 250	Sofia	
metals	3,8	4,4	4,6	4,8	5,2	5,5	1
glass	5,2	4,3	3,6	3,4	3,3	3,5	2
plastics	5,7	6.3	6,8	7,4	7.6	7.8	3
paper	13.4	14.3	14,6	14,8	15,1	15,4	4
Foods-waste	38	38	37	36	35	35	5
Construction waste	1.7	4.0	4.0	3,9	3,2	1,8	6
wood and cellulose	0,8	1,3	1,3	1,8	2,2	1,6	7
leather, rubber	1.8	2,3	2,3	3,3	2,2	2,1	8
Textiles	2,8	2,8	2,6	2,1	1,8	1,8	9
bones	1.6	1,5	1,4	1,1	0,8	0,6	10
Unidentificaly waste	28	20	21	23	23	24	11

Operations of crushing, tusks, and those of squeezing, baling, tamping is automated. First of all I can consider that the waste brought to the environmental landfill suffered a process of sorting on a conveyer.

After sorting the wastes are shredding and grinding to a technological necessary size. At basis of grinding process stay theories of Rittinger's, Kick- Kirpicev and Rebinder [3] which can be written that:

$$\mathcal{E} = k\Delta V + \sigma\Delta A \qquad (1.1)$$

In the first period is take in account the energy necessary for material elastic deformation and in the second period we discussed on energy necessary for the creation of new surfaces in material. If it is considered the case of big pieces shredding in small pieces, the area newly created is small and energy required for grinding can be regarded of the expression [3]:

$$\mathcal{E} \approx kV \qquad (1.2)$$

The pieces of material deformation while crushing operation can be:

$$\Delta V = k_1 V \qquad (1.3)$$

where: V is the volume from pieces of material shredding. Relation (1.2) is transformed and result:

$$\mathcal{E} \approx k\, k_1 V = k_2 V \qquad (1.4)$$

The constant k_2 is: $k_2 = kk_1 = k_0\, \gamma$ (1.5)

γ is specifically weight of grinding material. After replacement in (4), it is obtained even the relation Kick – Kirpicev[3]:

$$\mathcal{E} \approx k_0\, \gamma\, V = k_0\, G = C_R D^3 \qquad (1.6)$$

where: G is the weight of piece of material and D- is diameter of material pieces that is consider to be spherical.

If is doing a crushing with large grinding degrees the relation (1) can be wright as [3]:

$$\mathcal{E} \approx \sigma\Delta A \qquad (1.7)$$

In relationship (1.7) was unconsidered the deforming energy of the shredding material.

Relationship of grinding degrees is: $i = D/d$ (1.8)

If we considered the pieces of material with cubic form before and after grinding, the surface A before grinding is $A = 6D^2$. After grinding result N pieces of material with the surface $a = 6d^2 \times N = 6 (D/ i)^2 \cdot D^3/ (D/i)^3$.

Result is:

$$\Delta A = a – A = 6 (D/i)^2 D^3 / (D/i)^3 – 6D^2 = 6D^2 (i-1) \quad (1.9)$$

Replacing relationship 7, we obtained:

$$\mathcal{E} \approx \sigma \Delta A = \sigma 6D^2 (i-1) = C_R D^2 \quad (1.10)$$

By comparing relationships (1.10) with (1.6), we arrive at relationship of Rittinger [3].

Admitting that the necessary energy for crushed is proportional with geometric average between volume and material pieces area is obtained:

$$\mathcal{E} = C_E \sqrt{D_m^3\, D_m^2} = C_B\, D_m^{2,5} \quad (1.11)$$

This relationship is even the Bond formula [3]:

$$\mathcal{E}_B = C_B\, D^{2,5}$$

The grinding theory can be writing for a lot of pieces of material (waste) that mast be processed.

If we considered the pieces of materials by cubic form, the number N of small pieces that result after grinding was:

$$N = G/ (\gamma d_m^3) \quad (1.12)$$

The surface of N pieces of material is:

$$\Delta = a\, N = 6\, d_m^2\, G/ (\gamma d_m^3\,) = 6\, G/ (\gamma\, d_m) \quad (1.13)$$

Specifically surface is:

$$A_{sp} = A/G = 6/ (\gamma\, d_m) \quad (1.14)$$

The necessary energy to crush pieces of material on the relationship Kick – Kirpicev (rel. 6) is [3]:

$$\mathcal{E}_k = k_0\, \gamma\, D_m^3 \quad (1.15)$$

For N pieces of material that can be found in G tons of material, by using relationship 12, is obtained:

$$\mathcal{E}_k = k_0\, G \quad (1.16)$$

If the milling degree ($i = D_m / d_m$) has a great value than must to use a lot of steps of grinding. If we considered that the number of grinding steps is z, the partially milling degree i_p , is :

$$i_p = D_{med}/ d_1;\quad i_p = d_1/ d_2 ;\quad i_p = d_{z-1}/ d_{med} \qquad (1.17)$$

$$i = D_{med}/ d_{med} = (D_{med}/ d_1)\,(d_1/d_2)\,\ldots\,(d_{z-1}/ d_{med}) = i_p^z \qquad (1.18)$$

The energy [3] that corresponding for number of grinding z, is:

$\mathcal{E}_{k1} = k_0 G$; $\mathcal{E}_{k2} = k_0 G$; ….. $\mathcal{E}_{kz} = k_0 G$.

The energy necessary to grinding the G tons of material that corresponding at z number of grinding is:

$$\mathcal{E}_k = z k_0 G \qquad (1.19)$$

The number of grinding steps can be determining with relationship (1.18) and result:

$$z = \lg i/ \lg i_p \qquad (1.20)$$

After replacing in (19) the expression (20) is obtained:

$$\mathcal{E}_k = (\lg i/ \lg i_p)\, k_0\, G = K_k\, G \lg (D_m/ d_m) \qquad (1.21)$$

or: $$\mathcal{E}_k = K_k\, [\lg (1/d_m) - \lg (1/D_m)]G \qquad (1.22)$$

For establish the energy necessary to grinding a tons G of materials on Rittinger's theory, I take in account the initially and finally specifically surface for the G tons of material (rel. 14) and result:

$$A_0 = G\, A_{sp,\,0} = \frac{6G}{D_m};\qquad A_f = G\, A_{sp,\,f} = \frac{6G}{d_m} \qquad (1.23)$$

The necessary energy will be [3]:

$$\mathcal{E}_R \approx \sigma \Delta A \approx \sigma\, (A_{sp,\,f} - A_{sp,\,0}) \qquad (1.24)$$

or $$\mathcal{E}_R \approx (6\sigma/ \gamma)\, (1/d_m - 1/D_m)\, G \qquad (1.25)$$

The relationship (25) can be written like [3]:

$$\mathcal{E}_R = K_R\, (1/d_m - 1/ D_m)\, G \qquad (1.26)$$

After introduction of more grinding degrees is obtained:

$$\mathcal{E}_R = K_R\, (i - 1)/ D_m)\, G \qquad (1.27)$$

After sowing this theoretically elements on shredding of materials we can say that:

-for shredding the materials with average dimension D_m, the shredding energy is proportionally with grinding degree;

-for keeping the same shredding degree, if the average dimensions for pieces of materials, that must be shredding decrease, the energy consumption for shredding grow up proportionally.

We can demonstrate this last conclusion if we integrate the Charles equation [3]: $d\mathcal{E} = - Cdx/x^n$, for any value of n, with exception $n \neq -1$, between the limits d and D. After integrate of equation is obtained:

$$\mathcal{E} = (C/ (n - 1)) (1/ d^{n-1} - 1/ D^{n-1}) \quad (1.28)$$

If the energy consumption increase rapidly, with the increase of grinding degree like in figure 1 we can write[3]:

$$\mathcal{E} = K_B D_m^{2,9} N = K_B D_m^{2,5} G/ \sqrt{D_m^3} \quad (1.29)$$

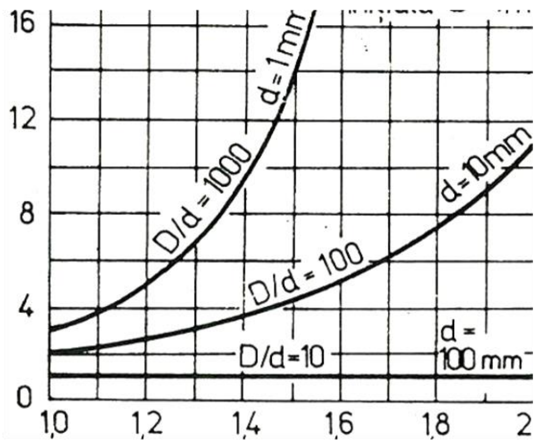
Or $$\mathcal{E} = k_0 (1/\sqrt{D_m}) G \quad (1.30)$$

Where: $k_0 = K_{B/\gamma}$

If the grinding of material is made in z steps the average diameter on each step will be [3]:

$$D_m;\ D_m/i_p;\ D_m/i_p^2;\ \ldots\ D_m/i_p^{z-1}$$

Relatively energy consumption (kWh)



Particle dimension (mm)

Fig.1.1. Energy consumption in function of grinding degree of waste particles [3].

The necessary energy for each grinding step for G tons of material, is [3]:

$$\mathcal{E}_{B1} = k_0\,(1/D_m^{0,5})\,G;\ \mathcal{E}_{B2} = k_0\,(i_p^{0,5}/D_m^{0,5})\,G\ldots\ldots\ \mathcal{E}_{Bz} = k_0\,((i_p^{z-1})^{0.5}/D_m^{0,5})\,G \quad (1.31)$$

The total energy consumption [3] is obtained when we do the sum of partially energy like:

$$\mathcal{E}_B = [1 + i_p^{0,5} + (i_p^{0,5})^2 + \ldots + (i_p^{0,5})^{z-1}]\,k_0\,(1/D_m^{0,5})\,G \quad (1.32)$$

We observe that sum from right parentheses is the sum of one geometrically progression with ratio $i_p^{0,5}$:

$$\mathcal{E}_B = \frac{(i_p^{0,5})^{z-1}\,(i_p^{0,5}-1)}{i_p^{0,5}-1}k_0 + \frac{1}{D_m^{0,5}}\,G = \frac{(i_p^{z})^{0,5}-1}{i_p^{0,5}-1}\,k_0\,\frac{1}{D_m^{0,5}}\,G \quad (1.33)$$

After replacing in used relationships we obtained a complete formula for total energy consumption in the shredding process of material [3]:

$$\mathcal{E}_B = \frac{1}{i_p^{0,5}-1}\cdot\left(\frac{1}{\sqrt{d_m}} - \frac{1}{\sqrt{D_m}}\right)\,k_0\,\frac{1}{D_m^{0,5}}\,G \quad (1.34)$$

1. 2. Accumulation rate, Predicting the amount

The rate of accumulation is the amount of solid waste, formed the basis of units of determination (one person in the city, a place in a hotel bed in hospital 1 m^2 in the shop.) for a certain period of time (day, year). The accumulation rate are of two types: general and differentiated. Accumulation rate for Bulgaria are shown in the book [13].

Aggregate amount B_t= b. N, kg, m^3; b – accumulation rate/Person; N - population size.

Clock accumulation:

$$B_Д \max = K.B_Д = K\frac{B_Г}{365} = K\frac{b.N}{365} \quad (1.35)$$

K = 1,25-1,40; K is the coefficient of uniformity clock.

For example, for Bulgaria in 2005: B = 2.9 million t MSW; B = 12 million m^3 solid waste.

The prediction of the quantity of solid waste going to the formula:

$$b_n = \frac{b_\infty}{1+e^{b_0 - a_n}}, m^3 / жител, год. \quad (1.36)$$

Bг= b.N; b ≠ const; N ≠ const where b is the change in time b = b (N) =bn where bn is the rate of accumulation of one resident.

Graph of forecasting the amount of solid waste is shown in Figure 1.2.

$$B_n = b_n . \lambda / n, m^3 / год.$$
$$M_n = B_n . \gamma_n, тон / год. \quad (1.37)$$

γ_n where the projected density, kg/m3

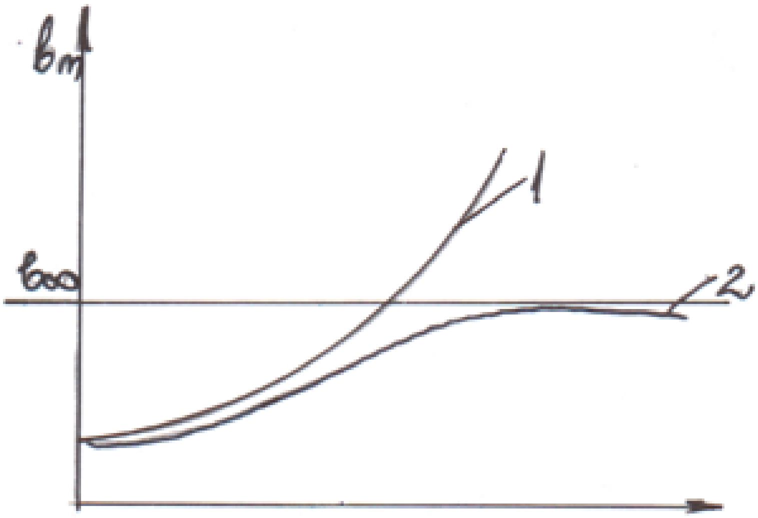


Fig. 1.2. Graph of forecasting the amount of solid waste

1.3. Properties of municipal solid waste

The properties of solid waste are divided into 4 groups:

1. Physical 2. Chemical 3. Biological 4. Thermal

1. Physical Properties determine the choice of method, apparatus and equipment for disposal. To their assessment as secondary raw materials fall: morphological composition, density, fractional composition and humidity.

A). Density - γ, kg/m3

γ density depends on the content of the paper and food scraps and is used for the sizing of the containers, bins, etc… For Bulgaria the data is shown in the [13].

B). Fractional composition - Allows content of MSW in size. Determined by sequentially sieving samples of the medium through sieves with a mesh size of 250, 150, 100, 50 and 15mm. E following general characteristics: sieve 150 mm - 10% - this is the combustible fraction (textile, paper, wood). The major part of the waste is larger than 100mm - up to 60% through a 15mm, food waste.

C). Humidity is external and hygroscopic. External humidity is lost moisture from the waste in % while drying in the air - dry state (when the waste do not change its mass at room temperature t = 15 – 20 grad C and normal relative humidity 50 %). Hygroscopic- Losses from air dry waste moisture in dried at temperature 150 grad C. The total humidity content amount W is on the external and the hygroscopic humidites. The external humidity - 80-90% of the total W, approximately 85% (W ≈ 85%). For Bulgaria: W 31-45%.

2. Chemical properties used to evaluate solid waste and material biotoplivo or composting. They are divided into three groups:

A). Organic substances - 45-65% of solid waste. It is divided in two subgroups:

* Active-containing protein and starch. Therefore decompose quickly. Subject of compost and organic fertilizer.

* Passive - Decompose very slowly (textiles, wood, leather, bones).

B). MINERAL SUBSTANCES - 25-45% of solid waste. The main chemical components are: carbon C = 20-30%, nitrogen N = 1-2%, phosphorus P_2O_5> 1% potassium K_2O<1%, Calcium CaO = 4-6%, sodium Na<1%, magnesium Mg<1%, acid reaction of the medium pH = 5-7% slightly acidic.

C). BALLAST 8-12% of solid waste- metals, glass, coal, stone and more.

3. Biological properties divided into two groups: Sanitary and microbiological properties. Microbiological properties are determined by the incoming solid waste microorganisms: bacteria, fungi, actinomycetes (lower plant organisms with traits of bacteria and simple organisms). Sanitary and hygienic properties

measured at three groups of indicators: bacteriological, hematological and entomological.

4. Thermal properties divided into two groups for burning: elemental composition and calorific value. Elemental composition includes carbon C, hydrogen H_2, oxygen O_2, nitrogen N, sulfur S. Calorific value is ability of waste to produce heat in the combustion process, kkal / kg or kJ / kg. Tables – in [13].

2. WASTE SHREDDING EQUIPMENT

The modality for crushing the solid material differs depending on the type of equipment used. The grinding of solid material [4] can be done by compression and friction (fig.2.1a) for an individually particles or group of material particles.

Areas of work of milling machine can be fine (Fig. 2.1a), or with diverse crushing configuration (fig.2.1b). In the latter case, in addition compression and friction material may be subject to tension and bending.

Another way of making the material grinding is in shock over an area long (fig.2.1c), a situation encountered at hammers mills.

All the hammers mills, meets crush and friction on the entire surface (force still- Fig. 2.1d). Solid material may be crushing between particles of material (Fig. 2.1e), as happens in the case with jet mills.

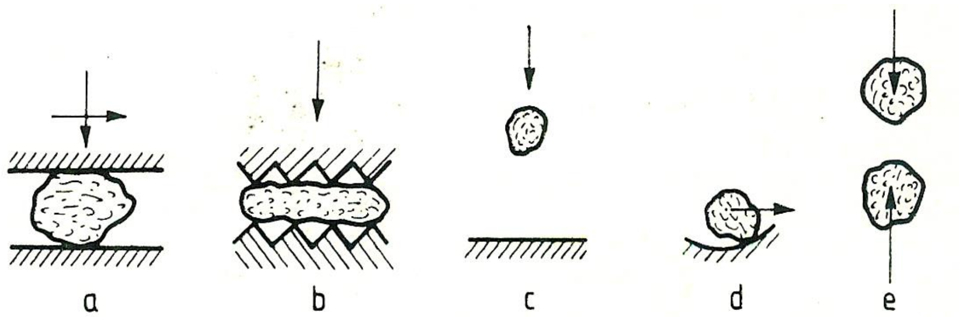


Fig. 2.1 – Types of crushing mechanisms [4].

2.1. Classification of shredded equipment

After the main mode of shredding for pieces of material, the crushed equipment can be divided into 2 classes [3]:

a. Equipment for materials crushing that using the compression and friction (machines crushing with jaws, conic machines, cylinders crushing equipment, crushing equipment with rolling parts, crushing between cylinder and grate of grinding machine, crushing between cylinders, fig.2.2 – a, b ,c, d, e);

b. Equipment that crushing the particles of material through sock (crushing equipment with hammer, milling machine with spherical grinding parts, disintegrate machine for materials, jet mills fig.2.2 – f, g, h, i).

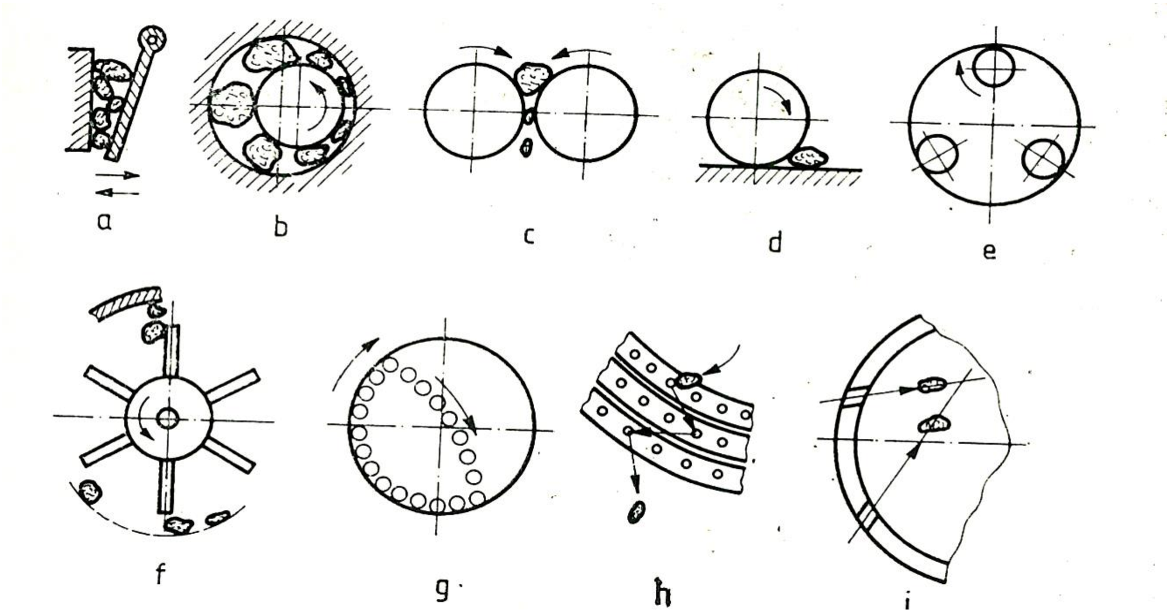


Fig.2.2. Types of crushed equipment [3] – a, b, c, d, e, f, g, h, i

Note: If the average dimension of particles is over 0.02 – 0.025 m we considered that material was processed on shredder equipment. If the average dimension of particles is under 0.02 – 0.025 m we say that material was processed on a grinding machines.

2.2 Grinding Steers

To achieve degree grinding, required by the technological process –where is asking a precise dimension for the resulting product- is necessary that the material be passed through several crushing steps. The crushing in most steps is doing on different machines (each step corresponding to a certain type of grinding machine-)

In table 2.1 are indicate the grinding steps for tough materials and soft materials[4].

The grinding steps for tough materials and soft materials Table 2.1

a) Tough materials

Operation		Initially size, D [m]	Finally size, d [m]	Grinding degree D/d
Crushing	Gross	$1.5 \div 0.3$	$0.5 \div 1$	3
	Medium	$0.5 \div 0.05$	$0.05 \div 0.01$	$5 \div 6$
	Small	$0.05 \div 0.02$	$0.01 \div 0.001$	$5 \div 20$
Grinding	Gross	$0.025 \div 0.003$	$\leq 5 \times 10^{-4}$	≥ 10
	Medium	$5 \times 10^{-3} \div 1 \times 10^{-3}$	$5 \times 10^{-4} \div 1 \times 10^{-4}$	≥ 10
	Fine	$1.2 \times 10^{-3} \div 1{,}5 \times 10^{-4}$	$8 \times 10^{-5} \div 1 \times 10^{-5}$	≥ 15
b) Soft materials				
Crushing		$0{,}5 \div 0.1$	$00.5 \div 0{,}01$	10
Grinding	Gross	$1.2 \times 10^{-2} \div 1{,}5 \times 10^{-3}$	$5 \times 10^{-4} \div 1 \times 10^{-4}$	20
	Fine	$4 \times 10^{-3} \div 5 \times 10^{-4}$	$1 \times 10^{-4} \div 1 \times 10^{-5}$	50
Colloidal grinding		$< 7.5 \times 10^{-4}$	≤ 0.1 µm	≥ 50

The division of solid materials on tough degree is doing with conventionally steers of Mohs [4] .

2.3 Equipment for solid materials shredding

The grinding machines are named in generally Shredders. Such a type of equipment has in generally the next pars:

2.3.1 Grinding machine with vertical axe

This equipment (figure 2.3) is used for grinding the waste from plastic material. At the top of their machinery is a mouth for the entrance of the materials.

At the interior of this equipment there is a vertical axe. On this axe is mounted in horizontal position 5 to 11 knifes.

These knives have curve or strait configuration. At the bottom of this equipment there is a ball bearing thrust that is the main support of the central rotate axe.

The drive system is composing from engine, gear box, couplings and a conic group, that transmit the rotate motion to the vertical axe with knife.

Between gear box and engine there is a coupling that transmits the torque and the rotation speed from the engine.

The evacuation of shredding material is made at the bottom of this equipment on a conveyor belt.

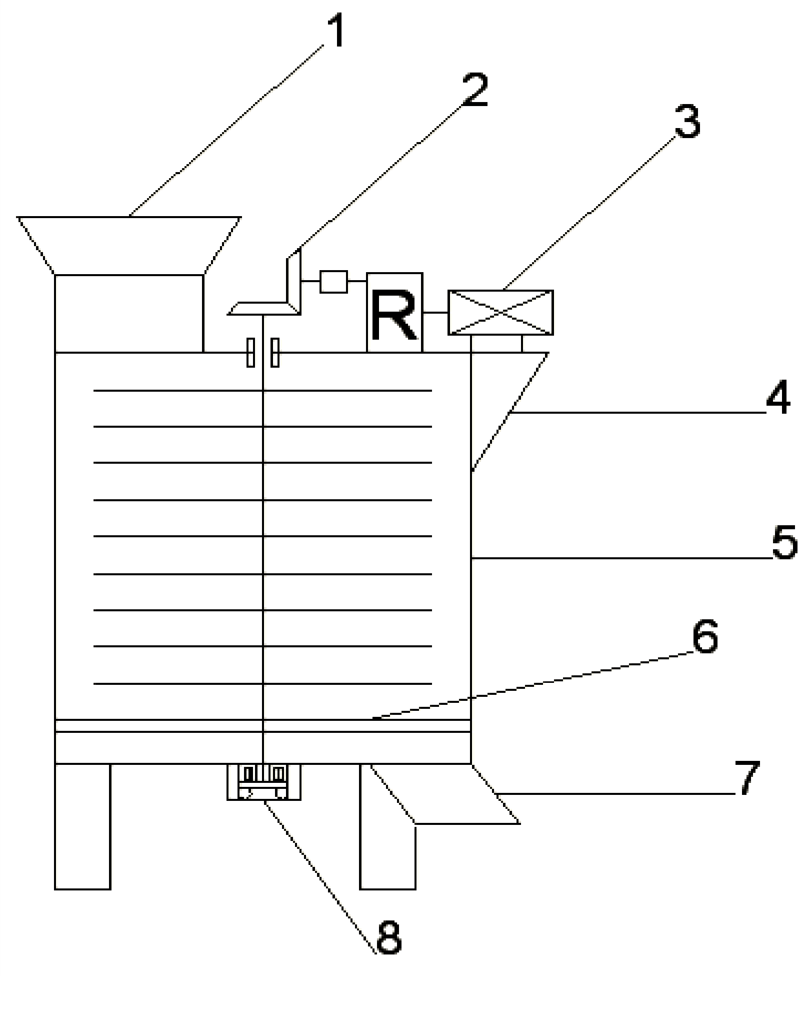


Fig.2.3. Grinding machine with vertical axe: 1-feeder for material entrance; 2-conic group and box gear; 3- engine; 4- engine support; 5- metallic shell; 6 – axe with knifes; 7 – materials evacuation; 8 – bearing ball thrust.

2.3.1.1. Calculus of Power engine.

For determine the engine power is necessary to calculate the resistant torque that are developed in while of machinery work. The two bearings take the internal resistance (friction forces) that is produced in the work. In the angular bearing (at the top of axe) is produced the first resistant torque like [4]:

$$M_r = F_r * \mu_l * \frac{D_r}{2} \qquad (2.1)$$

The second resistant torque is produced in cutting time [4]:

$$M_t = F_{t\,max} * L * \mu_m \qquad (2.2)$$

where: M_r – angular bearing torque, in Nm ; M_t - Cutting torque in Nm ; F_r- angular bearing force, in N; $F_{t\ max}$ - maximal cutting force in N ; Dr-angular bearing diameter; L – knife length ; μ_l - friction coefficient in angular bearing ; μ_m -friction coefficient between knife and material .

The third resistant coupling there is in bearing ball thrust (at the axe bottom) [4]:

$$M_a = (G_m + G_{axe}) * \frac{D_a}{2} * \mu l \qquad (2.3)$$

where: M_a –ball bearing thrust torque, in Nm ; G_{axe} –axe and knife weight, in N ; D_a - ball bearing thrust diameter; μ_l -friction coefficient in ball bearing thrust.

- Engine power calculus is based on the relationship [4]:

$$P_{SO} = kd \frac{(Mr+Mt+Ma)\, n_{axe}}{9550 \cdot \eta} \text{ [KW]} \qquad (2.4)$$

The efficiency mechanical is: $\eta = \eta_1 \cdot \eta_2$

After engine power calculus, is made the verification of engine. We choice an engine with nominal power Pn>Pso.

For verification is doing a comparison between dynamic coefficient of overloading calculate λ_{calc} and dynamic coefficient of overloading from table $\lambda_{tab.}$. It is necessary to calculus the dynamic torque Md, the static torque Ms and the nominal torque Mn. It made the sum between dynamic torque and static torque. Than is made the rapport between this sum and nominal torque like [4]:

$$\lambda calc = \frac{(Md+Ms)}{Mn} \qquad (2.5)$$

For the choice engine, we find in table the real value for dynamic coefficient of overloading λ_{tab}.

The conditions necessary for engine verification is [4]: $\boldsymbol{\lambda_{calc} < \lambda_{tab}}$ (2.6)

2.3.2. Equipment for grinding nonferrous waste

The wastes from brass, copper, bronze, aluminium are introducing for processing into the grinding machine like in figure 2.4.

This equipment has 3 or 5 axes with cutting discs. These axes are rotate in contrary sense. The fragile waste is grinding and the ductile waste is cutting.

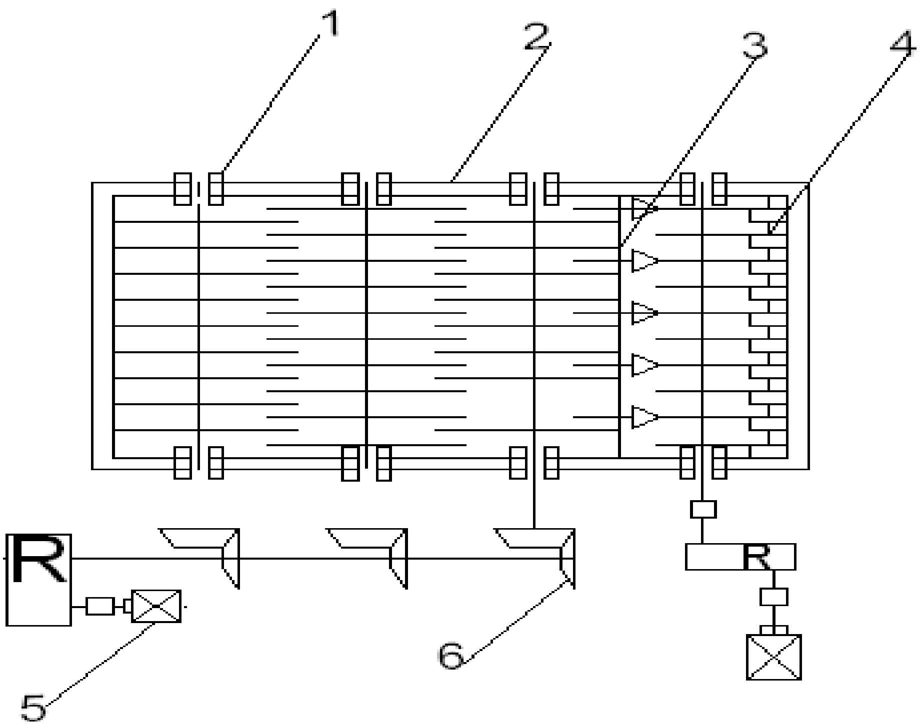


Fig.2.4. Grinding machine: 1–bearing; 2–shell machine; 3–cuttings discs on the axes; 4–grate evacuation;5–drive system ;6–conic group.

The cutting discs are arranged one by one on these axes of grinding equipment. The cutting discs are rotate in contrary sense. When the wastes enter between the cuttings discs and the pieces are grinding. The grinding machine has two compartments. First compartment has three or five axes with discs and made a primary grinding of waste. In side of the second compartment is made a secondary fine grinding of waste. In this compartment the waste are fine grinding between a lineally anvil and an axe with cutting discs. The drive system (that determines the rotation of cutting axes) is composing from engine, gear box, couplings and a conic group like in the figure no.2.4. The evacuation of grinding material is doing throw a grate mounted at the bottom of the grinding machine.

For calculus of engine power is necessary to determine the internal resistant torque and the exterior forces that are produced in while the grinding machine work. In the bearing mounted in the grinding machine body is produced the first resistant torque like [4]:

$$Mf_1 = (N_{ax}\, G_{ax} + G_m)\, \frac{D_{ax}}{2}\, \mu_l \quad [Nm] \qquad (2.7)$$

Where: is bearing friction torque, in Nm ; G_{axe}–axe and cutting discs weight, in N ; G_m– waste weight, in N ; N_{ax} –Number of axes and cutting discs; D_{ax} –axe diameter, in m; μ_l -friction coefficient inside of bearing.

The second resistant torque is created at the instantaneous contact of waste with cutting disc s[4]:

$$Mf_2 = Gm\, \frac{D_d}{2}\, \mu_{md} \quad [Nm] \qquad (2.8)$$

where: Mf_2 is friction torque between materials that exist instantaneous on the surface created by the cutting discs, in Nm ; G_m– waste weight, in N ; N_{ax} – Number of axes and cutting discs; D_d–exterior diameter of cutting discs, in m; μ_{md} -friction coefficient inside of bearing; n_{ax}–axe rotation speed, in rot/min.

- Engine power calculus is based on the relationship [4]:

$$P_{SO} = kd\, \frac{(Mf1+Mf2)\, n_{axe}}{9550 \cdot \eta} \quad [KW] \qquad (2.9)$$

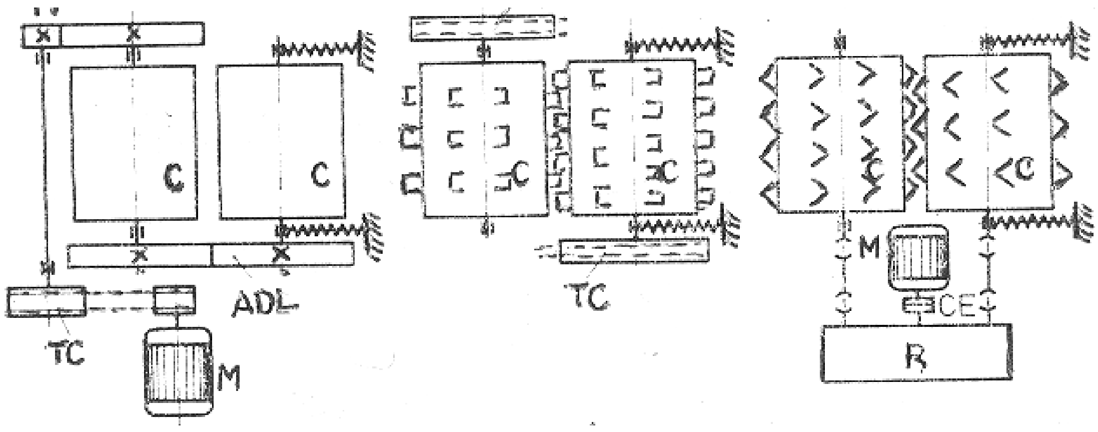
The efficiency mechanical is: $\eta = \eta_1 \cdot \eta_2$ (2.10)

After engine power calculus, is made the verification of engine. We choice an engine with nominal power Pn>Pso. For verification is doing a comparison between dynamic coefficient of overloading calculate λ_{calc} and dynamic coefficient of overloading from table $\lambda_{tab.}$.

2.3.3. Equipment for shredding tough material

The driving system is compose by an engine and strap wheel that transmitting the rotation moving throw a coupling bar to a gear box(fig.2.5a). It is possible that rotation of shredder cylinders be made from two strap wheels on each side of cylinders (fig.2.5b). The cylinders with shredder hammer can be rotate if they receive the moving from coupling bars. The coupling bars receive the rotating from a gear box (fig.2.5c). Engines transmit the torch and rotation to the gear box.

Equipment that crushing the particles of material through sock (crushing cylinders. with crushing hammer mounted on their surface), can have diverse shape for shredder hammer (pyramidal or prismatic) [4]. These types of equipment's are used for shredding material with the tangentially breaking effort τ_{max}=1.1-2.6x10^{7} N/m^{2}. In the figure 2.6 is showing three types of driving system for this machinery.



a) b) c)

Fig.2.5. Types of driving system for shredder machinery: a and b- with intermediary transmission and gear box; c- with sleeve bars ; M-electric engine; TC- strap wheel; ADL-intermediary transmission; R-gear box; C-shredder cylinders [4].

The crushing of material is produced between work cylinders. The shredder machines have like active parts two rotors. These rotors have a cylindrically shape. These work cylinders (the two rotors) are rotating in contrary sense and they ketch the pieces of material and crush them.

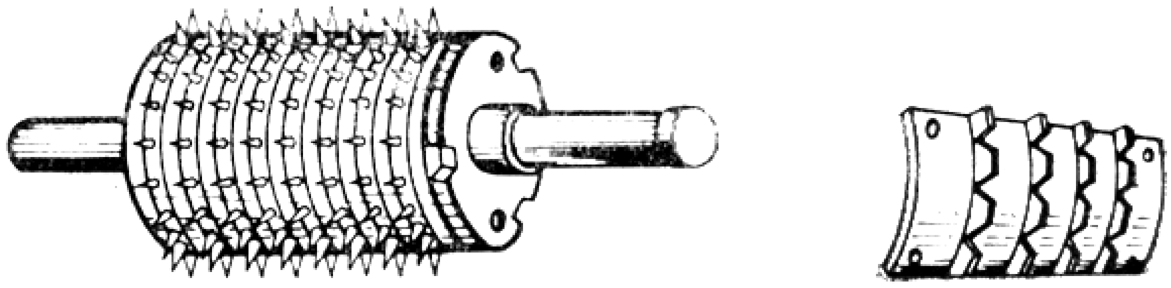


Fig.2.6. Diverse shape for shredder hammer mounted on the work cylinders shaft [4].

The components parts for shredding machinery are showing in figure 2.7. The rotation movement from engine is transmitting to the intermediary transmission (gears) throw a strap wheel.

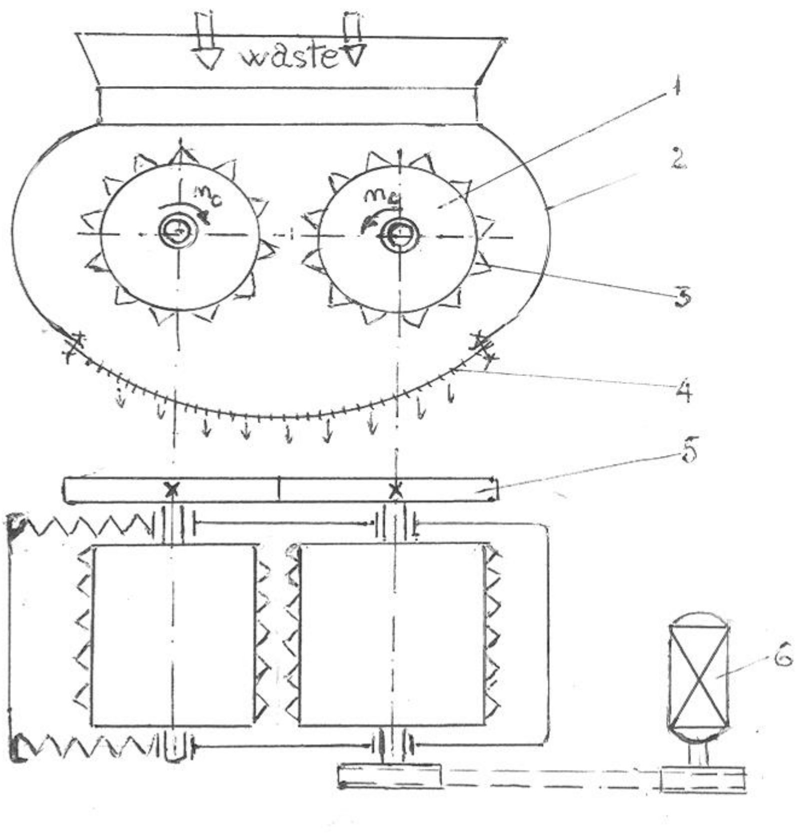


Fig.2.7.Cinematic schedule for a shredder: 1-crushing cylinders; 2- shredder shell; 3-crushing pyramidal hammer; 4-evacuation grate; 5-gears transmission; 6- electrical engine.

2.3.3.1 Power engine calculus.

For determine the engine power is necessary to calculate the resistant torque that are developed in area of shredder work cylinders. In the same time the inside of for bearing is produced in the work, powerful frictions couples. This first resistant torque can be writing [4]:

$$M_{r1} = (G_m + 2G_{cil}) * \frac{d_{cil}}{2} * \mu l \tag{2.11}$$

Where: M_{r1} –bearing torque, in Nm ; G_{cil} –cylinders weight in N ; G_m -material weight, in N; d_{cil}- bearing diameter; μ_l - friction coefficient in cylinders bearing.

The second resistant torque there is at the contact surfaces between material and cylinders in work [4]:

$$M_{r2} = (G_m) * \frac{D_{cil}}{2} * \mu m \tag{2.12}$$

Where: M_{r2} –friction torque between cylinders and material, in Nm ; G_m – material weight, in N ; D_{cil} –cylinders diameter in m; μ_m -friction coefficient between cylinders and material.

While the material is crushing between cylinders is produced a shredding mechanical work, like [4]:

$$Lm = (\sigma_R)^2 * \Delta V/2E \tag{2.13}$$

Where: Lm is shredding mechanical work, in Nm; σ_R –breaking resistance of material in N/mm^2 ; ΔV- volume of material that passing throw the crushing cylinders, in m^3; E-material elasticity modulus in N/mm^2.

Engine power calculus is based on the relationship [4]:

$$P_{SO} = kd \frac{(Mr1+Mr2+Lm)\, n_{cil}}{9550 \cdot \eta} \text{ [KW]} \tag{2.14}$$

The efficiency mechanical is: $\eta = \eta_1 \cdot \eta_2$ (2.15)

After engine power calculus, is made the verification of engine. We choice an engine with nominal power Pn>Pso.

For verification is doing a comparison between dynamic coefficient of overloading calculate λ_{calc} and dynamic coefficient of overloading from table $\lambda_{tab.}$. It is necessary to calculus the dynamic torque Md, the static torque Ms and the nominal torque Mn. It made the sum between dynamic torque and static torque. Than is made the rapport between this sum and nominal torque like [4]:

$$\lambda calc = \frac{(Md+Ms)}{Mn} \tag{2.16}$$

For the choice engine, we find in table the real value for dynamic coefficient of overloading λ_{tab}.

The conditions necessary of verification for calculate power engine, is [4]:

$$\lambda_{calc} < \lambda_{tab} \tag{2.17}$$