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DESIGN MODEL OF CORN GRANULATION AND GRINDING PROCESS*

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Abstract. The paper deals with a robotized, a ***integron*** as the model for semi-intelligent development of grain particles grinders. Integron, i.e. the mathematical model of runs and instantaneous, average values as well as standard expedient, deviations of energetic and plane shapening of sections, forces and energy of disintegration in creation with the application of genetic algorithms (GA-AI), innovative solutions of new generation multisided seeds grinders has been presented in the study.

Keywords: development of grinders, genetic algorithms, grinders, new construction

INTRODUCTION

The semi- or fully intelligent development machinery construction especially of grain grinders is not only because of the standardization by the European Commission today a hot topic. One of the consequences is the increasing inefficiency of not automated in the next years. Cognition and development of the existing and discovered machines' construction, so also shredders, takes place on the basis of the second degree signs, being mathematical models and at the same time the second degree signs of a construction – *signa signorum* [3]. Existence of machines, structure and character of machine's reality are included by theory, that responds to the concept of ontology. Machines' ontology is yet different than the ontology of existence, as apart from the real existence of machines it also includes their imaginary existence in real intelligence of a creator or artificial intelligence – of a creator and a computer (system of science on constructional and innovative knowledge, that is epistemology) [2,10].

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ASSUMPTIONS

1. Cognisance and the development of machines' construction takes place on the basis of mathematical models being the second degree construction's signs – *signa signorum*;
2. The analysis of the system, in the mathematical and genetic sense, includes two planes, two intersections: one horizontal and one vertical;
3. The following rules govern the organization and development of technological systems for disintegration: purposefulness of activity, energy (activity) minimum, auto-regulation, even if it is only a possibility of realization of matter distribution, and storeyed construction.
4. Disintegration *integron* is composed of units of well defined and temporary structures almost identical as far as surface, force and energy is concerned;
5. The development is indicated both by the increase of the number of interactions with the surroundings, as well as the increase of complications and elasticity (plasticity) of a genetic programme realization depending on the surroundings (environment) requirements;
6. There is no difference in the natures of the living and still world, the difference is on their complexity.

Constructional mathematical models of food corn disintegration engineering, include the following: physical and environmental issues, after-effects and are the second-degree signs, purposefully processed for the positive process of biological materials shredders' ontology.

The following rules govern the organization of living organisms:

- Purposefulness,
- Minimum of energy (of acting),
- Auto regulation and
- Storied construction.

Purposefulness shows a machine, the whole organism, but its every part carrying out a certain function in a dynamic system capable of reproducing.

The rule of *minimum energy* is expressed with the fact that all the reactions occurring in the machine and organism, proceed always in the direction of free energy decrease.

Regulation takes place through the changes of mutual interactions' changes, potentials' evening out, chemical reactions.

Storeyed construction consists in the fact, that each machine, biological system is built up of elements (units) that are connected in the units of the next order etc. from molecules up to organisms' population. Therefore, each unit is composed of sub-units, these sub-units from their sub-units, etc.

There are no differences between living and still world as far as their nature is concerned, **the difference is in complexity** [2,4]. „If metabolism were the result of spontaneous and probable reactions, organism would burn just like a system (machine) devoid of a regulator” [2,4].

MODEL OF A CONSTRUCTION’S DEVELOPMENT

From the general properties of a machine as a living organism (Fig. 1), that it is a homeostatic and anti-entropy, there results the necessity of preserving this state of being for a longer period of time. Populations, species, and not individuals, are subject to evolution. Individuals live relatively short, while populations and species are characterized by continuity and longevity [3,7]. Each chromosome in population of multi-shield, multi-edge grinders (constructional, admissible set) may be presented in the following form – Figure 2.

CONSTRUCTION LIVES, **SHE** IS **PROCESSED**, **SHE CHANGES** IN **USE**:

- creative,
- software,
- hardware,
- technological,
- storage,
- processing,
- exploational,
- ecological,……….

Fig. 1. Conditions, areas and states of the construction

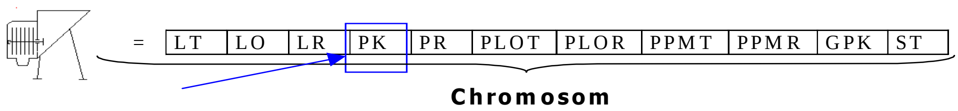

Fig. 2. Mechanism of inheritance as an application of multi-edge mill design; LT – number of shields, LO – number of openings in the first row of the first shield, LR – number of rows, PK – angular velocity, PR – row radius, PLOT – increase of the number of openings between shields, PLOR – increase of the number of openings between rows, PPMT – increase of the radius of rows between shields, PPMR – increase of the radius of rows in a shield, GPK – angular velocity gradient, ST – shields’ diameter

Two basic complexes of factors integrate population: 1) ecological, and 2) genetic. The first ones allow for its application on a given area. Genetic factors decide on the further development of population.

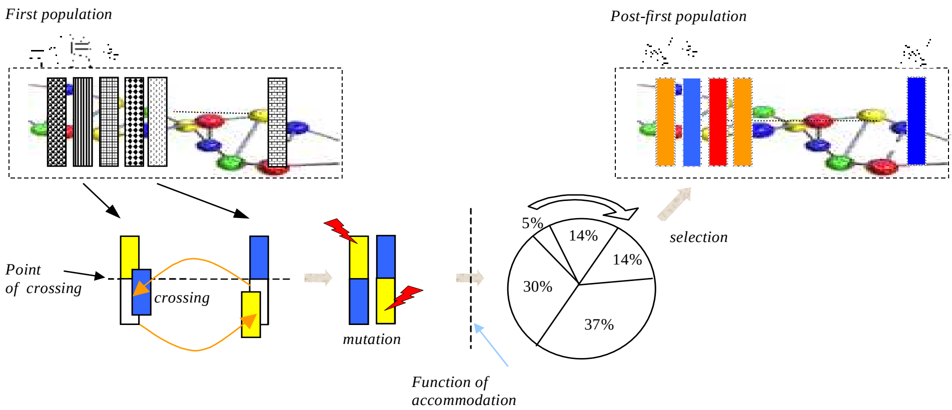

Fig. 3. Operating schema of genetic algorithm

As gar as genetics is concerned, population consists of individuals creating a pool of genes, that constitutes a material for evolution (Fig. 3) [10]. In case when *crossing* of individuals takes, place at random, then gametes and alleles also combine at random creating systems appearing with a specified frequency. Establishment of new hereditary features, that become the source of organisms changeability, is called *mutation*. In case when the arose mutation is harmful and presents a dominating allele, then mutation is harmful and presents a dominating allele, harmfulness is manifested immediately in phenotype, that in final effect shall be eliminated, and shall be subject to *selection*. The phenomenon of migration remains an additional issue if machines' construction, but it is a more complicated case as far as evolution is concerned. Functions of accommodation (elasticity) to [5, 11]: surrounding, terms of production, usage, feeding, monitoring, making diagnostics, etc., is the next important factor in genetic construction's development.

A genetically developed population is identified and represented by: a structure's complex of genes and a gene used for reading the genes of structure – so called integrator. This complex structure's of genes together with the operator's gene, has a form of a mathematical model and is called an integron.

Design model of grinders, integron in two planes

Disintegrating intersection – horizontal integron:

While determining integron, in the first phase during modelling the level of disintegration, the temporary intersection of disintegrating was applied (Fig. 4):

$$F_R = \int_{x_1}^{x_2} \left\{ b_2 + \left[R^2 - (x - a_2)^2 \right]^{1/2} \right\} dx - \int_{x_1}^{x_2} \left\{ b_1 - \left[R^2 - (x - a_1)^2 \right]^{1/2} \right\} dx \quad (1)$$

where: a_1, a_2, b_1, b_2 – openings co-ordinates, R – radius of the openings.

Such a proceedings is difficult due to long time of calculation of the area of disintegration for a big number of openings in shields and big number of shields.
It was decided, that in order to increase the efficiency of computer calculations, geometrical dependencies shall be applied for calculation of a circle's segment (Fig. 4). Calculation of the intersection of disintegration F_R between two openings of centre's coordinates $C_1\ (a_1,b_1)$, $C_2\ (a_2,b_2)$ consists in determination of distance between the centres of openings (Fig. 4):

$$\overline{C_1C_2} = [(a_2 - a_1)^2 + (b_2 - b_1)^2]^{1/2} \tag{2}$$

assuming, that field F_R is the sum of two equal circle segments determined by a chord B_1B_2, $\overline{C_1C_2} = w$ and the field of a circle segment is calculated in the following way:

$$1/2\ F_R = 1/2\ (\alpha - \sin\alpha) \cdot R^2 \tag{3}$$

where: α – is the central angle $< B_1C_2B_2 = < B_2C_1B_1$ the problem amounts to determination of a temporary central angle.

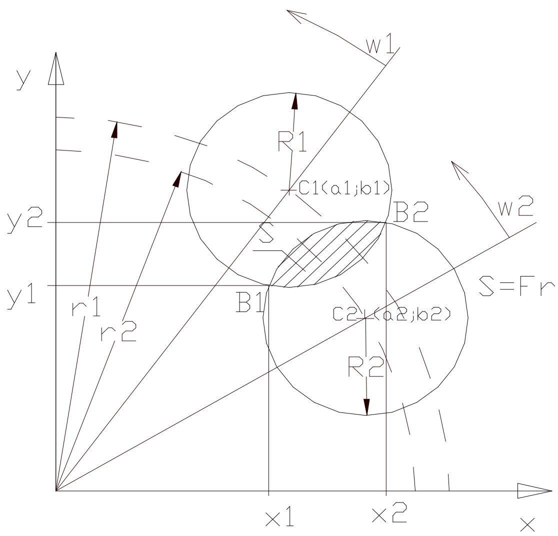

Fig. 4. Surface area between the edges of two openings on two storeys; integron – purposeful, energetic, storeyed sub-unit

In such a way, dependence (3) is given the form:

$$F_R = (B - A) \cdot R^2 \tag{3a}$$

$$F_R = \left\{ \left(2arctg \frac{\left[1-\left(\frac{w}{2R}\right)^2\right]^{\frac{1}{2}}}{\frac{w}{2R}} \right) - \frac{w}{4R}\left[1-\left(\frac{w}{2R}\right)^2\right]^{\frac{1}{2}} \right\} R^2 \qquad (3b)$$

it is integron of disintegration for two openings located in two adjacent storeys of shields and meeting the requirements:

$$R < \overline{C_1C_2} < 2R \qquad (4)$$

temporarily, in the adjacent shields in which the number of openings is bigger, there may be more pairs of openings meeting the requirement (4). The effective disintegrating surface for two shields (Fig. 5) is shown on a drawing as an example.

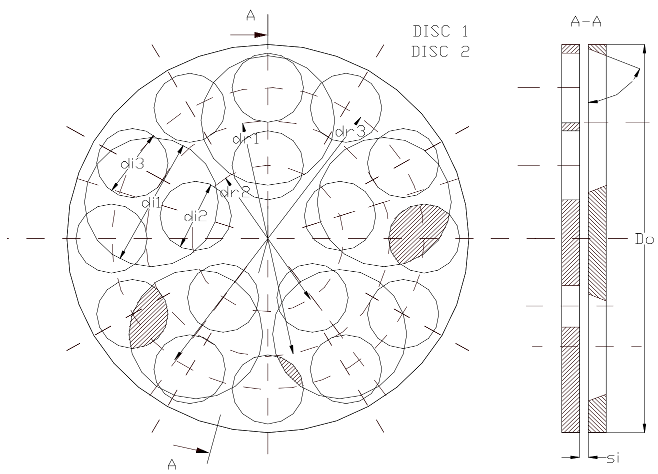

Fig. 5. Relations and area of surface between the edges of numerous openings, on two storeys; integron – purposeful, energetic, two-storeyed sub-unit

Due to a complex, but mathematically determinable character of integron's calculations: intersection, resistances and unit energy consumption for multi-shield disintegration, the minimum energy estimators assume the form:

- minimum difference of intersections for the considered time interval:

$$\Delta F = \frac{F_{\max} - F_{\min}}{F_{śr}} \Rightarrow 0 \qquad (5)$$

- minimum absolute energy for disintegration:

$$E_R \Rightarrow E_{Rmin} \tag{6}$$

- minimum energy difference for disintegration, for the considered time interval:

$$\Delta E_R = \frac{E_{R\max} - E_{R\min}}{E_{R\acute{s}r}} \Rightarrow 0 \tag{7}$$

Vertical-horizontal (oblique) integron

Curvature and torsion (second curvature) of oblique integron:
The number that characterizes curve's deflection (including point M in its small part) from the straight line (drawing 6) is called *curve K* of oblique integron's curve in point M [4]:

$$K = \lim_{\overset{\cup}{MN} \to 0} \left| \frac{\Delta t}{\overset{\cup}{MN} \to 0} \right| = \left| \frac{dt}{ds} \right|. \tag{8}$$

Curve's radius $\rho = 1/K$; K and ρ for space curves are always positive.

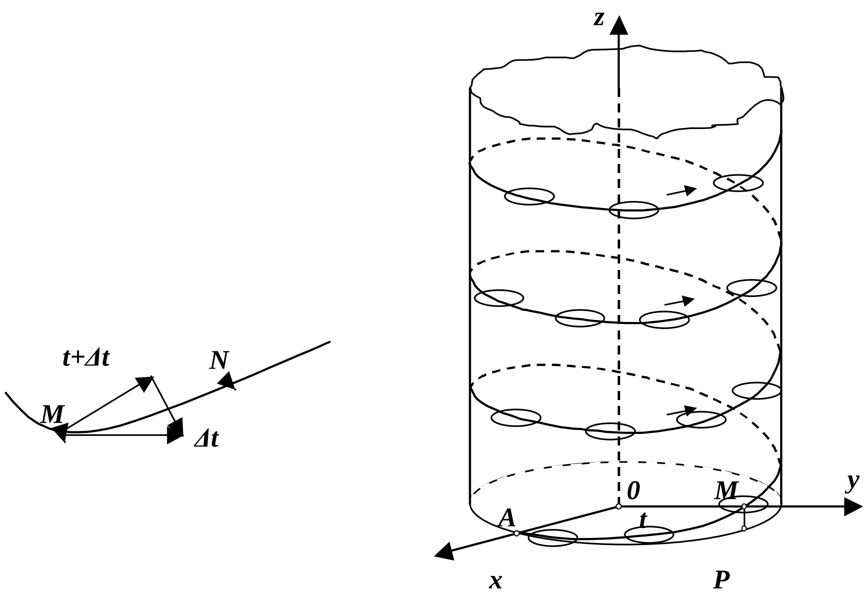

Fig. 6. Curve and torsion of vertical-horizontal *integron* for new generation grinder on many storeys

Formulae for *K i ρ* calculation:

a. For a given curve in the form of co-ordinates

$$K = \left|\frac{d^2 r}{dt^2}\right| = \sqrt{x''^2 + y''^2 + z''^2} \qquad (9)$$

(derivatives with respect to s).

b. For a given data in a parametric form

$$K = \sqrt{\frac{\left(\frac{dr}{dt}\right)^2\left(\frac{d^2r}{dt^2}\right)^2 - \left(\frac{dr}{dt}\bullet\frac{d^2r}{dt^2}\right)^2}{\left|\left(\frac{dr}{dt}\right)^2\right|^3}} = \sqrt{\frac{\left(x'^2+y'^2+z'^2\right)\left(x''^2+y''^2+z''^2\right)-\left(x'x''+y'y''+z'z''\right)2}{\left(x'^2+y'^2+z'^2\right)^3}} \qquad (10)$$

(derivatives with respect to t).

In order to find curvature of a screw line (Fig. 6) *x = acos t, y = asin t, z = bt when a>0, b≠0* (*), substituting parameter t for $s = t\sqrt{a^2+b^2}$ we obtain

$$x = \alpha\cos\frac{s}{\sqrt{\alpha^2+b^2}}, \qquad y = \alpha\sin\frac{s}{\sqrt{\alpha^2+b^2}}, \qquad z = \frac{bs}{\sqrt{\alpha^2+b^2}}, \qquad (11)$$

and from formula (9)

$$K = \frac{a}{a^2+b^2} = const \qquad \rho = \frac{a^2+b^2}{a} = const. \qquad (12)$$

The same result we obtain without going to parameter s applying formula (10).
The number defining curve's deflection (including point M in its small part) from plane curve is called as torsion or second curvature *T* of integron's curve in point *M*:

$$T = \lim_{\overset{\cup}{MN}-0}\left|\frac{\Delta b}{\overset{\cup}{MN}}\right| = \left|\frac{db}{ds}\right|. \qquad (13)$$

Torsion radius τ = 1/T.

([1]) Integron's screw line, defined by the above formulae and presented on Fig.6 is called dextrorsal. An observer placed inside a screw line along its axis, i.e. along O axis with his head in the positive direction of this axis shall see the next coils of screw line rising up in the counter clockwise. A screw line symmetric to dextrorsal screw line with respect to any plane is called a sinistrorsal plane.

Formulae for T and τ calculation:

1. For a given curve in the form of co-ordinates

$$T = \frac{1}{\tau} = \rho^2 \left(\frac{dr}{ds} \cdot \frac{d^2r}{ds^2} \cdot \frac{d^3r}{ds^3} \right) = \frac{\begin{vmatrix} x' & y' & z' \\ x'' & y'' & z'' \\ x''' & y''' & z''' \end{vmatrix}}{\left(x''^2 + y''^2 + z''^2 \right)} \tag{14}$$

(derivatives with respect to s).

b. For a given curve in a parametric form

$$T = \frac{1}{\tau} = \rho^2 \frac{\left(\frac{dr}{dt} \cdot \frac{d^2r}{dt^2} \cdot \frac{d^3r}{dt^3} \right)}{\left| \left(\frac{dr}{dt} \right)^2 \right|^3} = \rho^2 \frac{\begin{vmatrix} x' & y' & z' \\ x'' & y'' & z'' \\ x''' & y''' & z''' \end{vmatrix}}{\left(x'^2 + y'^2 + z'^2 \right)^3} \tag{15}$$

(ρ is calculated according to formulae (9) or (10)).

Torsion T calculated with application of (14) or (15) formulae may be positive or negative. If $T>0$, then for the observer standing on a normal main parallel to binormal, the curve in point M turns left up (just like in dextrorsal corkscrew). If $T<0$, then the turning direction is opposite, i.e. from left to right and up.

For construction integrons created in a screw line, turning T is a constant value. For a dextrorsal screw line, (when $b>0$) turning T amounts to

$$T = \left(\frac{a^2 + b^2}{a} \right)^2 \frac{\begin{vmatrix} -a \sin t & -a \cos t & b \\ -a \sin t & -\alpha \cos t & 0 \\ a \sin t & -a \cos t & 0 \end{vmatrix}}{\left[\left(-\alpha \sin t^2 \right) + (\alpha \cos t)^2 + b^2 \right]^3} = \frac{b}{\alpha^2 + b^2}, \qquad \tau = \frac{\alpha^2 + b^2}{b}. \tag{16}$$

For a sinistrorsal screw line, (when $b<0$) turning T is negative.

Vectors t, n and b derogative with respect to parameter s may be calculated with the application of the following formulae *Serre-Freneta* [10]:

$$\frac{dt}{ds} = \frac{n}{\rho}, \qquad \frac{dn}{ds} = \frac{t}{\rho} - \frac{b}{\tau}, \qquad \frac{db}{ds} = -\frac{n}{\tau}, \tag{17}$$

where: ρ is the curvature radius, and τ is the turning radius.

Force and energy

On the basis of grinding force equation [4, 5, 10]:

$$P_R = k_j \cdot v_r + \sigma_{\max} \cdot F_r + \varepsilon \cdot F_r^{'} \cdot v_r^2 \tag{18}$$

where: k_j – coefficient resistances of running idle (kg s^{-1}), v_r – grinding velocity (m s^{-1}), σ_{max} – maximal stresses in grinding area between edges and grain particles (N m^{-2}), F_r, $F_r^{'}$ area of milling field section (m^2), ε – coefficient of proportion (N s^2 m^{-4}),
it may be possible to obtain simplified equation determining energy consumption during milling [4]:

$$E_E = \frac{\left(k_j \cdot v_r \cdot \sigma_{\max} \cdot F_r + \varepsilon \cdot F_r^{'} \cdot v_r^2\right) \cdot v_r \cdot t}{\eta_S \cdot \eta_P} \tag{19}$$

where: t – milling time of relative field section (s).
This equation contains the main elements (parts) of efficient-energetic integron – model of multi-shield grinder. In consideration of milling specificity for fodder aims related to increase feed-efficiency, general energetic model may be determined [4]:

$$e_R = \frac{\left(\eta_{bio} - \eta_z\right) \cdot E_{brutto} \cdot \eta_S \cdot \eta_P}{\left(k_j \cdot v_r + \sigma_{\max} \cdot F_r + \varepsilon \cdot F_r^{'} \cdot v_r^2\right) \cdot v_r \cdot t \cdot M_k} \tag{20}$$

where: η_{bio} – factor of biological value, described on the ground of riddled analysis and in vitro digestibility for grinding material (–), η_z – factor of grain digestibility before grinding (–), E_{brutto} – average content of gross energy in 1 kg dry substance of grain, e.g.: rye – 15,7 MJ kg^{-1}, wheat – 16,2 MJ kg^{-1} , barley – 15,9 MJ kg^{-1}, oat – 16,5 MJ kg^{-1}, M_k – multiplier of mass attempt – if denominator components concern data different from 1 kg.
There is a possibility to calculate a factor of biological value η_{bio} for a definite section of each size groups of comminuted material [4, 6]:

$$\eta_{bio} = f_{<0,5}\ \eta_{bio<0,5} + f_{0,5\text{-}1,5}\ \eta_{bio0,5\text{-}1,5} + f_{>1,5}\ \eta_{bio>1,5} \tag{21}$$

where: $\eta_{bio<0,5}$ -, $\eta_{bio0,5-1,5}$-, $\eta_{bio>1,5}$- factor of grinding product biological value described by its dimension,

$f_{<0,5}$ -, $f_{0,5-1,5}$ -, $f_{>1,5}$- fraction share of described dimension.

The integron of energy calculated as above is a numerical interval determined with a suitable probability or average number for investigational criteria of purpose.

EVALUATION OF THE OBTAINED RESULTS

The constructive features of the working set of the multiple disc seed grinder should be selected in such a way that the function achieves the maximal value (because of the e_R, indicator value) or minimal (because of the value of the unit energy consumption indicator E_R).

The point where the function value fulfils the required criterion is called problem solution: $x^* = (x^*_1, ..., x^*_n)$. The solution is, of course, from the permissible area:

$$x^* \in \Phi$$

The principle of the support in the direction of getting the extreme solution can be defined:

$$\left\{X^* \in \phi\right\} : \left\{ \underset{x \in \phi}{\wedge} Z(x) \geq Z\left(X^*\right) \right\}, \tag{22}$$

in the case of minimization of energy consumption ($Z=E_R$)

$$\left\{X^* \in \phi\right\} : \left\{ \underset{x \in \phi}{\wedge} Z(x) \leq Z\left(X^*\right) \right\} \tag{23}$$

in the case of maximization of energetic grinding indicator ($Z=e_R$).

If the target point is known in the target space (e.g. $E_R < 10$ *kJ/kg*), it is possible to conduct the procedure aiming at approaching the given solution.

This way a new purpose function is obtained. It is in the form of the distance between the target condition and the countess condition in the target space:

$$Z_d(x) = \left\| Z_{\min} - Z(x) \right\| \tag{24}$$

where: Z_d – the distance between the solution quality vector Z(x) and the target solution Z_{min}.

In the case of Euclidean norm, the distance is expressed by the following formula:

$$Z_{dl}(x) = \left\{ \sum_{i=1} \left[Z_{i\min} - Z_i(x) \right]^2 \right\}^{\frac{1}{2}} \tag{25}$$

where: Z_{imin} – the value of unitary energy consumption for the target solution, $Z_i(x)$ – the value of the unitary energy consumption for the designed solution.

SOLUTION

The task of minimization of a standard deviation of a selected integron, for ex. value of disintegration intersection for a group of data, may be easily transformed into a problem of maximization – it is consistent with the assumed mode of application/interpretation of the accommodation function: the bigger is its value the better is the solution. Because of that, worse solutions (characterized by a bigger standard deviation, that is smaller value of an accommodation function) shall be slowly removed from population (natural selection) and individuals that shall remain, should be characterized by desirable – from the point of view of criteria – features of construction. In the programme IE_TEST-07_BIO [4], there is an option of selection by a user of the mode of calculation of deviations from the average:

- Standard deviations,
- Absolute value from half of the difference between extreme values.

A genetic algorithm is characterized by two basic information configured from the level of the programme:

- Size of population,
- Number of generations (turn).

Example

A preliminary analysis of the algorithm's results shows diversity of new solution of interesting estimators characteristics. It results from the analysis, that both the energetic effectiveness as well as optimum disintegration intersections are very sensitive to the changes of constructive features.

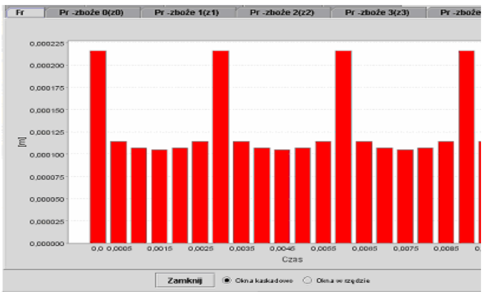

Fig. 7. Graph of temporary disintegration intersections – increase of openings between shields = 2

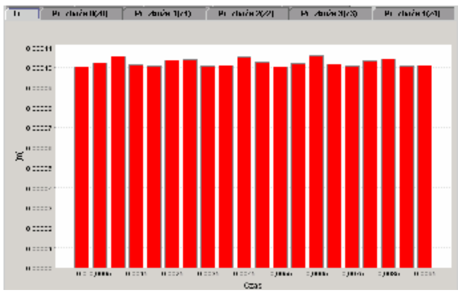

Fig. 8. Graph of temporary disintegration intersections – openings' increase between shields = 1

Many a time, after the change of one feature of the suggested by a genetic algorithm solution for epsilon value, the characteristics describing the solution violently lost their innovative character in the categories of efficiency. Exemplary graphs for constructions differing with the increase of the number of openings between shields for unit value are presented on Figure 7.

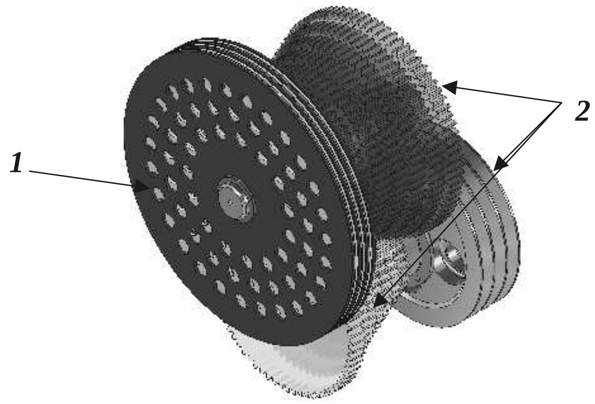

Fig. 9. Multi-disc corn grains new generation grinder construction unit – 1, and gear systems – 2 [1]

We may see, that on the drawing (Fig. 7) there appear characteristic, temporary files, very unfavourable from the point of view of energetic process. However, the decrease of the number of shields constituting the increase between shields for value 1 (Fig. 8), results in the fact, that the solution becomes more interesting due to the minimum intersection increase criteria and energetic efficiency. A detailed analysis of effectiveness of genetic algorithms used in the constructions supporting process, requires making systematic studies under the supervision of an expert on multi-shield biomaterials grinders.

Multi-disc corn grains new generation grinder (Fig. 9) belong to the group of devices in which the process of grinding is performed at linear speed of the cutting edge of approximately 1 m s^{-1}, and the noise level is low (approximately 76dB(A)). The grindered material remains in a permanent contact with the cutting discs within the grinding area. This property, and the lowered linear velocity, are two basic factors that contribute to high efficiency of the process [3,7]. It is assumed that the corn material is subjected to quasi-shearing that results in shredding of the material. Loads and non-dilatational strain in material grains may appear on one or two edges of holes in the discs (Fig. 9) that are in rotational motion with respect to one another.

CONCLUSIONS

On the basis of conducted considerations, proceedings in the direction of specifying the biological and technical analogies, searching for the model of evolution integron, progress and the development of construction of multi-shield biologic materials' grinders, certain generalizations and conclusions of a detailed character may be formed;

1. The following reactions and should be discovered and relations should be settled down for the existence of conditions favourable for the application of biological sciences in supporting the grinders' constructions: life-construction, within the scope of physical, environmental issues, results of activities, and that the grinders' constructions as subunits are the second degree signs, purposefully processed for a positive progress of biological materials ontology.
2. The following rules govern the development, progress, activity and organization of living organisms, machines' construction inclusive: purposefulness, energy (of activity) minimum, auto-regulation and storeyed construction, that are characteristic of the concept of *integron*, form-physical work, composed of units of "relatively well defined dimensions and structures almost identical" and changeability (morph-physiological), caused by a diversity of environments, that is a certain, timely mathematical model.
3. With the assumptions including the essence of biological and technological differences and convergences of the biological materials disintegration engineering, the model of storeyed intersection's development realized in order to obtain the increase of proper surface in the conditions of a minimum energy consumption may be suggested, that is integron – as a genetically evolution tool.
4. In the IE_TEST-07_BIO programme, there is an option of selection by a user of the mode of calculation of average values, deviations from the average, as estimators evolution the constructional chromosome's solution.
5. The average value of intersection for all the iterations in a single simulation is an additional measuring device of the solution's quality in case of a construction optimisation, due to a diagonal integron of disintegration intersection. That means, that a potentially interesting solution should be characterized with minimum intersection's fluctuation in the "total living cycle" and its high mean value.
6. Thanks to the integron-model application of the IE_TEST-07_BIO proceedings applying genetic algorithms, in the field of accepted assumptions, an optimal solution of a construction of 10-shields corn grains shredded in the integron conditions: intersection – force subunit, force – energy subunit, energy – disintegration subunit, disintegration – construction subunit, material and process parameters.

7. The constructional solution was verifies with a positive result within the scope of product's quality and process efficiency, in the conditions of constructional studies – testing ground.

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MODEL KONSTRUKCYJNY GRANULOWANIA I ROZDRABNIANIA ZIARNA

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Streszczenie. Na drodze rozwoju, semioptymalizacji i robotyzacji rozdrabniaczy ziarna, wykorzystano właściwości integronu jako modelu matematycznego. Integron jako model matematyczny konstrukcji pozwala, w oparciu o: celowość, minimum energii, samosterowanie i piętrowość, na koncypowanie i kreowanie, rozwiązań innowacyjnych a nawet nowych generacji wielotarczowych rozdrabniaczy ziarna. Prezentowane rozwiązanie semioptymalne, uzyskano w ramach zastosowań algorytmów genetycznych sztucznej inteligencji (AG-AI).

Słowa kluczowe: rozwój rozdrabniaczy, algorytmy genetyczne, rozdrabniacze, nowa konstrukcja