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Reasoning of parameters and operating conditions of the direct stroke grain crusher

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ABSTRACT

This article provides basic results of theoretical and experimental studies of the cornmeal crushing process using the direct stroke grain crusher. On analyzing the current state of the problem, the conclusion had been made considering that one the ways to improve the crushing process is the grain crusher scheme implementation with the preliminary separation of the initial material and grinding each fraction at separate stages. The authors have developed the method and the instrument for crushing grain by the direct stroke of operating parts in the form of metal fingers with the preliminary separation of the grain material. Such a direct stroke grain crusher can be effectively used on small livestock farms. The article contains a description of the pin crusher prototype with the vertical axis of rotor rotation, being served as the basis for creating an experimental installation. Theoretical and experimental researches were carried out in order to set rational ratios of grain crusher designing parameters. Experimentally obtained regression equations, making it possible to determine the parameters of the given grain crusher type size, were described. The technique of forecasting energy costs when crushing grain material was developed, having made it possible to implement the forecasting of the efficiency rate and capacity of crushing the raw stuff, using the grain crusher. Experimental researches have clearly proved that the rational range of technological modes determined that the content of dust-like fraction in the ready-made product is 3…5 times less than while crushing at hammer crushers of other constructions. The specific energy consumption of crushing process in the direct stroke grain crusher is 1.8…2 times less than for other crushers.

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1. Introduction

Crushing is one of the most power-consuming processes at processing of feed grain for the cattle and poultry. For this purpose hammer crushers are mostly used. At fine crushing these crushers give up to 30 % of powdered faction, and at rough - to 20 % of underground factions.

At present especially the problem of hardware, forage crushers for private, peasant and also small farms is getting especially urgent.

Among considered schemes of grain crushers it is possible to distinguish the following schemes of grain crushing with prior separation of initial product (grain): with open cycle; with recirculation of underground material; with multi-stage recirculation and crushing; with preliminary separation of initial product and crushing of each faction on the separate stages.

Examination of schemes of technological process of crushing with the division of grain into factions allowed drawing the following conclusions:

- the minimum power output of the process can be achieved with combining of grain supply in such interval of physical-mechanical properties which would provide the most complete crushing of grain on the given stage and optimal load of the cascades of the crusher;

- Providing the first condition the partial passing of underground grain to the next stage is possible, therefore the construction of crusher must provide the scheme of the multi-stage crushing.

We worked out a method and device for grain crushing by the direct strike of the driven elements in the form of metallic fingers [6, 7]. Such crusher of direct strike with prior separation of grain material is compact enough, does not require the use of powerful drive equipment and can be effectively used on small stock-raising farms [2-4].

The analysis of scientific publications allowed to educe the following most perspective ways of improvement of direct strike crushers constructions:

- decline of specific consumptions of energy and specific quantity of metal due to the application as crusher driven elements of the ultrafine hammer in the form of a thin metallic bar or metallic string;

- preliminary grain separation organization process considering the size;

- maximal discharge of the ground product of the specified size due to the creation of the effective constructions of separators;

- decline of the circulatory loading as a result of the speed-up taking of the ground up particles from the crushing chamber;

- increase of separation intensity of the sieve surface due to the application of the special form of the distributive surface of the sieve;

- maximal use of the peripheral and butt-end surfaces of chamber of the crushing chamber;

- crusher’s air mode rational organization.

In order to establish rational correlations of the developed crusher structural parameters, the methodology of the mathematical planning of experiment was applied.

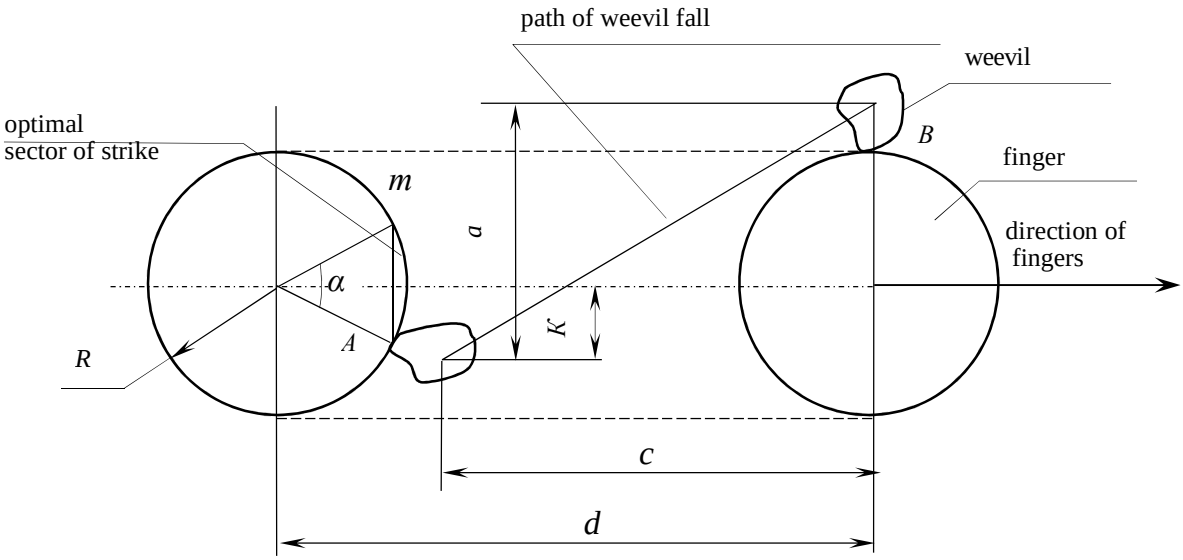
As a method of prognostication and determination of factors for realization of the experiment an expert method (method of Delphi) was chosen.

The criterion of optimization the module of grain crushing was chosen. The selection of factors for realization of optimization researches came true on the basis of review of literary sources, theoretical analysis of grain crushing processes and a priori ranging after the method of Delphi.

An expert group of 8 specialists estimated the following factors: ***X1*** – frequency of crusher rotor rotation ***n***, min^{-1}; ***X2*** – speed of falling of grain material ***v***, m/sec; ***X3*** - a grain material supply ***Q***, kg/sec; ***X4*** – grain material falling height ***H***, mm; ***X5*** - quantity of rotor fingers ***τ***, pcs; ***X6*** – grain material falling angle, degrees.

As a result of conducted a priori ranging, first 3 places occupied the following factors: rotor rotation frequency ***n***, min^{-1}; supply of grain material ***Q***, kg/sec and quantity of rotor fingers ***τ***, pcs.

In the picture 1 the design diagram is shown for determination of basic parameters of the weevil falling process between the fingers of the crusher. According to the picture, moving of weevil from the point ***A*** (maximum point on the finger, at which the strike will be given to the grain, sufficient enough for destruction) to the point ***B*** (the point of the end of the trajectory of weevil falling) is examined.



Picture 1. Design model of weevil falling between the fingers of the crusher

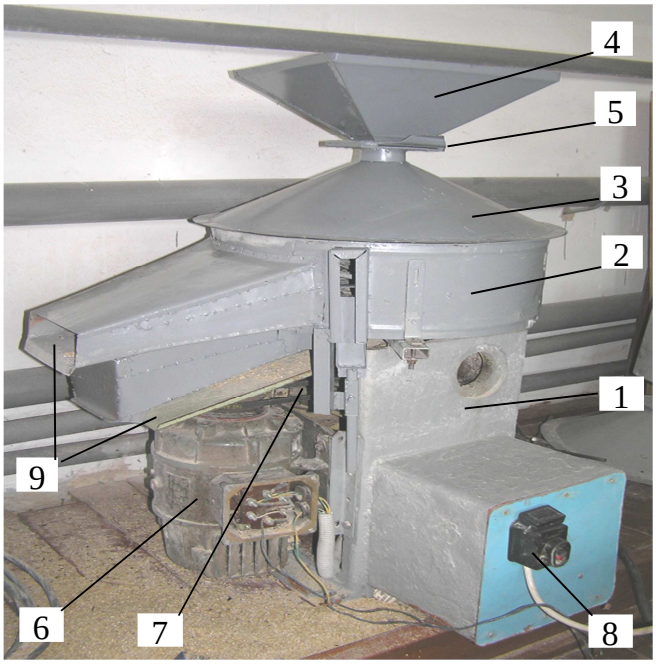
As a result the expression for determination of the number of fingers is received:

$$Z = \frac{60\pi \cdot R_\partial \cdot \sqrt{g}}{\pi \cdot R_\partial \cdot n\sqrt{R \cdot \sin\alpha + 2(R + R_з)} + 30(R + R_\partial)\sqrt{g}}$$

and minimum speed, necessary for destruction of weevil υ_{min}:

$$\upsilon \geq \upsilon_{min} \quad \text{or} \quad \frac{\pi \cdot n}{30} \cdot R_\partial \geq \upsilon_{min}$$

With the use of the worked out dependences the example of finger crusher is constructed with the vertical axis of rotor rotation which served as a basis for creation of the experimental device (picture 2).



Picture 2. General view photo of the experimental crusher:
1 – frame; 2 – crushing chamber; 3 – separator; 4 – bunker; 5 – regulative shutter; 6 – electric motor; 7 – strap transmission; 8 – control stand; 9 – areas of selection of bottom row of driven elements and bottom jalousie sieve.

The novelty of technical decision of crusher with the improved system of grain separation and products of crushing is protected by 4 patents of Ukraine on the invention and 4 declarative patents on useful models.

During realization of the planned experiment the matrix of three-factor experiment was extended by additional experiments for the receipt of equation of the second order. The experiment is conducted three times - at three different values of openings of the sieve device *8*, *10* and *12* mm.

For each pair factor interaction : rotation and supply frequency, frequency of rotation and number of fingers, the supply of material and number of fingers the surfaces and lines of levels of function of review are built to as for example, in the picture 3.

The received decoded models of the process of crushing looked like:

- for the diameter of openings of the sieve ***do = 8*** mm:

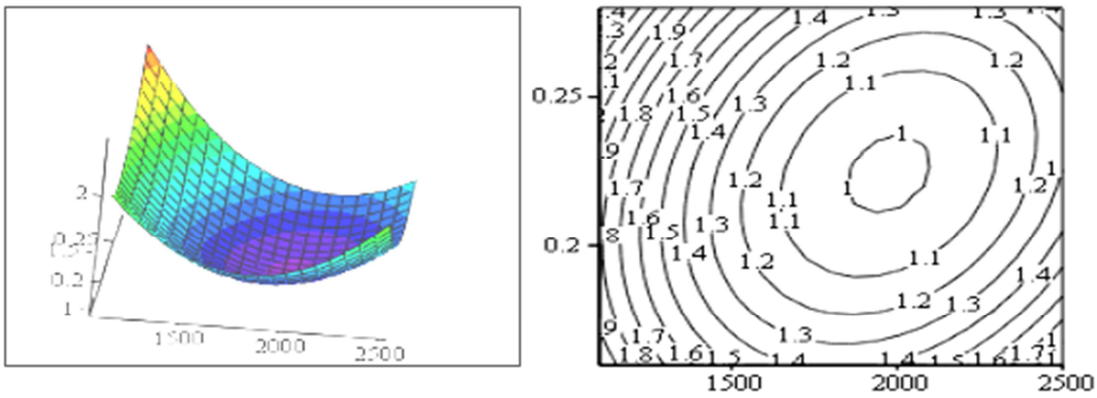
$$\tilde{y}_i = 10{,}4158 - 0{,}00151\,x_1 - 39{,}8645\,x_2 - 0{,}965\,x_3 - 0{,}0056\,x_1x_2 -$$
$$- 0{,}000229\,x_1x_3 + 0{,}6\,x_2x_3 + 0{,}000001164\,x_1^2 + 102{,}8099\,x_2^2 + 0{,}08625\,x_3^2$$

- for the diameter of openings of the sieve ***do = 10*** mm:

$$\tilde{y}_i = 18{,}33 - 0{,}00543\,x_1 - 46{,}13\,x_2 - 1{,}5835\,x_3 - 0{,}00313\,x_1x_2 +$$
$$+ 0{,}691\,x_2x_3 + 0{,}00000147\,x_1^2 + 104{,}132\,x_2^2 + 0{,}0893\,x_3^2$$

- for the diameter of openings of the sieve ***do = 12*** mm:

$$\tilde{y}_i = 18{,}44 - 0{,}00967\,x_1 - 0{,}0035\,x_1x_2 + 0{,}00000247\,x_1^2 + 103{,}802\,x_2^2 + 0{,}0413\,x_3^2$$



Picture 3. Surface and lines of levels of function of response for interaction of frequency of rotation and supply at ***do = 8*** mm

After the careful analysis of graphic dependences and equations of regression corresponding conclusions and recommendations were reached.

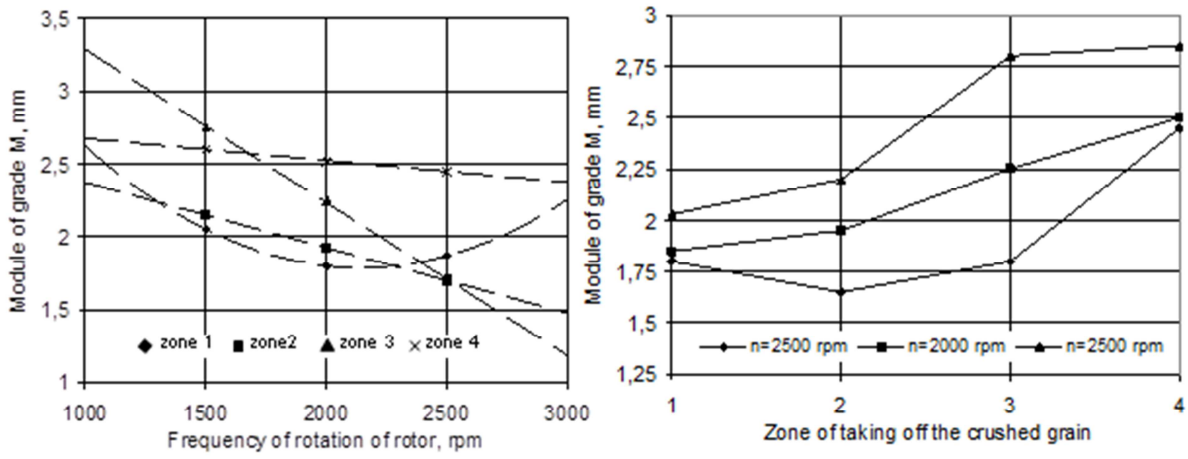
The received results at different diameters of openings of the sieve device are similar by the nature. For this dimension-type of crusher the most rational parameters to be accepted are: amount of fingers - ***8***, frequency of rotation ***1900.2100*** rpm, supply ***800...810*** kg/h.

At the change of diameter of openings of the sieves from ***8*** to ***12*** mm the maximal degree of crushing changes in rather small limits: from 0,95 to 1,14, therefore using replacement of sieves for the change of degree of crushing is inefficient. Change of value of degree of grain crushing from a supply is very substantial and such crushers need batching devices of grain supply, by adjusting the grain supply it is more effective to regulate the degree of crushing.

The conducted experimental researches showed that for receiving crushed grain with the middle value of the module of grade, ***M =1,4.2, 2*** mm it is not reasonable to increase frequency of rotation of rotor of crusher over ***2500*** rpm.

In the picture 4 experimental dependences of the change of the module of grade are shown on the areas of sampling from frequency of rotation of rotor and dependence of the module of grade from the area of selection of the crushed grain at different frequency of rotor rotation.

The analysis of diagrams enables to draw conclusion that for the receipt of high-quality product (by value module of grade) it is necessary to maintain rotor rotation frequency from ***1800*** to ***2500*** rpm. For the receipt of rougher grade it is needed to reduce rotor rotation frequency and, for a fine grade - to increase frequency of rotation.



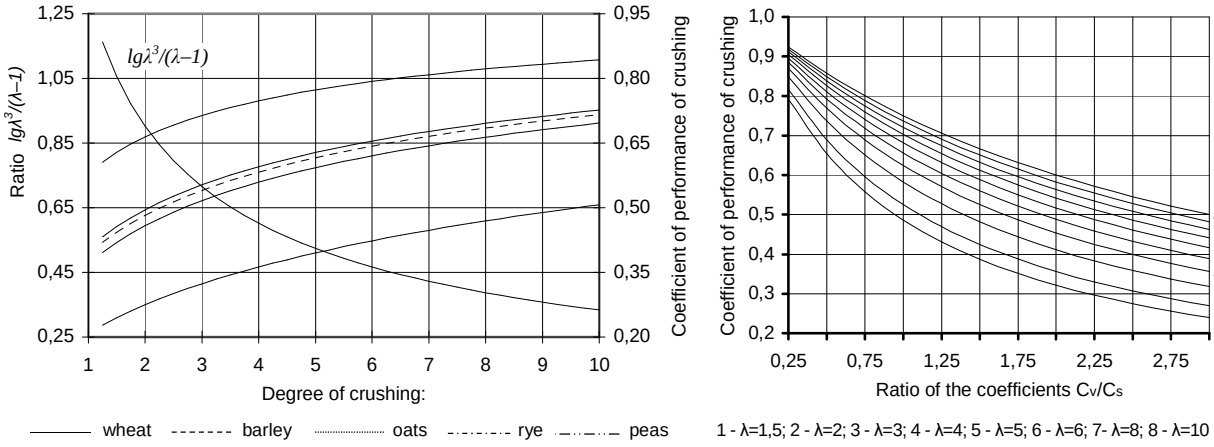
Picture 4. Dependences of the module of grade on frequency of rotation of rotor and areas of sampling of the crushed material

The problem of energy saving, increase of performance coefficient was, is and will be urgent. Therefore the authors of the given work conducted an analytical analysis of power balance and prognostication of grain crusher performance coefficient.

Theoretical considerations of S.V. Melnikov are taken for the basis of researches [1]. All making powers necessary for the drive of the crusher were considered and connection of separate constituents with the basic indexes of the crushed product somehow with the degree of crushing of the material λ and coefficients C_V, which expresses work of resilient deformations, taken to 1 kg of the crushed material and C_S, presenting work, needed for creation of new surfaces of the crushed material were defined.

It allowed deriving a formula for determination of performance coefficient of the crusher depending on the enumerated parameters.

In the picture 5 a) the diagrams of change of the value $lg\,\lambda^3/(\lambda-1)$ and values of coefficient of performance of crushing of grain-crops depending on the degree of crushing λ are given. The diagrams are built on the condition that the relation C_V/C_S during the whole process is a permanent value.



Picture 5. Diagrams of dependences of crushing performance coefficient from the basic indexes of process of crushing

In the picture 5 b) the diagrams of dependence of performance coefficient of the process of crushing from the value of relation of coefficients ***CV/CS*** at different values of degree of crushing ***λ*** are showed.

Thus, for exact prognostication of power consumption at crushing of grain material it is needed with maximal exactness to forecast a value of performance coefficient of the crushing process and, thus, value of power necessary for the realization of this process. The conducted researches enable to realize prognostication of performance coefficient and power of crushing of raw material on the grain crusher.

On the basis of finding we draw conclusion, that receipt of the prepared product of the set grain-size distribution, depending on the chosen mode of operations of the direct stroke crusher with previous separation of grain is fully possible. It proves the aim of researches. From data of frequency distribution on factions at the kinematics mode of crushing with the parameters of the direct stroke crusher of grain at ***Q = 800...1100*** kg/h. and ***n = 2000*** rpm maintenance of powdered faction (with the diameter less than 0,25 mm) in the prepared product at humidity of grain of 14...15% presents: for a wheat ***2,77 %***; barley ***2,86 %*** and their mixtures not more than ***2,81%***. It is by 3...5 times less than, than at crushing on the hammer crushers of other constructions.

Specific power-hungriness of process of crushing in the crusher of direct strike of grain is by ***1,8...2*** times less than for other crushers.

2. Analysis of recent research

The problems of economic security as a priority of the national policy were investigated in numerous theoretical researches and summaries of the native scholars, in particular Baranovskiy A., Boyko V., Heyets V., Hoychuk O., Hubskiy B., Varnaliy Z., Zhalilo Ya., Korets'kiy M., Muntiyan V., Paskhaver V., Pakhomov Yu., Sabluk P., Skydan O., Shlemko V., Yaremko L. and others. However, some aspects of the national strategy of economic security ensuring need to be further investigated.

Statement of research objectives

- to specify the essence of economic security;
- define the role of political institutions in the national security development and implementation process.

3. Results

The market relationship building, the ownership pattern change, the methods of public administration, the openness of national and regional economies define the necessity of economy sustainable development ensuring and permanent monitoring over social-economic processes. Many scholars consider that the basis of national security ensuring is a purposeful activity of a state on making the necessary conditions for encouraging the competitive advantage of national economy leading branches in external markets during strategically long period at the expense of the permanent forward development of economic activity preferred directions.

The notion "economic security" is part of the national security with ecological, defense, intellectual, information, demographic, psychological security and other. The complex of national interests is implemented by all components of national security; at the same time each component has its specifics depending on solved tasks and used means and methods for this purpose (Kovalchuk T., Varnaliy Z., Feschenko V., 2001).

Economic security characterizes the state of national economy which provides protection of national interests as well as interests of both certain citizens of a country and the society in whole. Economic security is directed to ensure proportional and continuous economic growth, inflation and unemployment decrease, formation of an efficient economy structure and a developed stock market, reduction of a budget deficit and national debt, social protection ensuring and life quality rise of a population and national currency stability keeping etc (Burdina O., 2006).

The start of economic security development in Ukraine is closely connected with an active work of National Security and Defense Council of Ukraine; within its frameworks the national strategy of economic security was formed and represented by Ukraine's Law "On Ukraine's National Security basics" №964-IV dated June 19, 2003. This council defined the most important measures for implementation of governmental documents' expertise from the point of economic security. It also determines threshold values of economic security. Overstepping them a country is under a threat of political independence loss and it becomes economically and socially vulnerable (The Law of Ukraine "On Ukraine's National Security basics", 2003).Unfortunately, it turns out that the majority of measures are not carried out; many governmental documents do not undergo the necessary expertise form the point of economic security. Despite the formed contours of economic security strategy the works in this sphere are insufficient.

A state plays the most important role in building and changing of institutional economy structure of any country. It can contribute to the efficient market institutions creating and, on the contrary, it can create an institutional structure which does not allow competition advantages to be developed due to a monopoly authority and other factors that lead to transaction costs. Everything depends on certain historical conditions and comparative efficiency under these conditions in some or other system of the economic coordination. Although namely a state is a necessary attribute of the progressive economic activity, the generated institutions might not encourage efficiency increase but prevent it.

The comprehension of constitutional state democracy is possible via relatively (and absolute) conflict agreement "principal-agent" among electorate and their managers (representatives). The principals are voters (citizens) who are true owners of supreme authority (sovereignty). They authorize some compatriots to govern sovereignty through a voting procedure. As a result they are agents who implement self-governing and the same time they are those who return a state the right to limit the personal liberty and also dictate principals what to do. This is absolutely different from private relations "principal-agent".

Theoretically, the same problem can be observed in transaction cost economics: there is an asymmetry of information before and after making an agreement. This situation is a result of opportunism a priori and a posteriori as specific investment of a voter assists some or other candidate. But this information is divided not only asymmetrically, it also most unlikely to define what will happen in the future. Thus, decisions made by law-makers, government, and state administration bodies and judges can not be perfectly limited with rules. It leaves some freedom for non-obligatory actions of agents who principals (electorate) have to trust. Therefore, the problem of government power to inspire confidence is its duty in front of voters.

The other compulsory problem sphere is that political exchange is carried out among representatives of different groups of society interests. This exchange of voters or deputies is project general support of each other; the voting is by the principle "you vote for my project, I vote for yours". Like at economic exchange it is necessary to build electorate confidence for the purpose of creating convenient institutional arrangement.

In both cases the relations “principal-agent” among electorate and politicians, from one part, and political exchange among interests of different groups, from the other part, are approaching to transaction cost application. But nowadays there is a limited rationality of legislators, imperfection of legal pressure and opportunism (rule-breaker).

Institutional arrangement affects greatly the capacity of agents to make political obligations confidential that allows a state to build economic security more efficiently. For example, clause 41 of Ukraine’s Constitution states: “Everyone has the right to own, use and dispose of his or her property, and the results of his or her intellectual and creative activity. The right of private property is acquired by the procedure determined by law. In order to satisfy their needs, citizens may use the objects of the right of state and communal property in accordance with the law. No one shall be unlawfully deprived of the right of property. The right of private property is inviolable. The expropriation of objects of the right of private property may be applied only as an exception for reasons of social necessity, on the grounds of and by the procedure established by law, and on the condition of advance and complete compensation of their value. The expropriation of such objects with subsequent complete compensation of their value is permitted only under conditions of martial law or a state of emergency. Confiscation of property may be applied only pursuant to a court decision, in the cases, in the extent and by the procedure established by law. The use of property shall not cause harm to the rights, freedoms and dignity of citizens, the interests of society, aggravate the ecological situation and the natural qualities of land” (*Constitution of Ukraine,* 2006). This acts to ensure security for private property owners against the government stealing.

4. Conclusions

Therefore, for economic security building the political institutions have to build, in the first place, the electorate confidence. Voters appoint responsible ones for their security building and transfer the parts of their liberty to a state. Due to this the role of a state in economic security ensuring is essentially increasing. The participation of a state is carried out through the above-mentioned functions of a state in the economic security sphere. It is possible to improve the quality and efficiency of their implementation by updating the corresponding normative legal documents and raising the level of specialist qualification in these kinds of activity.

The solution of the national development problems requires not only the state authority consolidation but building more confidence in its institutions as well as rationalization tools of decision making and economic policy building. At the same time, transferring from the conventional vertical public administration scheme it is necessary to ensure vertical inter-functional relations at Ukraine’s economic security building. Thereby, there is a further need in scientific investigations.

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