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# JUSTIFICATION OF ENERGY-SAVING TECHNOLOGY IN THE FACTORY FOR THE PRODUCTION OF CRUSHED STONE

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The article deals with one of the most pressing problems - the introduction of new resource-saving technologies in the processing of minerals for the manufacture of building materials in Ukraine. The technique of choice and justification of energy-saving technological scheme and equipment of crushing and screening plant. It outlines the main directions in the use of internal resources and technological capabilities of crushing and screening plant, which will ensure lower specific energy consumption in the production of commodity fractions of crushed stone.

**Key words**: energy-saving technologies, rubble, crushing energy intensity.

# ОБҐРУНТУВАННЯ ЕНЕРГООЩАДНОЇ ТЕХНОЛОГІЇ ЗАВОДУ ПО ВИРОБНИЦТВУ ЩЕБЕНЮ

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В роботі розглянута одна із актуальних задач - впровадження нових ресурсозберігаючих технологій при переробці корисних копалин для виготовлення будівельних матеріалів на Україні. Розроблена методика вибору та обґрунтування енергоощадної технологічної схеми і обладнання дробарно-сортувального заводу. Розкрито основні напрямки у вик0ристанні внутрішніх резервів і технологічних можливостей дробарно-сортувального заводу, які зможуть забезпечити зниження питомої енергоємності при виробництві товарних фракцій щебню.

**Ключові слова**: енергоощадні технології, щебінь, питома енергоємність дроблення.

PROBLEM STATEMENT. The modern economy requires growth in production and business activities. Ukraine has sufficient mineral reserves, and at the same time it belongs to energy-intensive states that meets their needs in energy resources by at least 50 %. Extraction of non-metallic building materials is characterized by excessive expenditure of resources per unit of gross domestic product.

Ukraine's accession to world markets by building materials can solve such major problems: the introduction of new advanced resource-saving technologies to reduce the cost of energy resources, improve product quality; creating environmentally friendly, including waste technologies. By saving technologies should include: upgrading energy consuming systems by increasing their workload, equipment instrumentation control costs energy, automated control regimes.

The aim of this work is to search for and evaluation of technological possibilities of using internal resources that would ensure reduction in specific energy splitting non-metallic building materials.

EXPERIMENTAL PART AND RESULTS OBTAINED. One of the main process stages of production of high quality gravel is crushing the rock mass to commercial sizes (fractions). Specific energy consumption crushers are determined mainly by the strength of rocks and particle-size composition of the rock mass input (RMI).

To address the problems in the developed method selection and justification of energy saving technological scheme and equipment crushing and screening plant (CSP). Further calculations are based on the performance of the CSP for finished products $Q_{fp}$ = 250,000 $m^3$ per year, apparent mass (density) of the input 1,7 and output 1,3 material - t/$m^3$ , and particle size distribution of rock that enters the plant after drilling and blasting working (Table. 1). Calculation held only for the first stage of crushing, due to the volume limitation article.

Table –1 Particle size of the input of the rock mass

| Size of faction, mm | Output of faction, r.u | Size of faction, mm | Output of faction, r.u |
|---|---|---|---|
| 0…0,14 | 0,01 | 0…70 | 0,16 |
| 0…5 | 0,03 | 0…100 | 0,25 |
| 0…10 | 0,06 | 0…200 | 0,58 |
| 0…20 | 0,08 | 0…300 | 0,80 |
| 0…40 | 0,09 | 0…500 | 1,00 |

Fragment of chart – the first stage of crushing, shown in Figure 1.

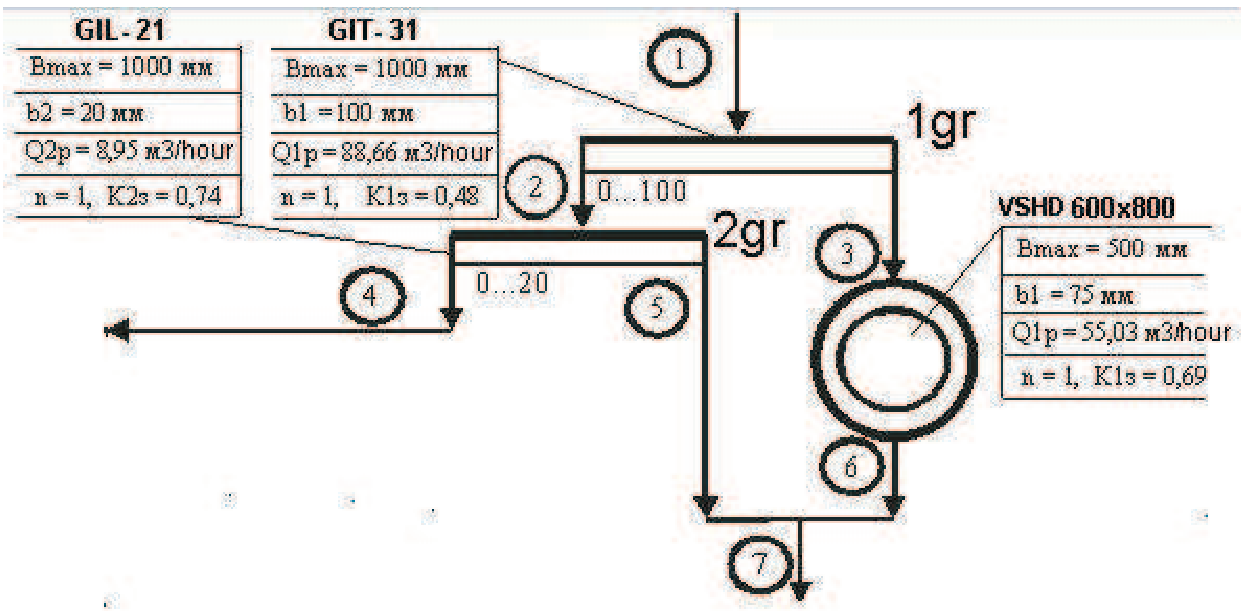



Figure 1 – Fragment of chart of the CSP - the first stage of crushing

Necessary for the performance of the CSP career which are respectively input to crushing weight $Q_{it}$ ($m^3$/year) calculated as [1, 2]

$$Q_{it} = Q_{fp} \cdot \delta_{fp} / (\gamma_{fp} \cdot \delta_{it}), \quad m^3/year \qquad (1)$$

where $Q_{fp}$ – performance CSP on finished products, $m^3$/year;

$\delta_{it}$ and $\delta_{fp}$ – respectively, the density of the input mining of rock and crushed rubble fraction, т/м$^3$;

$\gamma_{fp}$ – output of finished products based on waste management, r.u.

Hourly productivity CSP inputs for $Q_h$ (m3 /h) [1, 2]:

$$Q_h = Q_h / T_h, \qquad (2)$$

where $T_h$ – clean CSP time per year, hours.

These parameters for operations prior selected vibrating sieve 1 GIT-31 with the desired mesh size sieve (100 mm) sieve surface area of 2,0 $m^2$, from passport productivity 77 $m^3$/h. Calculation of equipment for screening and selection coefficients produced by the procedure laid down in [1, 2].

Estimated performance $Q_{p1}$ first sieve GIT-31 ($m^3$/h) is given by

$$Q_{p1} = c \cdot q \cdot F \cdot k \cdot l \cdot m \cdot n \cdot o \cdot p, \qquad (3)$$

where c = 0,85 – coefficient of the surface sieve, sieve to top sifter material under load in width 0,65 $B_c$;

$B_c$ – width sieve surface, m;

q – hour performance per unit volume ($m^3$/h) $m^2$ (Table. 2);

Table 2 – Per unit volume performance vibrating screens

| Hole sieve, mm | 5 | 8 | 10 | 12 | 16 | 20 | 25 | 32 | 40 | 50 | 70 | 80 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| The average value per unit volume productivity ($m^3$/h)$m^2$ | 10 | 16 | 19 | 21 | 24,5 | 28 | 31 | 34 | 38 | 42 | 50 | 55 | 63 |

F – the surface sieve area, $m^2$ [2];

k = 0,3 – 2,0 – factor takes into account the content of grain size smaller than half hole sieve;

l = 0,94 – 3,36 – factor takes into account the content of grain size larger than half hole sieve;

m = 2,30 – 0,67 – screening efficiency ratio;

n = 1,0 – 1,5 – coefficient taking into account the shape of the grains;

o = 0,2 – 1,0 – coefficient taking into account the moisture content of the material;

p = 1,0 –1,4 – factor considering screening method.

Estimated performance sieve GIT - 31 from sticking coefficient sieve is:

$$Q^3_{1p} = Q_{1p} \cdot K_3, \qquad (4)$$

where $K_3$= 0,7 – a coefficient of sticking of sieve is with natural humidity of material, 8 %.

Number of crashing to rubble GIT 31, admitted to pre-crashing in the first stage of fragmentation:

$$N_1 = Q_1 / Q_{p1}, \quad (5)$$

Sieve load factor is calculated as follows:

$$K_1 = Q_1 / (N_1 Q_{p1}) \quad (6)$$

After substitution of (1) – (6) reasonably selected quantitative values and analysis results suggest that a vibrating GIT-31 provides crashing in the first stage crushing load factor of 48 %.

The specific energy consumption $Q^e_{G1}$ (kWt · h/m$^3$) crashing for GIT-31 passport:

$$q^e_{G1} = \frac{N_{G1}}{Q_{G1}}, \quad (7)$$

where $N_{G1}$ – power GIT-31 passport, kWt;

$Q_{G1}$ – performance of GIT–31, m$^3$/h.

The specific energy consumption GIT-31 is real, if it provides the necessary performance CSP m$^3$ per year:

$$q_{G1} = \frac{N_{G1}}{Q_1 \cdot к_з}, \quad (8)$$

Calculations show that the vibrating sieve GIT-31 works with incomplete charging with an hour performance 27,25 m$^3$/h at a specific power consumption 0,403 kWt·h/m$^3$, and according to passport characteristics it can working with hourly productivity 88,66 m$^3$ h with a specific energy consumption 0,124 kWt·h /m$^3$.

According to accepted technological scheme of the first stage grinding (Fig. 1), the second operation is set vibrating sieve GIL- 21. The opening of sieve equal to 20 mm. Vibrating sieve is designed to select from the main stream of rock grain size which is less than 100 mm. This technological feature allows to reduce the load on the crusher first stage. This will reduce wear armor plates on the working surfaces and increase term trouble-free operation of the crusher. The calculation is similar to the calculation of the first screening.

Estimated performance vibrating sieve GIL-21 from sticking coefficient $k_з$= 0,7 fed with natural material moisture 8 % [1] is defined as:

$$Q^3_{2p} = c \cdot q \cdot F \cdot k \cdot l \cdot m \cdot n \cdot o \cdot p \cdot kз, \ м^3/hour \quad (9)$$

where c – coefficient taking of the filter surface to the upper sieve at load sifter material 0,65$B_c$ the width (c = 0.85);

q – hour performance per unit volume (m$^3$/h)·m$^2$ (Tab. 2);

F – the surface area of the filter, m$^2$ [1];

k · l · m · n · o · p – estimated coefficients.

Number of vibrating GIL-21 adopted for screening 2 in the first stage of fragmentation:

$$N_2=Q_2/Q^3_{2p}, \tag{10}$$

where $Q_2 = Q_{hour} \cdot \gamma_2$, – performance transaction screening of rubble 2, with consideration of the buildup on the screen , $m^3$/hour.

$\gamma_2 = 0{,}17$ – yield production from the second screening operation.

The load factor of the second ($K_{2)}$ screens:

$$K_2 = Q_2 / (N2 \cdot Q^3_{2p}) \tag{11}$$

Thus, one GIL-21 provides screening 2 at the first stage of crushing and a load factor of 76 %.

Specific energy GIL-21 for passport characteristics:

$$q^e_{G2} = \frac{N_{G2}}{Q_{G2}}, \tag{12}$$

where $N_{G2}$ – power GIL-21 for passport characteristics kWt;

$Q_{G2}$ – performance GIL–21, $m^3$/h;

Specific energy sifter GIL-21na technological process of crushing the CSP:

$$q_{G2} = \frac{N_{G2}}{Q_2 \cdot к_з}, \tag{13}$$

where $Q_2 = Q_1 \cdot \gamma_2$ – 2 screening operations performance with consideration of buildup on the filter, $m^3$/h.

Special attention is paid to the feasibility and efficiency of the vibrating screen GIL-21 screening operations at 2, because it has a high specific energy content screening.

To answer this question should conduct additional research that will answer on the feasibility of its use in economic terms. We must decide whether to increase the use GIL-21 in the second screening operation quality of products CSP.

Standards for technological design [1] offer the choice of method of calculation and equipment CSP. Performance jaw and cone crushers are usually determined according to the regulations amended to crushing, size, shape and material moisture to be crushing on the recommendations of process design standards.

Estimated performance $Q_{pd1}$ ($m^3$/h) vibration jaw crusher VSHD 600x800 for the first stage crushing determine how

$$Q_{pd1} = Q_{pd} \cdot K_c \cdot K_s \cdot K_f \cdot K_h , \tag{14}$$

where $Q_{pd}$ – performance crusher for the normative document $m^3$/h;

$K_c$ – factor in crushing especially durable materials, tensile compressive who $\sigma s \geq 250$ MPa, r.u.; ($K_c$ is a value from 0,8 to 1,2)

$K_s$ – factor in particle size material, r.u.;

$K_f$ – coefficient of form material is considered equal to 1.00 for crushing stones torn, r.u. ;

$K_h$ – the coefficient of humidity on material with a moisture content of 4 %, r.u.

To select a material factor $K_s$ in particle size of 0,5 should determine the width of the receiving hole cutters, in this example, B = 300 mm. Set contents fraction from 0 to 300 mm in the fractional part of the input of the rock mass, that he is 30 %. From table 3 define the $K_s$ = 1,03.

Table 3 – factor in particle size material $K_s$

| Content fractions larger 0,5B, % | 5 | 10 | 20 | 25 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| Value $K_s$, r.u. | 1,10 | 1,08 | 1,05 | 1,04 | 1,03 | 1,00 | 0,97 | 0,95 | 0,92 | 0,89 |

Shape factor $K_f$ material is considered equal to 1,00 for crushing stone torn and crushed sand at 0,85 boulders mass. If the latter is 20 % jagged stone then $K_f$ = 0,9 r.u.

The coefficient on the material moisture $K_h$ is considered equal to 1,00 at 4 % moisture content, r.u. In the absence of useable data taken from Table 4 or [1].

Table 4 – Carbon moisture content $K_h$, r.u.

| Material moisture, % | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|
| Value $K_h$, r.u. | 1,00 | 1,00 | 0,95 | 0,90 | 0,85 | 0,80 | 0,77 | 0,65 |

The necessary and sufficient crushers n1 in the first stage crushing - sorting plant

$$n = Q_3 / Q_{pd}1, \tag{15}$$

where $Q_3 = Q_{hour} \cdot \gamma_3$, – hourly productivity CSP third operation - the first crusher, $m^3$ /h;
$Q_{pd}1$– performance crusher VJC 600x800 calculated by (2).

The load factor of the first stage crusher PES $k_1$:

$$k_1 = Q_{hour} / (Q_{p1} \cdot n_1), \tag{16}$$

Estimated performance of selected mills VSHD 600x800 is 56,030 $m^3$/h. At the hour of productivity CSP 38,39 $m^3$/h if and only use the first stage of a crushing mills to be loaded at 69 %, that has a reserve of productivity.

Specific energy consumption at crushing operation parameters passport crushe VSHD 600x800:

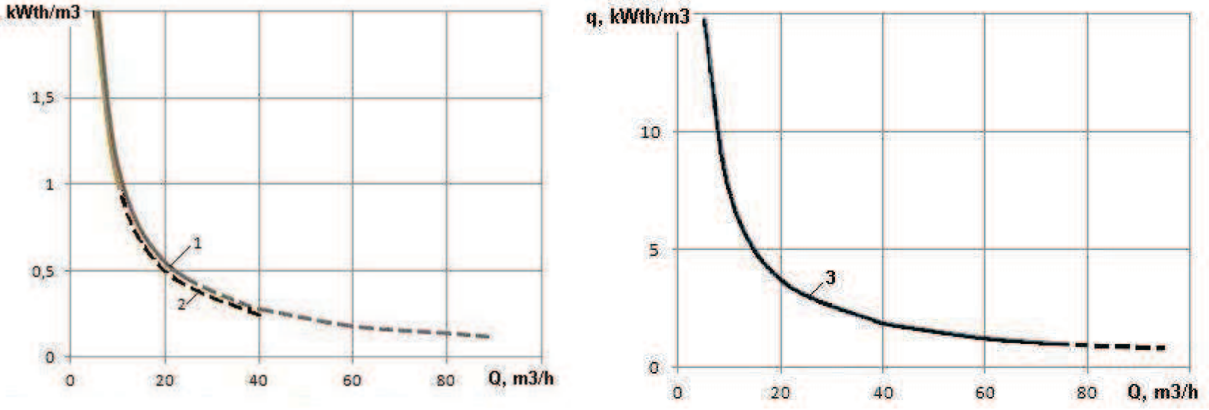
$$q^e_{D1} = \frac{N_{D1}}{Q_{D1}} \tag{17}$$

Specific energy operations in crushing mills design parameters chosen VSHD 600x800:

$$q_{D1} = \frac{N_{D1}}{Q_{D1} \cdot к_3} \tag{18}$$

The calculation showed that the download crushers VSHD 600x800 may increase by 21 percent. This crusher VSHD 600x800 will work with software specific energy splitting operations 0,791 kWt–h/$m^3$, which is below the calculated specific energy equal to 0,961 kWt·h/$m^3$.

Figure 2 shows the dependence of specific energy q from performance of Q: vibrating sieve GIT-31; GIL-21, and vibration jaw crusher (VSHD).




a) b)

Figure 2 – Dependence of specific energy q of performance Q:
a – GIT-31 (1) and GIL-21 (2); b) –VSHD jaw crusher (3). (— estimated),
and technically possible (- - - )

CONCLUSIONS. Analysis of the research and the results show the effectiveness of the proposed energy saving technology and equipment recommended for improving the basic performance of crushed stone plant (Fig. 2).

1. Vibrating screen GIT-31 that is set before the first crusher runs with a capacity 27,25 $m^3$/h at a specific power consumption 0,403 kWt·hour/$m^3$, and according to passport characteristics it can handle hourly productivity of 88,66 $m^3$/h with a specific energy consumption 0,124 kWt·h/$m^3$. That is, with increasing hours loading GIT-31 specific energy screening operations 1 can be reduced 3 times.

2. Vibrating screen GIL-21 in the second screening operation works with load factor 76 % of hourly productivity of 6,62 $m^3$/h which provides specific power consumption 2,16 kWt·h/$m^3$, and according to passport characteristics it can a performance of 39,2 $m^3$ hour with a specific energy performance 0,256 kWt·h/$m^3$. That is, with increasing load hours GIL-21 specific energy screening operations can be reduced from 2 to 8 times.

3. For the first stage crushing jaw crusher vibrating chosen VSHD 600x800 with an estimated performance of 56,030 $m^3$/h, that is, when productivity hour crushing and screening plant 38,39 $m^3$/h if and only use the first stage of a crushing mills, which has been downloaded 69 %, have a reserve of productivity.

4. With increasing downloading crushers VSHD 600x800 first stage of a 21 % sustained productivity at 93,50 $m^3$/h relative energy operations fragmentation reaches 0,791 kWt·h/$m^3$, which is below the calculated specific energy equal to 0,961 kWt·h/ $m^3$. And provided with a performance 77,04 $m^3$/h. Download crusher VJC 600x800 the first stage may increase by 21 percent.

5. The additional research to address the question of whether the use of the vibrating screen GIL -21 screening operations at 2 because it's loaded with only 17 % and have a high 2,16 0 kWt·h/$m^3$ specific energy screening.

REFERENCES

1. Normy technologicheskogo proektirovania predpriyatij nerudnysh stroitelnysh materialow / V.S. Abramson, V.S. Aksenov, I.K. Andronnikov I dr. L: Stroiizdat, Leningradskoe otdelenie, 1977. – 368 pp. Russia

2. Terentiev O.M. Teshnika ta teshnologia pererobky budivelnyh girskyh porid.[Text]: navch. posib. / O.M. Terentiev, V.G. Kravec. – K.: NTUU “KPI”, 2013. 220 pp. Ukraine

3. Terentiev O.M. Osnovy pererobky ta zbagachennyakorysnyh kopalyn. Metodychni vkazivky do vyvchennya kursu dlya studentiv specialnosti “Rozrobka rodovych korysnyh kopalyn. / Uklad. O.M. Terentiev, V.O. Horenko. –K.: IOC Vydavnyctvo ”Politechnika”, 2003. – 112 pp.

## ОБОСНОВАНИЕ ЭНЕРГОСБЕРЕГАЮЩЕЙ ТЕХНОЛОГИИ ЗАВОДА ПО ПРОИЗВОДСТВУ ЩЕБНЯ

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В статье рассмотрена одна из актуальных задач - внедрение новых ресурсосберегающих технологий при переработке полезных ископаемых для изготовления строительных материалов на Украине. Разработана методика выбора и обоснования энергосберегающей технологической схемы и оборудования дробильно-сортировочного завода (ДСЗ). Раскрыты основные направления в использовании внутренних резервов и технологических возможностей ДСЗ, которые смогут обеспечить снижение удельной энергоемкости при изготовлении товарных фракций щебня.

**Ключевые слова**: энергосберегающие технологии, щебень, удельная энергоемкость дробления.

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