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Contents

Содержание

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Laboratory-Scale Plant
for Demonstration and Study
of the Film Heat Exchanger Operation

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Key words and phrases: heat exchanger; laboratory-scale plant; liquid film.

Abstract. The aim of the study was to create a laboratory-scale plant for demonstration and studying the operation of a heat exchanger by students and conducting laboratory work to study the dependence of the degree of the liquid phase heating on the parameters of the switchgear of the laboratory-scale plant. The following tasks were solved to achieve the set goal: the existing designs of laboratory facilities of a similar purpose were studied and analyzed; the original design of the plant was proposed. The plant was created and tested as a result of the work.

The direct interaction of gas and a continuous liquid film flowing from the annular slot occurs in various heat exchangers of chemical technology. The steady flow of an axisymmetric liquid film flowing out of an annular slot was considered in the work [1].

The proposed plant includes an improved liquid distributor design. A distinctive feature of the device is the ability to control the thickness of the liquid film by changing its operation parameters.

The laboratory-scale plant is shown in Fig. 1. The experimental plant consists of the following parts: a liquid heating apparatus; a pump; a portable point action thermocouple; a manometer and an electric heater. The liquid film heater consists of a frame, a heat exchange tube, a bottom, an assembly unit – a liquid distributor, an upper flange.

The frame is a rigid construction made of metal profile. The working surface (table) is at a level of one meter from the ground. The use of a collapsible mounting scheme for the upper flange provides the possibility of its vertical movement for different heights pipes installing.

Two different pipes are used during the experiments. The first one is with the following parameters: outer diameter – 90 mm, wall thickness – 3 mm, height – 500 mm; the second one is with the following parameters: outer diameter – 173 mm, wall thickness – 4 mm, height – 1,250 mm.

The heated water is supplied from the pipeline to the upper part of the experimental plant by a pump. The temperature is measured at the entrance to the apparatus. The gap of the film-forming distributing slot device is regulated here, too. The liquid enters the distribution device through the fitting. This device consists of a body, a mandrel holder, a mandrel and a control
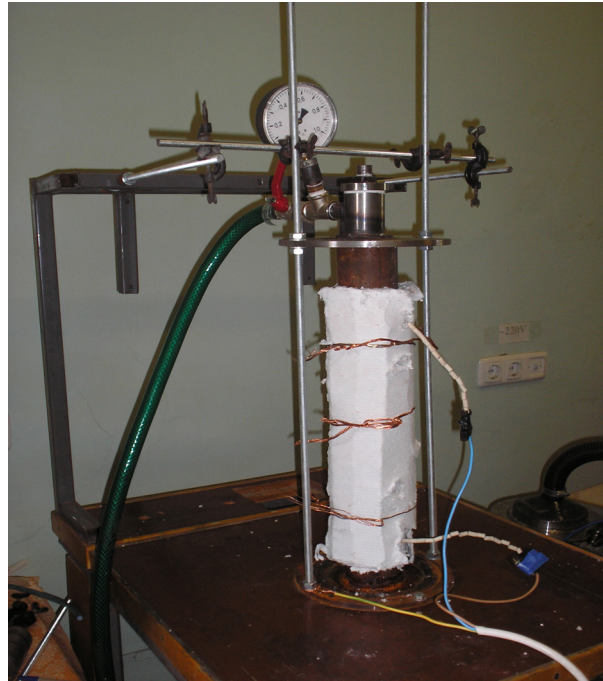
Fig. 1. Laboratory-scale plant

shell fixed to the body with screws. From the distribution device, the liquid in the form of a thin film enters the inner surface of the heat exchange tube and flows down it.

The pipe is heated from the outside with an electric heater. Asbestos cardboard is used as electrical and thermal insulation. Special holes are made in the insulation layer to measure the temperature of the heat exchange tube wall. The temperature of the heated liquid is measured at the heater outlet, where the liquid flow rate is also measured. The heated water enters the receiving tank through the lower fitting, and from there it comes into the sewer. Thus, the process is continuous non-circulating. This ensures a constant temperature of the liquid at the inlet to the apparatus.

The bottom is a truncated cone with flanging with grooves made in it for pipes fitting. The bottom is rigidly attached to the body of the apparatus by means of a threaded connection.

The liquid distribution device (switchgear) consists of a body, a mandrel holder, a mandrel, a cover, a gasket and a control shell fixed to the body with screws.

The top flange is a flat disk with grooves for fitting heat exchange tubes. The flange is rigidly connected to the switchgear by means of a threaded connection.

The experimental plant works as follows.

The gap of the switchgear outlet slot is set with a feeler gauge. The heated water from the pipeline is supplied to the upper part of the experimental plant by a pump. The temperature value is measured at the inlet to the apparatus. The liquid enters the switchgear through the fitting. The liquid from the switchgear in the form of a thin film goes on the inner surface of the heat exchange tube and flows down it. The pipe is heated from the outside with an electric heater. Asbestos cardboard is used as electrical and thermal insulation. Special holes for measuring the temperature of the heat exchange tube wall are made in the insulation layer. The temperature of the heated liquid is measured at the outlet of the heater. The heated water enters the receiving tank through the lower fitting, and then goes into the sewer.

The following parameters are measured during the experiment:
– the temperature of the liquid at the inlet to the apparatus;
– the temperature of the liquid at the outlet of the apparatus;
– the heated medium consumption;
– the temperature of the heat exchange tube wall in height.

The measurement of the liquid temperature at the apparatus outlet and the pipe wall temperature is carried out after the process has stabilized, i.e. the temperature fluctuations of the liquid and the walls of the pipe have stopped. On average, the time required to achieve an equilibrium regime is about 5 minutes.

Several series of experiments are carried out. Four variable quantities (fluid flow rate, height and diameter of heat exchange tubes, distribution slot gap) are taken into account in the first series of experiments when using liquids of different densities.

Various sizes of heat exchange tubes were used during the experiment. Liquids of various densities with varying flow rates were used as model ones. In this case, the gap width of the distribution slot of the film-forming device and the film thickness were measured.

RF patent No. 2380142 "Heat- and Mass Transfer Apparatus" was received on the basis of a number of solutions used in this laboratory-scale plant.

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Лабораторная установка для демонстрации и изучения работы пленочного теплообменного аппарата

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Ключевые слова и фразы: лабораторная установка; пленка жидкости; теплообменный аппарат.

Аннотация. Цель – создание лабораторной установки для демонстрации и изучения работы теплообменного аппарата студентами и проведения лабораторных работ по изучению зависимости степени нагрева жидкой фазы от параметров работы распределительного устройства установки. Для достижения поставленной цели были решены следующие задачи: изучены и проанализированы существующие конструкции лабораторных установок аналогичного назначения; предложена оригинальная конструкция установки. В результате работы была создана установка, проведена ее апробация.

UDK 72

The Features of Building's Architectural Composition Copying as a Means of Square or Crossroads Compositional Organization

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Key words and phrases: architectural composition; copying; crossroads; symmetry; square; urban fragment.

Abstract. The article deals with compositional formation of urban squares and crossroads by building's architectural composition copying technique. The research objective is to study it as a separate one. One also examines capability of full value applying of this method in practice. By comparative, compositional, system analysis its features and functioning are defined. The result of the work appears as determined characteristics of the technique.

The theory of architectural composition is an area of study that plays an important role in shaping the external appearance of the urban environment. Architects use it to make our streets, parks, squares, etc. more visually appealing. Therefore, it is necessary to work out in more detail, highlight, if necessary, its important topical aspects in order to offer practitioners more advanced tools.

The method of architectural composition, which is covered in this paper is well-known and has been applied for centuries and thousands of years. It is based on the symmetry with its copied elements. It has been discussed in teaching guides and research works many times [3; 5; 7]. However, not enough attention has been given to functioning and features of single building's composition copying, considered as method of formation of complete composition of urban open space like square or intersection. As practice shows us, this equal-part technique is applied in the cities along with hierarchical of full value way. In our current study we will compare them and give some speculation on method's features. Let us illustrate what is being studied.

Fig. 1 shows the crossroads of Ya.M. Sverdlov Street (soviet revolutionary, 1885–1919) and V.M. Asin Street (soviet revolutionary, commander of division, 1895–1920) in Yekaterinburg, Russia. That conjunction is formed by four buildings, which stand separately and have similar façades. There are many such examples in architecture: the crossroads with chamfered corners in Barcelona, the famous baron Haussmann's buildings of central part of Paris and others. Many would agree that, those urban fragments look very good. Moreover, there are instances, which we call of full value ensembles, such as, for example, The Registan (Samarkand, Uzbekistan), The Friday Mosque of Isfahan (Iran), formed by the same way of copying.

It is well known from the classical theory that a composition should have a hierarchical
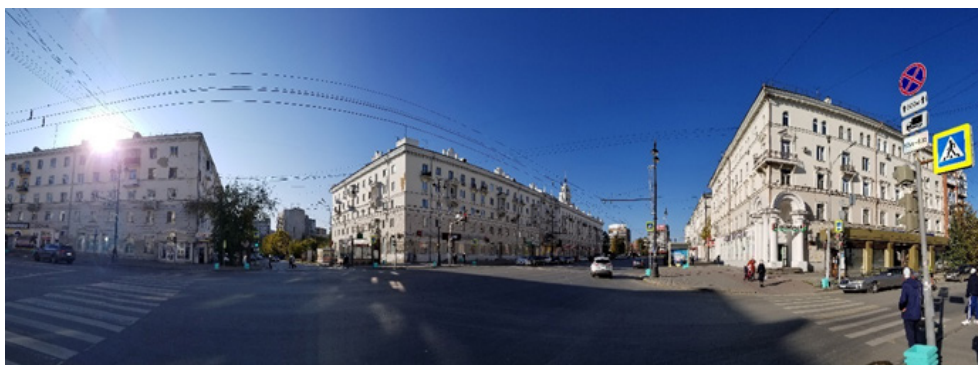
Fig. 1. Crossroads of Ya.M. Sverdlov Street and V.M. Asin Street
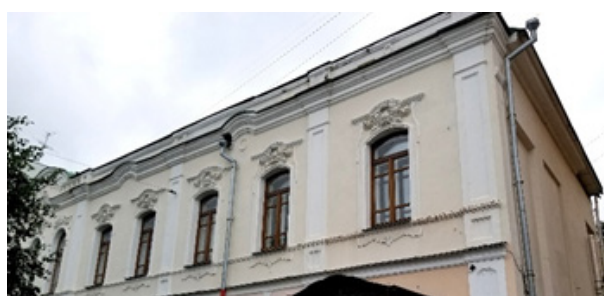
Fig. 2. Two buildings in Yekaterinburg

structure, including the so-called dominant and background with secondary dominants (accents) [1–4; 6; 8]. This method is hierarchical. It can be illustrated by the ensemble of the Louvre in Paris, in which the central, modern-looking glass pyramid easily stands out as the main dominant object, as well as the background with accents, in the form of surrounding buildings. The following questions arise: Why do equal-part fragments without above-mentioned main parts work so well for human eye? Can this way be valued on a par with full way of compositional organization? Is it true that the named above architectural ensembles do not have dominant and background at all?

Answering the first question, it must be said that, first of all, the main role is played by the presence of an attractive composition with subordinate parts, which is copied. It is executed within the framework of a hierarchical method, that is, it (the method) does not go anywhere. The mentioned generally accepted requirements for composition are fulfilled in the architecture of buildings (at the level of constituent elements), but are absent at the level of the overall whole. When such a beautiful composition is repeated, naturally logically its beauty is repeated and multiplied. This is illustrated by two examples of facades in Yekaterinburg (Russia) in Fig. 2. They are organized according to the principle of translational symmetry on the plane of the facade. On the left photo, a rectangular, compositionally undeveloped window is copied, but on the right, the window of the upper floor has decorative elements, and the view of an attractive composition.

Copying a composition in symmetry is always organized as a system based on a subordinate element, such as an axis or a point. In the absence of it, the parts look disorganized.

The question of usefulness in terms of visual appeal and independence of this method in its purest form leads to the following reflections. Obviously, the studied method of organization

Fig. 3. The Registan (left) and the Friday Mosque of Isfahan (right)

in cases with a beautiful composition of the building generates a fairly attractive fragment of the urban environment. However, the repetition of the same thing several times makes the whole more boring to a certain extent than solutions with a developed dominant, background, accents, which arouse more interest, therefore, are more balanced and attractive. Another important aspect is that its construction is partially based on the hierarchical method (the use of subordination in constituent parts), which makes it impossible to define it as completely independent and characterizes it as a combination of hierarchical and equal parts at different level.

As for original ensembles, which were mentioned above as the examples of the technique, they demonstrate a border state between composition with absence of dominant and background and fully hierarchized one. Consider the Registan (Fig. 3, left). In its volume-spatial solution, there are two largely identical buildings (Ulugbek Madrasah and Sherdor Madrasah), located opposite each other. The differences between them are not so strong; the main ones are ornament and domes. The third, the Tilla-Kari madrasah, has stronger main differences in relation to the first two, starting with the setting of the building perpendicular to their axis of symmetry, continuing with a two-level arcade to the right and left of the central iwan, the absence of minarets, and ending with a dome on the left on the main facade. The third building becomes dominant in relation to the other two. At the same time, the Tillya-Kari madrasah has the same basic form with an iwan, approximately the same size, and seems to be copied.

The same border state characterizes the next instance too – The Friday Mosque of Isfahan (Fig. 3, right). It has an open rectangular courtyard, on each side of which there is one aivan with an arcade on two levels. At first glance, all four sides with portals seem very similar, but they are different. Among other elements, the main blue iwan (indicating the direction to Mecca) stands out with two relatively small minarets at the top. Dominant and background are revealed. The considered examples show that they are not combined from completely identical parts, but from similar ones, with the dominant and the background highlighted. It should be emphasized that in the method under study, the center, if it exists, is always defined as one of the buildings (perhaps a side), or as its constituent part.

Regarding the mentioned intersections of Barcelona and Paris, it should be clarified that there is often no hierarchy among the buildings being copied. However, as said above, the architecture is there in many cases with nuanced differences that give more liveliness to the human eye. It's better than not having them. Although sometimes they still get a characteristic of monotony from people. Dissymmetry in the architecture of the building being replicated, as well as in the location, plays an important enlivening role in an equal way.

Practice shows that an architectural fragment made by the studied method with nuanced

differences and/or modifications towards a distinguishable dominant and background (intermediate state) is more pleasing to a person than in its pure form, and may even in the case of the latter acquire the status of an ensemble in some cases. The desire for hierarchization is obvious.

Does all the above criticism of the method mean its inconsistency and does it lead to the need to ban its use in design practice? No, it does not. Beautiful buildings repeated exactly or with nuances are able to organize much more attractive compositions than those that we have today in many cases in the cities of Russia. The method under study is different in that it is easy to perform – one just need to copy it. The difficulty lies in creating a beautiful pattern for copying. In this sense, no one has yet canceled the means and principles of compositional modeling.

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Особенности копирования архитектурной композиции здания как способа композиционной организации площади или перекрестка

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Ключевые слова и фразы: архитектурная композиция; городской фрагмент; копирование; перекресток; площадь; симметрия.

Аннотация. В статье затронута симметрия в формировании объемно-пространственного решения площадей и перекрестков городов, где архитектурная композиция отдельно взятого здания повторяется в том или ином виде несколько раз. Рассмотрены особенности этого способа. Осуществлено сравнение с иерархическим композиционным способом.

UDK 334

Zambia's Financial Policy and Banking System

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Abstract. For more than 20 years until the early 1990s, Zambia had extensive State ownership and administrative control over markets, including financial and banking markets. Interventionist policies combined with a sharp deterioration in the external terms of trade led to an economic downturn. In the early 1990s, a major program of market-based economic reforms was adopted, including reforms of the financial sector. The purpose of this article is to study a number of related hypotheses. Firstly, this interventionist financial policy was either ineffective in changing the way banks provide loans and/or had a negative impact on the stability of the banking system: control over interest rates led to the removal of obstacles in conditions of high inflation, when real rates were extremely negative, attempts by state-owned banks to provide loans to achieve development goals undermined their solvency, while administrative control or moral persuasion had little effect on the operational policies of foreign banks, which remained very conservative in their policies. Secondly, macroeconomic regulation was not given sufficient attention, which had negative consequences for the financial instability of the banking system, especially when local private sector banks were established in the 1980s and early 1990s. Thirdly, financial reforms are difficult to implement effectively and probably have a limited impact on the efficiency of the allocation of resources by the banking system, especially in conditions of macroeconomic instability. The main obstacles to improving efficiency are institutional in nature and cannot be eliminated quickly.

This article examines how financial policy has influenced the development of Zambia's banking sector since independence.

The course of Zambia's economic strategy after independence was determined by the Mulungushi Declaration of 1968. The strategy, motivated by economic nationalism and the desire to eliminate political and economic inequality, provided for import-substituting industrialization

carried out by the state and broad state control over the distribution of resources. Some foreign companies operating in Zambia were nationalized, a large semi-public sector was created and administrative controls over foreign exchange, imports, prices and interest rates were introduced. Economic indicators, however, were very low: the economy was severely affected by the sharp drop in copper prices since the mid-1970s, while interventionist policies led to inefficiency and structural rigidity that prevented adaptation to external shocks. Since 1976, a number of IMF stabilization programs have been implemented in an attempt to overcome the economic crisis, but, with the exception of a short period of 1985-87, the government adhered to the main components of the interventionist strategy until the late 1980s-early 1990s.

The financial system in the mid-1960s was dominated by foreign commercial banks, mainly servicing the credit needs of foreign and foreign enterprises. The general thrust of financial policy after 1968 was to enable the Government to exercise greater control over the financial system and to ensure that the distribution of loans was more in line with the Government's overall economic strategy. The financial policy consisted of three main directions: the nationalization of foreign financial institutions, the creation of State-owned banks and development finance institutions, as well as administrative control over interest rates and, to a limited extent, the distribution of loans.

ZANAKO was founded by the government in 1969. Its goals included providing loans to Zambians and expanding bank branches in rural areas. The Government, however, soon realized that ZANACO would not be able to expand fast enough to meet the expectations placed on it, and in 1971 announced plans to nationalize all foreign financial institutions, including commercial banks.

The purpose of nationalization was to control the "commanding heights" of the economy and prevent capital flight. Most non-bank financial institutions were nationalized and merged into financial parastates, such as the State Insurance Corporation and the National Building Society of Zambia. But with one exception (the Bank of the Netherlands), the banks were not nationalized because foreign banks threatened to withdraw their management from among foreigners, and the Zambian government was not sure that it could manage banks without them. The Indo-Zambian Bank was established in 1984 as a joint venture between the Government and three state-owned Indian banks, and in 1987 the Zambian Export-Import Bank was founded to finance trade. Development finance institutions were established to provide concessional and/or long-term financing of priority sectors from funds mobilized by the Government or from external sources. These included the Zambia Agricultural Development Bank and the Agricultural Finance Company, which were merged into the Lima Bank in 1987, and the Zambia Development Bank.

An important direction of the Government's financial policy was the introduction of administrative control over financial institutions. However, with the exception of interest rates, direct administrative control over the allocation of resources in the banking system was not widely applied by the government: for example, there were no detailed industry guidelines for lending. The government did try to channel more loans to Zambians by requiring banks to seek permission from the Bank of Zambia (BOZ) before lending to foreign companies, and by setting lower maximum ratios for foreign borrowers than for Zambian borrowers. This did not lead to a significant expansion of lending to the private sector in Zambia, and in an attempt to remedy this, the Government created a credit guarantee system for small businesses in 1987.

Since the mid-1980s, there has been an increase in both inflation and nominal interest rates. The implementation of the stabilization program led to a slight increase in regulated interest rates in 1984 and the abolition of interest rate controls and the introduction of an auction of

Treasury bills in September of the following year. After that, lending rates rose sharply – to about 30 percent in 1986 – although, since this was accompanied by an acceleration in inflation, real interest rates remained negative. Interest rate controls were reintroduced in May 1987 after the failure of the IMF-backed adjustment program and remained below 20 percent for the remainder of the decade. In 1989, the Government adopted a new IMF-supported adjustment program, under which interest rates were raised again, although they remained well below the prevailing inflation rates, which by that time had reached levels exceeding 100 percent per year. In the 1990s, interest rates were raised again and then liberalized.

In order to prevent risky lending that has led to bank failures in other African countries, especially insider lending, and to ensure that adequate reserves are created for non-performing loans, it is essential that banking regulators are able to closely monitor banks and monitor banks' loan portfolios, especially through on-site inspections.

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Финансовая политика и банковская система Замбии

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Ключевые слова и фразы: банковские кредиты; высокая инфляция; государственные банки; иностранные банки; контроль за процентными ставками; платежеспособность; устойчивость банковской системы; финансовая политика.

Аннотация. На протяжении более 20 лет до начала 1990-х гг. Замбия обладала обширной государственной собственностью и административным контролем над рынками, включая финансовые и банковские рынки. Интервенционистская политика в сочетании с резким ухудшением внешних условий торговли привела к экономическому спаду. В начале 1990-х гг. была принята крупная программа рыночных экономических реформ, включавшая реформы финансового сектора.

Целью данной статьи является изучение ряда связанных гипотез. Во-первых, эта интервенционистская финансовая политика была либо неэффективной в изменении способа предоставления банками кредитов, либо оказала негативное влияние на устойчивость

банковской системы: контроль за процентными ставками привел к устранению препятствий в условиях высокой инфляции, когда реальные ставки были крайне отрицательными, попытки государственных банков предоставлять кредиты для достижения целей развития подрывали их платежеспособность, в то время как административный контроль или моральное убеждение мало повлияли на операционную политику иностранных банков, которые оставались очень консервативными в своей политике. Во-вторых, макроэкономическому регулированию не уделялось достаточного внимания, что имело негативные последствия для финансовой нестабильности банковской системы, особенно когда в 1980-х и начале 1990-х гг. были созданы местные банки частного сектора. В-третьих, финансовые реформы трудно эффективно проводить и, вероятно, они оказывают ограниченное влияние на эффективность распределения ресурсов банковской системой, особенно в условиях макроэкономической нестабильности. Основные препятствия на пути повышения эффективности носят институциональный характер и не могут быть устранены быстро.

UDK 338

Problems of the Formation of Big Data in the Digital Economy

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Key words and phrases: digital economy; government experiment; personal data protection.

Abstract. The purpose of this study is to identify problems associated with the formation of an unhindered digital environment in key areas of the country's economy. The article used statistical methods of comparison, analysis and synthesis of data. The results of the study revealed that it is extremely important to control the formation of databases, especially during the period of mass digitalization.

The issue of the need for early integration into the digital economy is acute of today. It is a great achievement for the Ministry of Russian Economy to use a special experimental legal regime, which has contributed to the development of innovation and artificial intelligence. The state authorities carried out the preparatory work of the legal and regulatory experimental framework, as well as selected innovative projects that will be launched under the experimental tax regime.

Big data technology is an integral part of the digital economy and the basis for the implementation of experimental bills.

The experience of Belarusian scientists Yu. Gavrilchenko and Yu. Khvatik, who studied the problems of the development of the digital economy, indicates that appropriate staffing is needed for effective incorporation into the legal field. The lack of experienced specialists complicates the development of digital transformation, and innovative economic activity based on new technologies may be outside the legal zone.

The team of authors – V.B. Naumov, Ya.V. Butrimovich, A.A. Kotov – in the article "Ensuring the quality of legal regulation of experimental legal regimes" showed that, despite its advantages, the technology itself and the experiments conducted by states can have difficult to assess or even negative consequences. There is a risk of violating the laws and conditions of competition due to the privileged position of participants in the digital economy market, in other words, the risk of turning the regime from "voluntary" into "de facto mandatory".

In the development and implementation of digital technologies in the Russian economy, it is necessary to ensure the uniform development of personal data protection systems and the creation of new methods for working with big data.

Thus, it is necessary to complete the following tasks:

1) to identify the least protected areas of activity and life of society in the digital economy of the country;

2) to assess the problems of creating databases, with the protection of personal information about citizens, trade secrets, etc.;

3) to present the results of a study in the field of secure generation of big data.

To implement the objectives of the study, various big data platforms were studied: personalization services, geospatial analysis, sales planning, advertising platforms, as well as the development of IT infrastructure. The rationale for choosing these areas for the formation of large databases is the presence of the greatest risks of losing personal information of citizens and business entities. The interest in natural commercial and social tasks is quite justified. Since, for a deeper study of the target audience, detailed data is often needed: the interests of citizens, geolocation, current needs, places of recreation, etc.

Thus, the creation of databases, in order to introduce the digital economy into the life of the country, requires an assessment of the consequences of implementation, including in various spheres of human life, society and the state.

As the practice of global digitalization of the economy has shown, platformers that help the rapid transition to electronic form have network efficiency, low marginal costs and replication. The creation and use of platformers carries risks that are associated with the accumulation and use of data about citizens. Therefore, the tasks of ensuring the protection of the rights and interests of citizens of the Russian Federation and, at the same time, stimulating innovative development are so urgent.

Consider the formation of big data through personalization services. The following mechanism works: the system collects data about users, analyzes behavior and makes individual offers. In practice, this type of big data collection is useful for the efficient operation of business processes, namely, based on the collected data about customers in online stores and marketplaces, it is possible to form special offers for goods of interest, free delivery for different segments of users who came from regions, any advertising channels. To date, there is no adequate regulation of the described process, which is the collection of data on the personal information of a citizen.

Geospatial analysis is the process of finding spatial patterns in the distribution of geographic data and relationships between features. This approach is represented by the collection and ordering of information about the places of frequent visits of a citizen. Such a system of approach is able to provide information not only about the location of a person during a vacation or working period of time, but also about the method of movement, places of purchase of goods, and so on.

This segment of big data collection is especially responsible, since it not only violates the rights and freedoms of a citizen, but can also be dangerous information in the event of a data breach.

Collecting big data for effective sales planning is important for marketing purposes. The following goals of this approach are distinguished:

1) creating a descriptive profile of target consumers, including height, weight, color preferences, and so on;

2) predicting the reaction of the relevant target audience to the appearance of a new product;

3) presenting maximum ad personalization;

4) the received data about the customer expectations makes it is possible to restructure or change the goods within the limits of the needs.

In this segment of big data, it is also necessary to control the encryption of information. Marketing offers should correlate, among other things, with state social programs and not violate

the principles of healthy competition. A similar principle must also be followed in the formation of big data in advertising platforms.

Due to the development of digital information and the practice of its transfer in the form of databases to business entities, as well as the development of the digital economy as a whole, there is an urgent need to make additional revisions to the Federal Low "On Personal Data" No 152-FZ of 27 July 2006. Due to the appearance of such terms as "big user data", "processing of big user data", the concept of personal data in the law turned out to be vague, devoid of a specific list of information considered personal. At the same time, today, there are many ways to form large databases that accumulate in platformers and integrate into an accessible form for the user.

There is an urgent need to form databases based on the personal needs of citizens, while the system for encrypting personal data in a single format remains unfinished. Monopoly browsers also collect personal data to improve their own competitiveness. Today, this process of generating big data is difficult to fully control due to the lack of experience in functioning in the digital economy, as well as the breadth of the scope of the areas of freedom of choice.

It must be understood that if personal data is needed for an experiment, then it is necessary to depersonalize it and establish clear rules for loading such data and rules for destroying it after the experiment. It is important in this experiment not to cross the boundaries that violate the rights of a citizen: secrets of correspondence, privacy, and so on. Therefore, a paramount search for a balance in the areas of activity of business, society and the state presented in the article is necessary. So, an early decision should be made to specify what "personal data" is for personalization services, geospatial analysis, sales planning, advertising platforms, as well as the development of IT infrastructure.

These types of directions are chosen according to the principle of the most important technological interests of all branches of the development of the digital society.

The practical significance of the study is the need for the mass application of depersonalization techniques in order to reduce the risks of leakage of personal data, protect the secrets of life and other constitutional presumptions of citizens. Customer centricity must be controlled.

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Проблемы формирования больших данных в цифровой экономике

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Ключевые слова и фразы: государственный эксперимент; защита персональных данных; цифровая экономика.

Аннотация. Целью данного исследования является выявление проблем, связанных с формированием беспрепятственной цифровой среды ключевых сфер деятельности экономики страны. В статье использовались статистические методы сравнения, анализ и синтез данных. Результаты исследования выявили, что крайне важно контролировать формирование баз данных, особенно в период массовости цифровизации.

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Game-Theoretic Approach to the Analysis of Parallel Algorithms

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Key words and phrases: parallel algorithm; congestion game; optimality principles.

Abstract. Game-theoretical approach to the analysis of parallel algorithms is proposed. The approach is based on presentation of the parallel computing as a congestion game. In the game processes compete for resources such as core of a central processing unit and a communication subsystem. There are players, resources and payoffs (time delays) of players which depend on resources usage. Comparative analysis of various optimality principles in the proposed model may be performed.

Introduction

Development of optimal control methods is of great importance for different problems, see for example [1–3]. One of actual such problems is high-performance computing which is complex problem including both hardware (see e.g. [4]) and software [5]. Execution of parallel applications may be considered as complex interaction of few components. First one is set of parallel programs queued on high-performance computing cluster. Each parallel application is constituted of processes with communications between them. Second component is parallel computing system which consists of computing nodes and communication subsystem. A computing node provides central processor and memory to executing programs. Main component of the software environment is operating system with scheduler which orchestrates set of processes placed on the node. Due to limited hard ware resources parallel computing may be considered as a competition of a set of processes for resources. Such competition should not decrease overall efficiency of the whole system so search of optimum and analysis of various optimality principles is of significant importance for the control of parallel computations. We propose game-theoretical approach to the analysis of parallel algorithms. There are players (processes), resources and payoffs (time delays) of players which depend on how much of a resource is used by processes placed on the computing node. It is the case of congestion or, more general, potential game [6]. Results of congestion games theory was used in consideration of networking problems [7].

Model of parallel computing

An algorithm of a parallel application process may be presented by directed acyclic graph
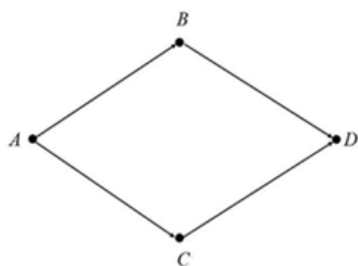
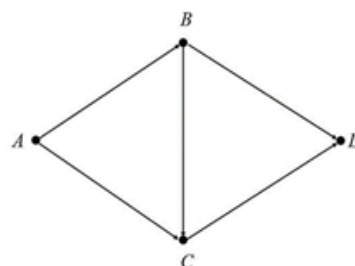**Fig. 1.** Information graph of sequential or simple parallel algorithm

Fig. 2. Information graph of parallel algorithm

(**DAG**) [8]. In the article we will refer to the DAG as information graph of an algorithm. Nodes of an information graph are macrooperations. The macrooperation transforms input data into output and send result to next macrooperation or a final result to the user. Links present data transactions between macrooperations. We consider case when only one source s (data input) and only one sink t (data output) are associated with any information graph: $PG = (V, L)$, $s, t \in V$. Here V is set of nodes of the graph and L is set of directed links. At first let us consider case of sequential program. Its graph is given, for example, by upper half of the graph in Fig. 1.

Here, $s \equiv A$ is source which receives input data and $t \equiv D$ is sink which performs output operations of the resulting data. In the graph two branches exist: *ABC* and *ACD*. Both branches correspond to execution of the same sequential program on two different computing nodes. If the target computing system is symmetrical this two cases are equivalent. In the case of asymmterical system the branch is preferrable which corresponds to execution on the node with higher performance. One of the most important metrics of a parallel application is its total time of execution which may be defined as maximum of execution times over all processes. Now let us suppose that Fig. 1 is information graph of the algorithm which is almost ideally parallel and macrooperations *B* and *C* have equal computational complexities. Again let us consider the case of symmetrical target computing system. Here optimum in time of execution has place when data flow from *A* is divided into two equal parts. It is Nash equilibrium because if one player, for example, corresponding to the branch *ACD* tries to improve time of its own execution by decreasing amount of data then the second player (*ABC*) have to process greater amount of data. Overall performance in this case will be less then in equilibrium. In general, the Nash equilibrium is a set of strategies in a non-cooperative game when each player knows the equilibrium strategies of the other players, and no player can't get additional benefit by changing only its own strategy. In general Nash equilibrium doesn't guarantee best performance. Next let us consider information graph (Fig. 2). It is the classical simplest example where the Braess paradox may take place [9]. Now three paths of execution there are exist: *ABD*, *ACD* and *ABCD*. In this case *BD* and *BCD* may be placed onto different computing nodes.

In the model we propose in the article influence of other processes placed on computing nodes have to be taken into account. Due to competition for limited resources the more is the load of the node the more is time of execution of the process. It is the case of a congestion game. Generally, software developer takes care for minimization of time of execution of every branch of a parallel algorithm. In game-theoretical language it may be interpreted as selfish behaviour of players. A congestion game is $CG = (G, (s, t), (f_e)e \in L)$, where f_e is nonnegative, continuous and nondecreasing latency function and G is graph of an algorithm. Latency function describes slowing down of process execution due to dependence of the time of computation

on the data volume and possibly from other factors. In more general case in latency function may be included accounting of the competition of different processes for limited resources. Total latency function is alsow defined as follows: $LF_{tot}(x) = \sum_{e \in \Phi} f_e(x)$, where Φ is a set of links in the path of execution for the given parallel algorithm. $LF_{tot}(x)$ may be taken as a criteria of optimization. In the model described existence and uniqueness of Nash equilibrium should be studied. Analogue of Nash equilibrium in the game with infinite number of players is Wardrope's equilibrium [9].

Using the template

In the article game-theoretical approach to the analysis of efficiency of parallel algorithms is proposed. It is assumed that parallel computing may be considered as congestion game with finite or infinite number of players. Principles of optimality may be formulated for such game and different kinds of equilibrium should be studied.

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Теоретико-игровой подход к анализу параллельных алгоритмов

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Ключевые слова и фразы: игра с перегрузкой; параллельный алгоритм; принципы оптимальности.

Аннотация. Предложен теоретико-игровой подход к анализу параллельных алгоритмов. Подход основан на представлении параллельных вычислений как игры с перегрузками. В игре процессы конкурируют за ресурсы, такие как ядро центрального процессора и подсистема связи. Есть игроки, ресурсы и выплаты (временные задержки) игроков, которые зависят от использования ресурсов. Может быть проведен сравнительный анализ различных принципов оптимальности в предлагаемой модели.

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