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Addition to the structural theory of optimising energy efficiency in consumer systems

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Abstract. The topicality of energy efficiency (or the topicality of ensuring the maximum effectiveness of energy use) in agro technical complexes that incorporate production by means of natural resources (land, water, forests, solar energy), technogenic energy supply systems and biogenic objects (plants, animals, birds) are not defined only by specific features but also by the complexity of scientific issues.

At stationary manufacturing enterprises, the main object of energy consumption is an artificial energy system that incorporates technological processes and the effectiveness of energy processes that determines the overall effectiveness of energy use. Hence, the scientific basis for energy efficiency lies in the mathematical description of energy processes in an artificial energy system through efficiency parameters.

In the consumer's artificial energy system, the transfer of energy from element to element involves a breakthrough that makes it impossible to describe the energy line as a whole. It is necessary to elaborate a method for describing energy movement within each element and possibility of transferring from element parameters to line parameters. It is recommended to use the method of finite relations that is based on the energy conservation law within an element and includes the initial energy value Q_I, final value Q_F and losses ΔQ.

The method of finite relations regards Q_F as the main functional parameter. The division of the total value Q_F gives the parameter a new meaning that corresponds better to the evaluation of the effectiveness of an energy process. Almost all technogenic elements in an artificial energy system represent an organised space that simplifies the relation between the volume and coordinates.

By juxtaposing the energy processes in an artificial energy system with processes in economy, we can see the analogy with regard to such notions as the ineffective development of an energy process and the absolute limit point in economy. Considering that the information about parameters and the coordinates of the point in an energy system can be available at all times (i.e. the position of the limit points can be defined at any moment by considering the rearrangement on axis X), it is clearly possible to evaluate trends in economic processes.

Key words: Method of finite relations regards, economic effectiveness, energy efficiency.

INTRODUCTION

The topicality of energy efficiency (or the topicality of ensuring the maximum effectiveness of energy use) in agrotechnical complexes that incorporate production by means of natural resources (land, water, forests, solar energy), technogenic energy supply systems and biogenic objects (plants, animals, birds) are not defined only by specific features but also by the complexity of scientific issues.

In agriculture, energy efficiency can not be viewed only as a way of becoming competitive in the market, but also as a means of solving the energy issues characteristic of the field of economy, such as increasing the energy supply for work processes, taking the energy consumption in villages to the level of that in urban areas, preservation and development of rural settlements, conflict-free invasion of unoccupied territories, etc.

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MATERIALS AND METHODS

The consumer's artificial energy system is a collection of technical equipment (elements) that form energy lines and a network for a unidirectional movement of energy. The final branches of the network supply energy for the processes of energy technology that represent the goal of energy consumption and are characterised by a specific result

(Karpov, 2005), encompassing the diversity of the process. The key element is the productive process of energy technology that yields the product that is realized in the market. Another type of processes of energy technology is made up of auxiliary processes that support the main process whilst the third type is represented by the processes that provide the resources vital for human life (heating, lighting, ventilation, etc).

Integration of the consumer of energy technology processes in an energy process is a prerequisite for analysing the energy efficiency to evaluate it compared to the existing practice of calculating the maximum capacity of energy supply systems. The main analysis of energy transmission in an artificial energy system could be based on a function describing energy dependence on time and coordinates. Quite a profound and comprehensive approach to such a description has been presented in the works by Professor N. A. Umov (Umov, 1990) explaining energy conservation by the density of the space concerned, considering the boundaries of the environment under review. However, the absence of processes of energy technology restricted the analysis and the characteristics (state) of the transfer environment; moreover, losses in the surrounding environment were taken into account only in some cases of spatial order.

In the consumer's artificial energy system, the transfer of energy from element to element involves a breakthrough that makes it impossible to describe the energy line as a whole. It is necessary to elaborate a method for describing energy movement within each element and possibility of transferring from element parameters to line parameters. It is recommended to use the method of finite relations (Karpov, 1999) that is based on the energy conservation law within an element and includes the initial energy value Q_I**,** final value Q_F and losses ΔQ:

$$Q_I - Q_F = \Delta Q \qquad (1)$$

The method of finite relations regards Q_F as the main functional parameter (considering the processes of energy technology at the end of an energy line). The division of the total value Q_K (1) gives the parameter a new meaning that corresponds better to the evaluation of the effectiveness of an energy process:

$$\frac{Q_I}{Q_F} - 1 = \frac{\Delta Q}{Q_F} \text{ or } Q_E - 1 = \Delta Q^* . \qquad (2)$$

The parameter Q_E stands for the energy intensity of the final value whilst ΔQ^* stands for relative losses.

RESULTS AND DISCUSSION

Almost all technogenic elements in an artificial energy system represent an organised space that simplifies the relation between the volume and coordinates. For a cylinder, it is, for example, important to note that the volume is a linear function of the coordinates that simplifies the description of energy on the coordinate axes significantly. If the values of Q_I and Q_F can be measured, the difference between them can be viewed as a growth of the function since the losses can be expressed in accordance with the Lagrange theorem as the multiplication of the mean derivative within an interval. Within the method of finite relations, the ratio $\frac{\Delta Q}{Q_F}$ changes in relation to the mean derivatives, giving in turn the link between energy intensity Q_E and their derivatives. Indeed, the derivative Q'_E has an autocatalytic expression in time that allows applying methods of synergy for analysing the state of an element:

$$Q^*{}_E = \frac{Q^*{}_I}{Q_F} - Q_E \frac{Q^*{}_F}{Q_F} \qquad (3)$$

Consequently, by measuring Q_I and Q_F, it is possible to determine the changes in the element and the effect of the changes on energy intensity, i.e. on the effectiveness of the energy process. The expression (2) determines the extent of the effect on the state of the element that corresponds to the change in the energy intensity. It is worth noting that the method of finite relations considers also reversible and irreversible losses that allow its application not only for energy transfer elements but also for processes of energy technology to ensure the high effectiveness of the processes.

The fundamentality of the presented method of finite relations (Karpov, 1999) is proved not only by mathematical definiteness but also by a possibility to create a spatial system of effectiveness parameters. The lower limit is the effectiveness, in the case of which the ratio between the losses and final energy is one. According to the expressions presented herein, in this case the relative energy intensity equals two. The spatial order allows determining the smallest volume (or element length) where it is possible to achieve the maximum effectiveness. For a cylinder with radius r, the structural unit is a link with the length $r/2$. If the element length exceeds $r/2$, the maximum effectiveness corresponds to the number of the links that allows viewing the energy efficiency theory based on the method of finite relations as a structural method that gives access to direct information parameters.

One of the peculiarities of the structure is the transmission of the parameter state in coordinates. If the lateral surface corresponds to length Δx, the energy loss through the surface during time *t* can be determined as follows, where Q_T is the derivative by time, *t* is time, and Q'_X is the mean derivative on the coordinate with interval Δx, thus,

$$Q'_T \cdot t = Q'_x \cdot \Delta x. \quad (4)$$

We use the notion of a common structural element - cylinder link with length $\frac{r}{2}$ wherein the end surface is equal to the lateral surface. In this case, if the energy carrier has the constant speed *v*, the time that corresponds to one link is:

$\Delta t = \frac{r/2}{v}$, whereas the time for the control of losses can be expressed by interval Δt, st $m = \frac{t}{\Delta t}$. The length Δt of the coordinate interval can be likewise expressed by the relative unit $n = \frac{\Delta t}{r/2}$. By introducing the corresponding parameters to expression (4), we get

$$Q'_T \cdot \Delta t \cdot m = Q'_x \cdot (r/2) \cdot n. \quad (5)$$

By converting (5), we get

$$Q'_T \cdot m/n = Q'_x \cdot v. \quad (6)$$

At constant speed v and single pass of energy m/n = 1, hence, we get an invariant expression for the structure.

$$Q'_T = Q'_x \cdot v. \quad (7)$$

Invariance determines the speed as the derivative of the role of the transmission operator on the coordinate by time and allows analyzing energy processes using the final values of Δt and Δx.

This is vital for the theory since the mathematical conditions for the derived function with Δt and Δx approaching the zero lead to the zero value of the volume of the organised space, i.e. the energy.

It is worth noting that macro- and microeconomics have recently applied the parameter of economic possible maximum effectiveness (Daily, 2005) that is analogical to the energy parameter ΔQ^* (2) and expresses the possible maximum expediency of financial expenditure as a function of production. Such an analogy can not be regarded as accidental.

The notion ‘ineffective’ production growth adopted in economy to describe the situation where expenditure on ecology exceeds the effectiveness of production, i.e. the level of meeting human needs and wishes (welfare), in essence, leaves but a single possibility of effective growth of consumption – at the expense of new technologies that lower the expenditure on energy resources without increasing their adverse effect on ecology. Thus, if it turns out to be possible to show that the process of energy efficiency (i.e. upon reducing the energy intensity of production) leads to a growth of energy productivity (or a reduction in the energy price per production unit), it allows concluding that energy is the key component that makes it possible to transcend the limits of ‘ineffective’ growth in economy.

CONCLUSIONS

By juxtaposing the energy processes in an artificial energy system with processes in economy, we can see the analogy with regard to such notions as the ineffective development of an energy process and the absolute limit point in economy. Considering that the information about parameters and the coordinates of the point in an energy system can be available at all times (i.e. the position of the limit points can be defined at any moment by considering the rearrangement on axis X), it is clearly possible to evaluate trends in economic processes. This possibility must be viewed as an essential addition to the method of finite relationships in the analysis of the effectiveness of an energy system.

(Karpov, 1994; Karpov & Štšur, 1997) show that the final growth allows finding new solutions for upgrading the effectiveness not only in elements that transmit energy but also in processes of energy technology.

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