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ALGORITHMIZATION MECHANICS OF SOLIDS (MS)

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In the article the major problems of algorithmization in MS are solved. The problems of automation of MS research are considered. Automation of all stages of investigations is called algorithmization in MS, methods of formalization in MS are called algorithmic methods, the system of computer-aided research in MS - MS algorithmic system. Algorithmization stages are given: experiences-laws-problems-mathematical models-algorithms-program maintenance-computational experiment. Practical realization algorithmization stages carrying out by means of six core: B_1-data, B_2-laws, B_3-feature, B_4-models, B_5-algorithms, B_6-applied program and two auxiliary B_0-statament, B_7-operating algorithmic banks are given.

Keywords: mechanics of solids, automation, methods of formalization, system, laws, feature, models, algorithms

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1 General formulation

The algorithmization processes in the Mechanics of solids (MS) are implemented with the help of six main and two auxiliary banks. Here, the information blocks of the bank of the production and the six main banks are formed. Their interaction is provided in the operating bank $B7$, which is essentially a monitor of the entire system [1].

Information in the bank formulation B_0 is written out in the form of text having a special structure, with the help of which the algebra of banks is constructed in [1].

Algorithmic banks are denoted by $B_\partial \left(\partial = \overline{0, ..., 7}\right)$. These banks work consistently, i.e. one bank regulates the work of the bank B_j, it is assumed that B_i is preceded B_j and written [1].

$$B_i \supset B_j \tag{1}$$

The set of words of the bank B_∂ is denoted by F_∂. If B_i preceded B_j, then the word B_j has the structure [1];

| element F_i | | element F_j | (2) i.e. to the word from B_j is attributed (in front of) the word out B_i.

The statement bank B_0 contains the codes of systems, subsystems and tasks. The word from this bank is denoted by $S \in F_0$. This bank is the source.

In the database B_1, digital information about the system is available as a tagged array m, when $m \in F_1$ and B_i $B_0 \supset -B_1$.

The words of the bank of laws are denoted by $q \in F_2$. This includes conservation laws, empirical laws, boundary and initial conditions, constraints and conditions of the optimum, and tensor symbols. The Bank B_2 is regulated by banks B_0 and B_3:

$$B_0, B_3 \supset -B_2$$

The features of the task (bank contents B_3) are expressed in words $p \in F_3, B_0 \supset -B_3$.

In the model bank, the parameters of the models displayed on the computer are set. In reduced algorithmic systems, it is allowed to input such models into a computer. Therefore, the model bank contains only the operating unit and words $\lambda \in F_4$ correspond to the programs of model analysis. Since the tasks are formed in the bank B_7, that the work of bank 7 is regulated by the bank $B_4 : B_4 \supset -B_7$. The bank of algorithms to the ready procedures B_5 works under the scheme $B_4 \supset B_5$ and contains programs of a choice of algorithm and construction of the resolving system. In addition, in this bank, a command is made to call the initial data of the application program. The words of the bank of algorithms are denoted by

$$\alpha \in F_5 \tag{2}$$

The words $q \in F_6$ of the bank B_6 correspond to the ready-made procedures for solving the resolving equations.

For the algebraic recording of the transition of banks' work, census operations are introduced

$$B_i \xrightarrow{[\partial]} B_j \tag{3}$$

and staging.

1) In (3) Words from the sign $[\partial]$ correspond with the bank B_j. Substitution of words is performed according to the scheme of normal algorithms.

The order of operation of algorithmic banks is considered.

1. The work of the algorithmic system begins with the input of words marked in B_0 words.
$$[\partial] = [S_0, S', S''(S_1, S_2, \cdots, S_6), S^r, S^k] \tag{4}$$
to the operating bank B_7. In (4) S_0 – the call and substitution procedure call, S' – the equation sign, S'' – the sign of the summand, $S_1, S_2, \cdots, S_6$ the task feature, S^r the boundary conditions, S^k the coefficients.
2. U_3B_6 Census procedures are rewritten
3. U_3B_6 in the B_7 equations are rewritten (by S'-), crossed out summands (by S''), and from B_3 – the features of the problems. In this case, the constructions (2) of words from banks B_2 and B_3. The operations of the tensor symbolism are rewritten in all cases on the basis of S^T. After the census of the equations, extra terms on the features S'' are deleted, as well as unnecessary procedures and operations. This completes the first stage of the system.
4. In the fourth step, the model is output. First, the extra terms are deleted in the general equations, then tensor quantities are revealed with the help of the features, the obtained expressions are again substituted into the initial equations $[k_1, k_2, \cdots, k_b]$. All these operations are performed using the substitution procedure.
5. The procedure for analyzing the model U_3B_4 to B_7 is rewritten and its features are developed.

6. Further, $B_5 \overset{[r_1,r_2,\cdots,r_6]}{\rightarrow} B_7$ and there is a choice of the algorithm for constructing the resolving equation. Features of data $[n_1, n_2, \cdots, n_6]$ and program $[\prod_1, \prod_2, \cdots, \prod_6]$ call are produced.
7. The census $B_1 \overset{[n_1,n_2,\cdots,n_6]}{\rightarrow} B_7$ ensures the formation of resolving equations, and the $B_1 \overset{[n_1,n_2,\cdots,n_6]}{\rightarrow} B_7$ solution of the equation.

This is the sequence of interaction between algorithmic banks. At the same time, digital data, symbolic relations and programs (procedures, rewriting, substitutions) are rewritten from the information and operational blocks of the bank B_0 and the main banks to the operating bank B_7 as words.

The content of the operational blocks of algorithmic banks determines the composition and structure of the mathematical support of the MS algorithmic system.

Let's start with the data bank. The operating unit of the data bank includes two types of programs - form and search. The information block of the data bank consists of a permanent array $M_1 1$ that is constantly populated, and a variable array $M_1 2$ formed during the statement of the problem, each of these arrays being collected from a multitude of matrix type arrays of different dimensions.

In accordance with this, the forming programs include programs for arranging arrays, calculating their contents and searching.

Arrangement for arrays from $M_1 1, M_1 2$ is carried out according to the headings: the name of the array; the form of the function, the values of the numbers , the names of the process types, the location of the array (memory tag).

When forming under the arrays $M_1 1$ of the headings and the numerical values of the coefficients are individual libraries. In the array $M_1 2$, both parts are formed together. "Calculation"programs realize the processing of experimental data by the methods of correlation analysis. Through these programs, the output from the MSS system is implemented in an experimental setup.

When the search program is running, the initial data is the names of the arrays, the process type, the memory tag. On these data, a call is formed, and the array is transferred to the account cell of the operating bank.

The operating unit of the law bank consists of a program library of logical operations, which are formalized in the form of procedures. This includes the census programs of the formulation of integration and the tensor symbolism.

The order of these procedures (the scheme of the normal algorithm) is formed in the features bank and transferred to the operating bank. The operational part of the features bank includes programs for reducing similar members, differentiation, integration, variation and others.

Bank model procedures. Analysis of models highlights the features of differentiation, integration. Then inequalities are distinguished, the conditions of the optimum are established, the order of the systems is determined, the known and sought-for functions are sorted, and the constant coefficients are sorted. After analyzing the models, the dimension of the equations is transferred to the bank of algorithms, the order of differentiating the features of the given functions.

The bank of algorithms includes procedures for forming the resolving equation, checking its stability and convergence, optimizing the algorithm, generating the initial data, and calling the application program.

Computing Bank consists of computer library application programs, gradually replenished with research programs.

Such are the composition and structure of the mathematical support. To implement all these analytical and computational procedures, it is necessary to choose a programming language and develop a program structure [1]. As a programming language, choose the C++ programming language.

2 Structure and organization of the functioning of the algorithmic system

Consider the requirements that must be presented to the bank formulation objectives. First, it is the unification of the statement of tasks. In other words, all tasks intended to be solved with the help of this system should be put uniformly. Secondly, the formulation of tasks should be completely formalized and not allow for duality. This requirement is based on the fact that the system is designed for automatic operation, i.e. without human intervention in the decision process, and, consequently, does not require compulsory participation in the work of specialists in the field of solving mathematical programming problems. In the absence of such specialists, who are able to specifically set optimization tasks, the requirements for complete formalization of tasks take on special significance so that even the technician-programmer correctly enters the problem into the MSS system [2].

To ensure this, the following conditions are also important:

– convenient recording of the original data.

– the maximum simplicity of formulation the problem.

The necessity of fulfilling these conditions for the organization of B_0 is obvious and, in our opinion, does not need any additional argument.

Successful operation of the system is impossible without the organization of communication between the external language (the language of the statement of the problem) and the internal language of the computer, which B_0 must provide.

When formulating tasks, errors of various kinds are possible, related to the actions of the user and the programmer servicing the system. In order to save the time resource after input of the initial information to the computer before the entire system starts working, it is necessary to monitor the correctness of the statement of the problem from the syntactic side. To do this, the corresponding service programs should be provided in B_0.

The formulated requirements B_0 to the position of analyzing the functions of the technical systems outlined in [1, 2] are considered, since the algorithmic MSS system can also be referred to similar systems.

Briefly described is the technique for analyzing the function of technical systems (TS), which will be used in the future, adhering, in the main, to the terminology and notation in [1, 2].

The TS function is denoted by F. If the TS is multifunctional, then its functions are denoted by $F', F'', \cdots$. The system under consideration is divided into functional elements. It can be elements of different levels.

Functional elements of the first level are enlarged elements (or blocks of the system), each of which has some number of independent functions to ensure the operation of other units and the entire MSS system. For the MS considered by the elements of the first level are algorithmic and auxiliary banks B_i $\left(i = \overline{0, ..., 7}\right)$ each of which has a clearly defined circle of the function – respectively $F'_{0-1}, F''_{0-1}, \cdots, F'_1, \cdots$. Each of the elements of the first level is a TS and consists of elements $B_{0-1}, B_{0-2}, \cdots, B_{1-1}, B_{1-2}, \cdots$ of the second level with its functions $F'_{0-1}, F''_{0-1}, \cdots, F'_{0-2} \cdots, F'_{1-1}, \cdots$ which, in turn, can consist of elements of the third level etc.

Thus, it is possible to analyze the functions of the system and construct the corresponding table up to indivisible elements (operators).

Considering Bo, we distinguish the following functions:

$F_0^{/}$ - statement of the problem (unified, formalized);

$F_0^{//}$ - input information into the computer;

$F_0^{///}$ - control of the correctness of the statement of the problem;

$F_0^{/V}$ - distribution of data for other elements of the first level B_i.

To implement each function B_0, respectively, the proper elements of the second level must be beaten.

From $F_0^{/}$ it follows that the task formulation block is intended for recording in a form convenient for further processing by the MS system.

The analysis of the assignment B_0. B_0 is the bank for formulation the tasks;

$F_0^{/}$ - statement of the problem;

$F_0^{//}$- - input information into the computer;

$F_0^{///}$- control of the correctness of the statement of the problem;

$F_0^{/V}$ - distribution of data by other elements of the first level B1, B3, B4.

B_{0-1} - information part;

F_{0-1} - information about the task in a convenient form for further processing of the MS

B_{0-2} - the operating part;

$$F'_{0-2} \equiv F''_0;$$
$$F''_{0-2} = F'''_0;$$
$$F'''_{0-2} \equiv .F_0^{/V}.$$

B_{0-2-1} - input module: F'_{0-2-1} - obtaining information from B_{0-1} $F''_{0-2-1} \equiv F'_{0-2}$;

B_{0-2-2} - verification unit: $F'_{0-2-2} \equiv F''_{0-2}$;

F''_{0-2-2} - Informing the user about errors in formulation the task;

F'''_{0-2-2} - stop the system;

B_{0-2-3} - distribution unit: $F_{0-2-3} \equiv F'''_{0-2}$.

3 Bank features B_3

Bank features B_3 serves to store and process logical information designed to identify each specific task. Bank B_4 - models and B_5 - algorithms use in their work the features of the problem, identified by the bank of features.

Functions B_3 are:

F'_3 - storage of logical information about the feature space describing all the models provided in B_0;

F''_3 - formation of feature values;

F'''_3 - transmission of feature values in B_1, B_4, B_5.

These functions perform the elements of the second level B_{3-1} - information part B_3 and B_{3-2} - the operational part B_3, which, in turn, is divided into the elements of the third level:

B_{3-2-1} - module for the formation of feature values;

B_{3-2-2} - module for transmitting feature values in B_1, B_4, B_5;

B_{3-2-3} - a monitor that controls the operation of B_{3-2-1} and B_{3-2-2} [2].

Purpose bank features. Bank of features:

$F_3^{/}$ - storage of logical information about the MS calculation criterion

$F_3^{//}$ - formation of feature values;
$F_3^{///}$ - passing feature values to .
B_{3-1} - information part:
B_{3-2} - operating part:
B_{3-2-1} and B_{3-2-2} [2].
Deformable solid bodies [1].
Classes of tasks are formed by imposing restrictions on movement $\overrightarrow{U}$.
The theory of rods in Cartesian coordinates is constructed by means of representations

$$\left.\begin{array}{l} u^{(1)} = \sum u_i(z,t)\varphi_i(x,y) \\ u^{(2)} = \sum v_i(z,t)\psi_i(x,y) \\ u^{(3)} = \sum w_i(z,t)\chi_i(x,y) \end{array}\right\} \tag{5}$$

Generalized deformation coordinates $\varphi_i,\ \psi_i,\ \chi_i$ are given on the basis of various hypotheses.

1. The hypothesis of flat sections of Bernoulli and Coulomb:

$$u^{(1)} = u + \theta,\ \ u^{(2)} = v \pm \theta y,\ \ u^{(3)} = -(\frac{\partial u}{\partial z}x + \frac{\partial v}{\partial z}y). \tag{6}$$

2. Torsion of the rod, when the tangential stresses in all sections are the same:

$$u^{(1)} = -\theta y,\ \ u^{(2)} = \pm\theta x,\ \ u^{(3)} = \varphi(x,y)\frac{\partial\theta(z,t)}{\partial z}, \tag{7}$$

where $\varphi(x,y)$ function of torsion.

3. Joint longitudinal transverse and torsional oscillations:

$$\begin{gathered} u^{(1)} = u - \theta y,\ \ u^{(2)} = V + \theta x, \\ u^{(3)} = w - \frac{\partial u}{\partial z}x - \frac{\partial v}{\partial z}y + \varphi(x,y)\frac{\partial\theta}{\partial z} + \psi_1(x)\beta_1(z,t) + \psi_2(y)\beta_2(z,t). \end{gathered} \tag{8}$$

4. Mathematical theory of torsional oscillations of cylindrical rods:

$$u^{(1)} = u^{(3)} = 0,\ \ \ u^{(2)} = u(r,z,t). \tag{9}$$

5. Mathematical theory of longitudinal oscillations of cylindrical rods:

$$u^{(1)} = u(r),\ \ \ u^{(2)} = 0,\ \ \ u^{(3)} = w(r). \tag{10}$$

6. Thin cylindrical shells:

$$u^{(1)} = w(\varphi,z),\ \ u^{(2)} = \frac{r}{R}V - \frac{r-R}{r}\frac{\partial w}{\partial\varphi},\ \ u^{(3)} = u - (r-R)\frac{\partial w}{\partial z}. \tag{11}$$

7. Wave equations of the shell:

$$\begin{gathered} u^{(3)} = w(x_1,x_2,t), \\ u^{(1)} = (1+k_1 z)u(x_1,x_2,t) - \frac{z}{A}\frac{\partial w(x_1,x_2,t)}{\partial x_1} + \varphi_1(x_1,x_2,t)\vartheta_1(x_1,x_2,t), \\ u^{(2)} = (1+k_1 z)v(x_1,x_2,t) - \frac{z}{B}\frac{\partial w(x_1,x_2,t)}{\partial x_2} + \varphi_1(x_1,x_2,t)\vartheta_1(x_1,x_2,t). \end{gathered} \tag{12}$$

where A, B the main curvatures of the middle surface.

In practice, combinations of such systems are also considered: For example, a system of rods connected by hinges, forms trusses, and when the rods are rigidly joined, frames are obtained. When calculating buildings and structures, models of shells and plates supported by ribs are adopted, etc.

In all these cases, the MS ratios for the desired functions can be introduced from the principle of possible displacements

$$\int_V \overline{P_*}\delta D dV - \int_V (\overrightarrow{F} - \rho\frac{\partial \overrightarrow{V_*}}{\partial t})\delta\overrightarrow{u} dV + \int_{\Omega_1^*} (\overrightarrow{P^*}_{(n)}\delta\overrightarrow{u})d\Omega_1. \tag{13}$$

Here it is necessary to add the relations

$$D = \left[\frac{1}{2}(\nabla_i u_i + \nabla_j u_j \nabla_i u^k \nabla_j u_k)\right]_{1-3}^{1-3} \tag{14}$$

$$C = \frac{1}{2}\left(\nabla_i u_j + \nabla_j u_i\right) \tag{15}$$

$$\overline{P_*} = \left[\sigma_*^{ij}\right]_{1-3}^{1-3} \tag{16}$$

$$P_* = \varphi_0\overline{u} + \varphi_1\overline{D} + \varphi_2\overline{D}\cdot\overline{D} + \varphi_2\overline{C} + \varphi_4\overline{C}\cdot\overline{C}. \tag{17}$$

$$\nabla_j u^i = \frac{\partial u^i}{\partial x_i} + u^n\Gamma_{*i}^j \tag{18}$$

The algorithm for deriving the initial equations is organized as follows. First, the values of the displacements $\overrightarrow{u}$ (5)-(10) from are introduced in (17); then the substitutions are (18) $\to$ (14), (15) $\to$ (17), then performed - the operations of variation $\delta\overline{D}$ and the values $\overline{P_*}$ are substituted in (13). In all these calculations, the tensor-operators φ_i are assumed to be given, that is, the physical laws of the process are fixed in advance.

In the process of substitution of further transformations, equations and boundary conditions for the unknown functions are derived. These equations are solved by the variational method (in series) or by the grid method [1].

4 Bank statement and bank features [1]

When constructing the algorithmic theory of MSS, the methods of inference and solving the equations of classes of problems must be formalized, expressed in the form of atomic words and features. Let us first consider the concept of atomic words.

Over the long years of development of the MSS, the terminological bases of this science have been worked out.

First of all, let us single out aero hydrodynamics and a deformable solid.

Within the aero hydrodynamics, such objects as gas filtration, oil filtration, fuel combustion, a wing, a nozzle, etc. are considered. In the mechanics of a deformable solid body, the concepts of the rod, pipelines, frames, trusses, plates and shells are solved. In the mechanics of a deformable solid, the torsion of a rod, the calculation of plates of medium thickness, etc. In addition, MSS introduces the concepts of ideal and real media, elastic and elastic-plastic bodies, etc.

In the algorithmic MS, all these words are considered atomic and are written out in strict order. The list of these words is the contents of the production bank B_0. To each atomic word there corresponds an equation from the bank of laws B_2 and a sign from the bank B_3.

The Bank B_0 ensures the formulation of the MS task, i.e. dialogue between the customer and the computer. This bank (B_0) consists of the task name is completed from the atomic words written out in the B_0 strict order, and it is assumed that the table of atomic words is complete and minimal, i.e. it should accumulate all the necessary words to solve the selected classes of problems of the MS and only they. The conditions of minimality ensure completeness and visibility of the table of atomic words.

The set of words in the table of atomic words provides a choice:

1) Equations from the bank of laws (B_2) and terms of these equations;

2) Conditions from the bank of the features (B_3) imposed on the parameters of the process, the relationships between these parameters, constraints, the conditions of the optimum;

3) Features of algorithms for solving problems from the bank B_3.

In the algorithmic MSS, the derivation of equations is performed in a strict order, which determines the location of atomic words in the atomic word table.

The formulation bank consists of four blocks: model, area, coefficient, kinetics.

The first block contains an ordered list of atomic words for outputting the model. In the second block, the area is described, borders and boundary conditions are formed, and in the third block the initial coefficient is set or instructions are entered into the bank. If the reacting mixture is considered, then in the fourth block the chemical formulas of all reactions

$$\sum_j v_{ij}^{'} A_{ij} \rightleftarrows \sum_j v_{ij}^{''} B_{ij}$$

The structure of the "model"block is described. In this block, all atomic words are numbered consecutively and function along nine arrays: 1-system, 2-problem, 3-problem, 4-parameters, 5-empirical laws, 6-constraints, 7-optimum, 8-region, 9-algorithm .

In M1, atomic words are written for the choice of laws.

In M2, MS problems are formed, i.e. direct, inverse and optimization problems are set, as well as problems of calculating strength, stability of oscillations, etc.

M3 collects features that determine the properties of several parameters. For example, in the words of the boundary layer "flow"there are restrictions on the pressure and on the derivative of the velocity.

The array M4 consists of tensor and scalar features of the system parameters. Here the constraints are superimposed on one parameter.

With the help of words M5, equations of state are formed, phenomenological and physical laws.

The meaning of arrays M6, M7 and M9 is the name. B includes the names of the most typical areas considered in the MS.

The block "Model"of the bank B_0 is made out in the form of a table. When formulation the task, the customer marks the words in the table.

To link with other banks and compile the necessary output programs, the word "model"is coded.

For the code of the atomic word from the block "model"you can take the word itself, its initial letter, the standard designation of the parameter or the word number. The choice of code is decided by the convenience of programming all stages of output.

Each atomic word is put in correspondence to a certain number (or code) of the law from , the number of another atomic word from the "model"block or a sign from B_3, with the codes of the word display systems from B_0 into words from the B_1, B_3 contents of the algorithmic system and stored in the computer's memory. Such is the structure of the atomic block "model"of the bank of the production B_0.

When solving MS problems, boundary and boundary conditions are set, which is formalized as a block in B_2.

Coefficients can be specified when formulation a task or using special features. In particular, for an elastically isotropic body, the values of the moduli are determined by the types of materials. Therefore, the search for the law in the bank is carried out by the code of materials.

This is the general structure of the formulation bank. When constructing the software, the contents of the bank are detailed and adapted to the types of objects [1].

Let's move on to building a bank of features. In accordance with the words from B_0, the conditions imposed on the parameters of the system and on the connection between them are written out. In this case, the bank of the features bank is linked to the word codes from the formulation bank. Here are fragments of banks B_0 and B_3 [1].

Bank of the production B_0	Bank of features B_3
Parameters of the stress tensor flat	$\begin{pmatrix} \sigma_{11} & \sigma_{12} & 0 \\ \sigma_{21} & \sigma_{22} & 0 \\ 0 & 0 & 0 \end{pmatrix}$
The strain tensor is flat	$\begin{pmatrix} \varepsilon_{11} & \varepsilon_{12} & 0 \\ \varepsilon_{21} & \varepsilon_{22} & 0 \\ 0 & 0 & 0 \end{pmatrix}$
The strain speed tensor is flat	$\begin{pmatrix} \varepsilon_{11} & \varepsilon_{12} & 0 \\ \varepsilon_{21} & \varepsilon_{22} & 0 \\ 0 & 0 & 0 \end{pmatrix}$
Movement: one-dimensional	$\overrightarrow{U} = \sum_i \beta_i(x^2, x^3)\overrightarrow{\partial_i}(x^1, t)$
Two-dimensional	$\overrightarrow{U} = \sum_i \eta_i(x^3)\overrightarrow{\xi_i}(x^1, x^1, t)$
Static speed	$\overrightarrow{V} = 0$

5 The data bank B_1 [2]

The data bank B_1 serves to store all the numerical data necessary to solve the problem, as well as to provide the required data upon request. To do this, the source data should be appropriately distributed, and their search and delivery should be organized. Hence the purpose B_1: $F_1^{/}$ - of storing the original data; $F_1^{//}$ - memory allocation; $F_1^{///}$ - search for data; $F_1^{/V}$ - statement of data in B_6. The element of the first level B_1 is divided into two elements of the second level: B_{1-1} - the information part; B_{1-2} - operating part. B_{1-1} performs a function F_1^1, i.e. plays the role of an information database or database. B_{1-2} - performs other functions.

The information about the data is divided into a variable and an unchangeable one. To the variable information are data on a specific task [2].

Analysis of appointments B_1. B_1 – databank: $F_1^{/}$ - storage of source data; $F_1^{//}$ - memory allocation; $F_1^{///}$ - search for data; $F_1^{/V}$ - transfer in $B_4 B_6$.

B_{1-1} - informating part: $F_{1-1} = F_1^{/}$ informating part.

Stationary	$\frac{\partial \overrightarrow{V}}{\partial t} = 0$
Irrortless the potential	$rot\overrightarrow{V} = 0,$ $\overrightarrow{V} = grad\varphi$
Acceleration of liquid solid	$\overrightarrow{w} = \frac{\partial \overrightarrow{V}}{\partial t},$ $\overrightarrow{w} = \frac{\partial^2 \overrightarrow{U}}{\partial t^2}$
Volumetric forces are potential	$= grad$
Gravitational	$g\overrightarrow{x}$
Coriolis	$= 2\rho(\overrightarrow{w} * \overrightarrow{v}) - \rho\overrightarrow{g}$
Filtration	$= c\overrightarrow{v}$
The density is incompressible	$\frac{d\rho}{dt} = 0$
Filtration	$\rho = m\rho$
Temperature isothermal standard atmosphere	$T = 0, \quad T = T_0 - ax^3$
Metrics Descartes cylindrical orthogonal	 $g_{ij} = 1,\ g_{ij} = 0\ (i \neq j)$ $g_{11} = 1,\ g_{22} = r^2,\ g_{33} = 1$ $g_{ij} = 0\ (i \neq j)$

B_{1-2} - operating part: $F^{/}_{1-2} = F^{//}_{1};\ F^{/}_{1-2} = F^{///}_{1};\ F^{///}_{1-2} = F^{/V}_{1}$.
B_{1-2-1} - memory allocation unit: $F_{1-2-1} = F^{/}_{1-2}$.
B_{1-2-2} - output statements: $F_{1-2-1} = F^{//}_{1-2}$.
B_{1-2-3} - transmission operator: $F_{1-2-3} = F^{///}_{1-2}$.
B_{1-2-4} - monitor: F_{1-2-4} - control $B_{1-2-i}(i = \overline{1-3})$

The data bank stores the values of the values from the MSS empirical laws, as well as the coefficients characterizing the motion of the system [1]. All these data are formatted as number arrays. The data bank is filled with experimental data. The parameters of the motion are given in the form of different numbers [1].

Any empirical parameters included in the phenomenological and physical MSS laws for anisotropic media are tensors of different rings. For example, tensors of elasticity E of viscosity β, thermal conductivity L, of diffusion δ, thermal diffusion τ, dielectric permittivity ε, magnetic permeability μ, Peltte π, etc. Because of the symmetry, many elements of these tensors are zero, and in the isotropic case the number of coefficients is reduced to three (fourth-rank tensor) or even up to one (second-rank tensor).

Let us give some examples. The elastic tensor E has the fourth rank (only 32 coefficients). For crystalline bodies with various symmetries, its components have the following form: for a triclinic system

$$E_{1111} = \lambda_1,\ E_{2222} = \lambda_2,\ E_{3333} = \lambda_3,\ E_{1122} = \lambda_4,\ E_{1133} = \lambda_5,\ E_{2233} = \lambda_6,\ E_{1212} = \lambda_7,$$
$$E_{1313} = \lambda_8,\ E_{2323} = \lambda_9,\ E_{1233} = \lambda_{10},\ E_{1322} = \lambda_{11},\ E_{2311} = \lambda_{12},\ E_{1112} = \lambda_{13},\ E_{2221} = \lambda_{14},$$
$$E_{3331} = \lambda_{15},\ E_{2223} = \lambda_{16},\ E_{3332} = \lambda_{17},\ E_{1113} = \lambda_{18},\ E_{1213} = \lambda_{19},\ E_{2312} = \lambda_{20},\ E_{1325} = \lambda_{21},$$

For a cubic system

$$E_{1111} = E_{2222} = E_{3333} = \lambda_1;\ E_{1122} = E_{1133}E_{2233} = \lambda_2;\ E_{1212} = E_{1313} = E_{2323} = \lambda_3$$

Expressions of numbers	Contents of number
$\gamma = \frac{C_{P_0}}{C_{V_0}}$	A measure of the relative structural complexity of a molecule (the ratio of specific heat capacities)
$M = \frac{u}{\sqrt{\gamma R_p T_0}} = \frac{u}{a_0}$	Compressibility measure (Mach number)
$R_e = \frac{P_0 uh}{\mu_0} = \frac{uL}{V_0}$	Measure the ratio of the inertial force to the force of viscosity (Reynolds number)
$F = \frac{u^2}{lg}$	Fruit number
$R_H = \frac{\mu_e H_0^2}{P_0 u^2} = \frac{V_H^2}{u^2}$	The ratio of the magnetic pressure to the pressure (the number of magnetic pressure)
$P_2 = \frac{C_{P_0}\mu_0}{\chi_0}$	A measure of the relative role of viscosity and heat conductivity (the number of pranadles)
$R_e = \frac{t_0 u}{L}$	Measure the frequency
$R_e = \frac{u^2}{c^2} = u^2 \mu_e z$	Ratio of speeds
$C = \frac{1}{\sqrt{\varepsilon \mu_e} = 30 * \frac{10^3 m}{s}}$	Speed of light
$a = \sqrt{\gamma R_p T}$	Sound speed
$G = 6.67 * 10^{-9}\ din * m$	Gravitational constant

All other components of the modulus tensor are zero. The resistance tensor has the second rank in Cartesian coordinates

$$R = \begin{pmatrix} R_{11} & R_{12} & R_{13} \\ R_{21} & R_{22} & R_{23} \\ R_{31} & R_{32} & R_{33} \end{pmatrix}$$

For a plane isotropic case

$$R_{11} = R_{xx};\ R_{12} = R_{xy};\ R_{13} = R_0;\ R_{21} = R_{xy};\ R_{yy};\ R_{23} = 0;\ R_{31} = 0;\ R_{32} = 0;\ R_{33} = 0.$$

For a completely isotropic medium $\overline{R} = \overline{RU}$ ($\overline{U}$ unit tensor).

Each of these cases is specified in the formulation of the problem, i.e. is made out with the help of special features.

The following type of modules is considered in the study of nonlinear physical processes in hereditary environments. For example, for an elastoplastic, the loaded stress-strain ratio $\frac{\sigma_i}{e_i}$ can be specified in the form of polynomials in powers e_i. Then the ratio of the coefficients of these polynomials is written to the data bank.

In hereditary environments, the relaxation kernel Γ is determined by means of power, exponential, and other types of functions. Types of such functions are considered known, and their coefficients fixed in the database. Now you can outline the structure of the data bank. The bank is formed from a certain number of arrays. Each array is marked by three indicators - the name of the environment, the name and the values of the coefficients. For each medium, the values of all feature numbers and tensor modules are consecutively written out. It is assumed that the symbols of these modules fully correspond to the standard MS symbolism.

If the values of the coefficients are absent in the data bank (B_1) and are set by the customer, then their autonomous input into the computer is ensured, and, if necessary, storage in the data bank. These are the principles of building a data bank in an algorithmic MSS. The data bank has a relatively simple structure and, in its construction, there are no fundamental difficulties [1].

6 Bank of Laws

From the point of view of the theory of algorithms, the content of the bank of laws is the basic axioms of the theory, from which mathematical models of all MSS problems are subsequently generated. We recall that here we have in mind polarized reacting mixtures. Thus, the set of axioms of a bank of laws must be complete, but at the same time minimal. These are the first conditions for the formation of a bank of laws. Therefore, the MS axioms are written down in the notation of the tensor calculus in arbitrary curvilinear coordinates, and the most universal ones are chosen from the set of equations.

In the algorithmic system, the MS axioms are represented as words in certain alphabets. The alphabet of the algorithmic MS includes the following letters:

A_1 variables - all upper and lower case letters of the Latin and Russian alphabets with alphabetic and numeric indices, except for the letters D, $\sum$, ∇;

A_2 { digits 0,1,2,3,4,5,6,7,8,9};

A_3 { vectors are features of the alphabet with an arrow "$\rightarrow$" };

A_4 { tensors - features of the alphabet with a double arrow at the top };

A_5 { vector and tensor operators – div, rot, grad, Grad, Div};

A_6 { differentiation – D, $D^{\tau}_{\alpha,\beta,\gamma}$, ∇_α, ∇^α};

A_7 { integration - $\int_V$, $\int_\Omega$, $\int_\iota$, $|_a^b$ };

A_8 { functional simbols $+, -, \times, /, 0, \div$ };

A_9 { comparison symbols $=$, $<$, $>$, $\leqslant$, $\geqslant$ };

A_{10} { technical symbol (,) };

A_{11} { sum sign $\sum$ };

Let us dwell on the alphabet of the MS language. The alphabet consists of the letters $a, b, c, \dots, A, B, C, \dots \Omega, \sum, \dots, x, y, z, \dots, x, y, z, \dots$. It does not include the features of D, ∇, used differentiated. Indices (upper and lower) are formed from numbers, the letters $a, b, c \dots, \alpha, \beta, \gamma, \dots$. Vectors and tensors are written like this: $\overrightarrow{a}, \overrightarrow{n}, \dots; A, \tau, \dots,$ the second-rank tensor is included in the alphabet. Since the work adopts tensor symbolism, both the vector and tensor operators are included in the alphabet.

In the alphabet $D = \dfrac{d}{dt}$, $D^{\tau}_{\alpha,\beta,\gamma} = \dfrac{\partial}{\partial x_1^\alpha \partial x_2^\beta \partial x_3^\gamma \partial t^\tau}$.

In the case where three of the four indices are zero, the partial derivatives become ordinary.

When forming a bank of laws, some letters (tensors, vectors, scalars) receive a semantic interpretation, thereby ensuring the transition from physical to formal expressions. In this case, the following notation is introduced.

I. Tensors

P is the stress tensor (H).

D is the strain tensor (D),

C is the strain rate tensor (C).

Tensors P, D, C are classified by physical (index on top), and all the rest by mathematical (index at the bottom) considerations. The following system of indices is adopted:

physical:

q is the deviator tensor,

w is the spherical tensor,

n is the directing tensor;

mathematical:

k is a covariant tensor, b is a contravariant tensor, and c is a mixed tensor.

Here is an example of recording a covariant stress deviator: P_K^D.

II. Vectors

$\overrightarrow{w}$ - speed-up, $\overrightarrow{V}$ - speed, $\overrightarrow{u}$ - movement.

III.Scalars ρ_K - component density K, C_K - component concentration K, T - temperature, P - pressure, U - energy, S - entropy.

This is the general scheme for recording laws in the MSS. Data bank laws are processed on the computer automatically that require a strict sequence of records of the main, expressions. This sequence in many ways predetermines the order of output of mathematical models.

When solving problems, they first determine $P = R^{\sigma_1}\rho^{\sigma_2}T^{\sigma_3}, \overrightarrow{U}, \rho_K, T, \overrightarrow{E}, \overrightarrow{H}$ or $\overrightarrow{V}, \rho_K, T, \overrightarrow{E}, \overrightarrow{H}$ and then the values of the individual quantities are calculated using certain formulas.

In the algorithmic MSS, the order is preserved, so the MSS axioms in the law bank are divided into five groups. The first group includes: the laws of conservation of the mass of momentum, energy,

laws of electrodynamics (Maxwell equations),

restrictions on the voltage of speed, displacement, temperature, pressure,

optimal conditions (volume, weight, cost).

Closing conditions (boundary, initial, and on discontinuities).

To simplify the calculations on the computer, four types of volume forces-gravity, centrifugal, Coriolis, and electrodynamic forces-were introduced into the balance equation. Expressions for these forces form the second group of relations.

The first and second group of relations includes all the tensors, vectors, and scalars listed. Transition to $D, C, \overrightarrow{V}, \rho_K, T, \overrightarrow{E}, \overrightarrow{H}$ in the first group is carried out with the help of empirical laws entering the third group:

Equations of state,

phenomenological laws,

equations of chemical kinetics.

The transition from the tensors D and C to K vectors is carried out by means of the geometric relations of the fourth group:

The relationship between deformation and displacements,

The relationship between the rate of deformation and the velocities of displacement,

Equation of continuity.

After these substitutions, the equation for the unknown quantities is obtained in tensor notation. The transition to the coordinate system is performed using the fifth group relationships, i.e. by the tensor calculus formulas.

Here are the basic laws (axioms) of the MS:

$\rho\frac{d\overrightarrow{V}}{dt} = DivP + \overrightarrow{F} + \overrightarrow{F_{\mathrm{Im}}} + \overrightarrow{F_{\Phi}}$ momentum equations

$\rho\frac{dC_K}{dt} = -div\overrightarrow{J_K} + \sum_{j=1}^{r}\partial_{K_j}\overrightarrow{J_J}$. Equation of continuity for multicomponent media taking into account chemical transformations.

$\rho\frac{dU}{dt} = -div\overrightarrow{J_2} - P;\ Grad\overrightarrow{V} + U_g + U_{\mathrm{Im}} + U_\rho$ - energy equation

$\int_V \delta(P:D)dV = \int_V \delta(\overrightarrow{F} - \overrightarrow{\rho}\frac{\partial\overrightarrow{v}}{\partial t})\overrightarrow{u})dV + \int_\Omega \delta(\boldsymbol{P^*}_{(n)}\boldsymbol{u})d\Omega$ - various conservation principles

$$\left.\begin{aligned}\overrightarrow{U} &\leqslant \overrightarrow{U}_0(x,t)\\ \overrightarrow{V} &\leqslant \overrightarrow{V}_0(x,t)\\ \overrightarrow{T} &\leqslant \overrightarrow{T}_0(x,t)\\ \overrightarrow{P} &\leqslant \overrightarrow{P}_0(x,t)\end{aligned}\right\}\text{constraints}$$

$$\left.\begin{array}{l} Y \to \max \\ S \to \min \\ G \to \min \end{array}\right\} \text{Optimum conditions}$$

$$\overrightarrow{F} = \overrightarrow{g} + \overrightarrow{\omega_0} \times \overrightarrow{r} + \tfrac{1}{2}(\overrightarrow{v} \times \overrightarrow{\omega_0}) \text{ Volumetric Forces}$$

$$\left.\begin{array}{l} \overrightarrow{u} = f_u(\overrightarrow{x}, t)\ \overrightarrow{x} \in \Omega_u \\ \overrightarrow{V} = f_V(\overrightarrow{x}, t)\ \overrightarrow{x} \in \Omega_V \\ \overrightarrow{T} = f_p(\overrightarrow{x}, t)\ \overrightarrow{x} \in \Omega_p \end{array}\right\} \text{Border conditions}$$

$$\left.\begin{array}{c} P = \varphi_0 \underline{U} + \varphi_1 D + \varphi_2 D \cdot D + \varphi_3 C + \varphi_4 C \cdot C \\ D = \psi_0 \underline{U} + \psi_1 P + \psi_2 P \cdot P \end{array}\right\} \text{Physical dependencies}$$

$D = \left\| \frac{1}{2}(\nabla_i U_i + \nabla_j U_j + \nabla_i u^k \nabla_j U_K) \right\|_{1-3}^{1-3}$, $C = \frac{1}{2} \left\| \frac{1}{2}(\nabla_j V_i + \nabla_i V_j) \right\|_{1-3}^{1-3}$ Geometric dependencies

$$\left.\begin{array}{c} \frac{d\overrightarrow{V}}{dt} = \frac{\partial(\overrightarrow{V} + (\overrightarrow{V})\nabla_a(\overrightarrow{V}))}{\partial},\ Grad\,\overrightarrow{a} = \left\| V_i a^K \right\|_{1-3}^{1-3}, \\ \overrightarrow{a} \times \overrightarrow{b} = \boldsymbol{i}(u_2 w_3 - u_3 w_2) + \overrightarrow{j}(u_3 w_1 - u_1 w_3) + \overrightarrow{k}(u_1 w_2 - u_2 w_1) \\ div\,\overrightarrow{a} = \sum_i \nabla_i a^i;\ grad\, f = \| V_i f \|_{1-3}\ rot\,\overrightarrow{a} \| \nabla_\alpha a_\beta - \nabla_\beta a_\alpha \|_{1-3} \\ \nabla_i a^m = \frac{\partial a^m}{\partial y_i} + a^n \Gamma_{ni}^m \end{array}\right\} \text{formulas of vector calculus}$$

$$\left.\begin{array}{c} \overrightarrow{V} \cdot \overrightarrow{W} = [V_i W_K]_{i,K},\ \overrightarrow{V_0} T = [V_i T_{Ki}]_{i,k},\ T \cdot \overrightarrow{V} = [T_{k,l} V_i]_{i,k,l}\ \overrightarrow{V_0} T = [V_i T_{kl}]_{i,k,l} \\ A \cdot B = [A_2^\beta, B_{\gamma\delta}^\varepsilon]_{\alpha,\beta,\gamma,\varepsilon,\delta}\ \overrightarrow{V} \cdot \overrightarrow{W} = \sum_i V_i W_i,\ T \cdot \overrightarrow{V} = [\sum_k T_{ik} V_k]_i \\ \overrightarrow{V} \cdot T = [\sum_k T_{ik} V_k]_i,\ S \cdot T = [\sum_i S_{ii} T_{ik}]_{i,k},\ S : T = \sum_{i,k} S_{i,k} T_{ki} \\ Div\, T = \left\| \sum_{i,k} \nabla_k T^{ki} \right\|_{1-3} \end{array}\right\} \text{tensor analysis formulas}$$

$\Gamma_{\alpha\rho,i} = \dfrac{1}{2}\left(\dfrac{\partial g_{i\alpha}}{\partial x^\alpha} + \dfrac{\partial g_{i\beta}}{\partial x^\beta} + \dfrac{\partial g_{\alpha\beta}}{\partial x^i}\right)$, $\Gamma_{i,j}^k = \dfrac{1}{2} g^{ks}\left(\dfrac{\partial g_{is}}{\partial \varsigma^j} + \dfrac{\partial g_{is}}{\partial \zeta^i} + \dfrac{\partial g_{ij}}{\partial \zeta^s}\right)$ the Christoffel symbols.

All the above expressions are written into the computer memory with a computer cipher, which allows you to choose the laws that correspond to the system in question [1].

7 Model Bank

The B_4 model bank is used for research and identification of mathematical models of problems. Its main functions [2]:

$F_4^{/}$ - Identification of models based on features formed in Base B_3;

$F_4^{//}$ - study of models;

$F_4^{///}$ - transmission of data about models in base B_5.

Elements of the second level and their functions [2]:

B_{4-1}- information part, storing logical information about models;

F_{4-1} - storage of information about models;

B_{4-2} - the operating part, processing B_{4-1} and performing functions;

B_{4-2} - is divided into elements of the third level;

B_{4-2-1} - module for identification of models by features;

B_{4-2-2} - model research unit;

B_{4-2-3} - the operator of data transmission to the base B_5.

$B_{4-2-2-1}$ - module for forming test models;

$B_{4-2-2-2}$ – The module of a choice of the test model, as much as possible approached to investigated

Assignment of bank of models.	Model Bank Functions
Element	Functions
B_4	$F_4^{/}$ – identification; $F_4^{//}$ – research; $F_4^{///}$ – $datatransfer$
B_{4-1}	F_{4-1} – data storage
B_{4-2}	$F'_{4-2} \equiv F'_4$; $F''_{4-2} \equiv F''_4$; $F'''_{4-2} \equiv F'''_4$.
B_{4-2-1} – identity module by feature	$F_{4-2-1} \equiv F'_{4-2}$;
B_{4-2-2} – research unit	$F_{4-2-2} \equiv F''_{4-2}$;
B_{4-2-3}- transmission operator	$F_{4-2-3} \equiv F'''_{4-2}$;
B_{4-2-4} – monitor	F_{4-2-4}- management
$B_{4-2-2-1}$ – Monte Carlo module	$F'_{4-2-2-1}$ - the outline of points uniformly distributed over the region; $F''_{4-2-2-1}$ - transition to an unconditional model (penalty functions); $F'''_{4-2-2-1}$ - computation of unconditional model in points
$B_{4-2-2-2}$ – block for forming a test model	$F_{4-2-2-2}$- formation of a test model
$B_{4-2-2-3}$ – optimization block	$F_{4-2-2-3}$- optimization of test models
$B_{4-2-2-4}$ – test model selection module	$F'_{4-2-2-4}$ - the definition of a test model as close as possible to the model under study; $F''_{4-2-2-4}$ - data transmission to B_{4-2-2} [2].

Mathematical models of problems derived from general MSS laws based on bank features data are analyzed using bank model procedures, which is performed by mathematical and functional analysis.

First of all, the types of tasks are set. There are three types of tasks: tasks for direct and reverse counting and optimization. The type of the problem is determined when the problem is raised in the bank B_0. When solving inverse counting tasks, a list of calculated system parameters and experimental data on the process flow are given. In optimization tasks, the objective function and constraints are indicated.

Next, the type of equations (operators) is established. By the nature of the operators, the MS equations are divided into algebraic, differential, integral and integro-differential.

All these types of equations are divided into two groups: linear and nonlinear.

The next stage of the analysis of models is reduced to studying the nature of the change in the coefficient, the properties of the terms and the boundary conditions. Here there may be concentrated factors, discontinuous functions or functions that are continuous up to a derivative of n order (perhaps, $n = \infty$).

From the point of view of functional analysis, the MS problem models are represented in the form of an operator equation

$$Ax = y, x \in X, y \in Y$$

and the problem reduces to an equation of the type of sets and the operator A. As a rule, they are linear spaces of functions of various types. Integral and integro-differential operators are derived from differential operators in the process of solving the problem.

The type of the task is indicated in the formulation bank, and the analysis of the equations is formalized in the form of bank model procedures. We list these procedures.

1. Procedure "Analysis of functions". With its help stand out:

a_1) functions defined on the boundary ;

a_2) functions defined in the domain ;

a_3) classes of functions (continuous, continuous with respect to the derivative, summable, summable with a square, etc.).

2. Procedure "Analysis of the set". With this help you can install:

b_1) type of functional set (continuous, continuous up to a set of n-th order);

b_2) the metric of the set;

b_3) the norm of a set;

b_4) scalar product;

b_5) type of set (linear, complete, closed, separable, compact, etc.).

Here it is assumed that the metric and norm are consistent and all operations are performed in Banach spaces.

3. Procedure "Analysis of the operator". With its help, the type of operators is set:

c_1) differential (ordinary or partial differential equations, hyperbolic, parabolic, elliptic);

c_2) integral;

c_3) integro-differential;

c_4) with the energy norm;

c_5) positive;

c_6) positive definite;

c_7) linear or nonlinear.

All these procedures are based on the axioms given in [1].

In procedure 1, the types are related to the boundary conditions, but a_2 to the volume force. These types are set in advance and fixed in the bank B_0. Classes of functions (a_3 type) are distinguished using algorithms of mathematical analysis. In this case, the zeros and singular points of the function and its derivatives are determined. Therefore, procedure 1 includes a subroutine for differentiating and calculating the coordinates of points, where the function and its derivatives go to zero or to infinity.

The algorithms of the procedure "Analysis of the set"are given in § 5 of Chapter IV in [1]. Here the most crucial moment is the introduction of the metric and norm. For some standard function spaces they are known in advance. Therefore, procedure 2 begins with the definition of the type of function spaces(b_1). The block b_1 is constructed according to the data of block a_2 and procedure 1.

The norm and scalar product, as a rule, are selected in accordance with the metric (blocks b_3, b_4).

Block b5 of procedure 2 is constructed on the axioms and theorems of functional analysis. When the type of function space is fixed in advance, the construction of the block b_5 is simplified, the type of the set is set directly.

The "Operator Analysis"procedure consists of seven blocks. The presence of differentials and integrals, as well as the order of the equations, are established by a simple listing. The definition of the type of partial differential equations requires an analysis of the corresponding quadratic forms obtained by uncovering the determinants.

The energy norm follows from the usual norm, and its properties are established by the axioms of functional analysis or by direct calculations.

For the construction of blocks c_5 and c_6 axioms of functional analysis are used, and for the block, c_7 bust.

This is a brief outline of the construction of procedures for the bank of models and its blocks. In the final analysis, all these procedures are constructed using schemes of normal algorithms and inference rules [1].

8 Bank of algorithms B_5

Bank of algorithms B_5 serves for storing all necessary information about available algorithms for solving extreme problems, and also for choosing the optimal algorithm for each particular model [2].

We describe the construction and operation of the bank of algorithms

The main functions of bank B_5:

F'_5 – choice of algorithm for solving the problem;

F''_5 – parametric optimization of the algorithm (formulation it for a task);

F'''_5 – constructing an optimizing sequence of algorithms;

F_5^{IV} – communication in B_6.

Elements of the first level:

B_{5-1} – information part providing F_{5-1} - storage of information about the characteristics of algorithms;

B_{5-2} – The operating part that provides the following functions:

F'_{5-2}– algorithm selection;

F''_{5-2}– search for optimal values of algorithm parameters in B_{5-1};

$F'''_{5-2} \equiv F''_5$; F_{5-2}^{IV}– constructing a sequence of algorithms;

F_{5-2}^{IV}– constructing ε'– a sequence of algorithms;

$F_{5-2}^{V} \equiv F_5^{IV}$.

Elements of the first level consist of the following elements of the second level:

B_{5-1-1} – array of applicability of algorithms;

B_{5-1-2} – array of optimal parameters of algorithms;

B_{5-1-3} – array ε– of sequences of algorithms for classes of tasks;

B_{5-1-4} – array ε'– of sequences of algorithms for classes of tasks;

B_{5-2-1} – algorithm selection block;

B_{5-2-2} – algorithm optimization block;

B_{5-2-3} – block for constructing ε– sequences of algorithms;

The purpose of the bank of algorithms B_5. Functions of bank algorithms

Element	Functions
B_5 – bank of algorithms	F'_5– choice of algorithm for model resolution; F''_5– algorithm optimization; F'''_5– constructing a sequence of algorithms; F_5^{IV}– transfer of information to B_6
B_{5-1} – information part	F_{5-1}– transmission of information about the characteristics of the algorithm
B_{5-2} – operating part	$F'_{5-2} \equiv F'_5$; F''_{5-2}– search for optimal values of algorithm parameters in B_{5-1}; F'''_{5-2}– parametric optimization of the algorithm.
B_{5-2-5} - monitor	F_{5-2-5} – control B_{5-2-i} $(i = \overline{1,5})$ [2]

In the bank of algorithms, the mathematical model is transferred from the bank of models, where its analysis is performed, ie, the type of operators is established. All data will be called parameters of the model [1].

In the bank of algorithms, a computational scheme is chosen, resolving equations are constructed and signals are generated to select numerical data from the bank B_1 and application programs from bank B_6. Therefore, the algorithm bank generally includes the following procedures:

construction of computing schemes;

construction of resolving equations;

verification of convergence and stability;

generation of a selection signal and substitution into the resolving equations of the initial data;

generation of the program selection signal from the bank application package B_6.

At the first stage of the development of the algorithmic MS system, a computational scheme based on the experience of solving MS problems is fixed in advance and indicated in the bank B_0 [1].

In the mechanics of a deformable solid, variational methods are used in displacements or stresses. In this case, the resolving equations can be obtained by the variational method or by the methods of collocation, nets and finite elements.

A more general problem about the automated choice of a circuit is based on the conditions for optimizing calculations.

Procedure 2 (construction of resolving equations) is associated with the name of the computational schemes. When it is formed, a special block is constructed for each scheme, which is stored in operating part of the bank algorithms.

In procedure 3, convergence and stability are investigated within specific problems. In this case, general theorems of functional analysis, indicated in chapters IV in [1], are applied; or use existing computer account experience.

It is assumed that in the internal software of the computer there is a special unit for storing the results of the account.

In procedure 4, the corresponding arrays of source data are sent from the bank B_1 to arrays of resolving equations.

Solving equations in direct problems are obtained in the form of systems of algebraic or differential equations (linear or nonlinear). Applied programs (procedure 5) for solving such equations are chosen taking into account the volumes of the initial matrices and their conditionality.

In the optimization task of MS, search methods are mainly used, which leads to a sequential solution of the direct problem. This is, in general, a scheme for constructing a bank of algorithms for the algorithmic MS system [1].

9 Bank of applied programs B_6 [2]

Computing bank B_6 is intended for storage of all search models corresponding to different algorithm algorithms of the bank of algorithms, selection of the appropriate module after receiving information from the bank of algorithms, creating a work program for solving the problem with a subsequent account after receiving information from the data bank.

Thus, the functions of bank B_6:

$F_6^{/}$ – storage of modules;

$F_6^{//}$ – the formation of a work program;

$F_6^{///}$ – substitution of initial data and parameter values of algorithms;
F_6^{IV} – transfer to the account.
These functions perform:
B_{6-1} – information part;
B_{6-2} – the operating part, which, in turn, consists of the elements of the second level:
B_{6-2-1} – the block of formation of the working program;
B_{6-2-2} – the block of a call and statement of the data;
B_{6-2-3} – monitor, controlling B_{6-2-1} and B_{6-2-2}.

Upon receipt from the bank B_5 of the number of the chosen algorithm, the bank B_5 organizes an appeal to the procedure that implements the specified algorithm with the introduction of all the necessary initial data and subsequent transfer to the account. After passing the invoice for printing, the results of the required function are displayed. Assignments of the bank B_6 [2].

Element	Functions

B_6 – computer bank	$F_6^{/}$ – storage ofΠmodels;
	$F_6^{//}$ – the formation of a work program;
	$F_6^{///}$ – data substitution;
	$F_6^{/V}$ – transfer to an account

$B_{6-1} - informationpart;$
$B_{6-2} - operatingpart;$
$B_{6-2-1} - blockformation;$
$B_{6-2-2} - datacallblock$
	$F_{6-1} \equiv F_6^{/}$
	$F_{6-2}^{/} \equiv F_6^{//}; F_{6-2}^{//} \equiv F_6^{///}, F_{6-2}^{///} \equiv F_6^{/V};$
	$F_{6-2-1}^{/} \equiv F_{6-2}^{/}; F_{6-2-1}^{//} \equiv F_{6-2}^{///}$
	$F_{6-2-2}^{/}$ – call data fromB_1, B_5;
	$F_{6-2-2}^{//}$ – substitution of data into a work program

B_{6-2-3} – monitor	F_{6-2-3} - control B_{6-2-1}, B_{6-2-2} [2]

The application bank consists of a library of subroutines and a library of modules. The first includes all existing programs included in the computer software (CS) and in the second - programs that supplement the archive CS of the general use computer of the computer [1]. Standard programs such as the $lnx, cosx, tgx$ solution of algebraic equations by the Gauss method, Runge-Kutta methods for solving a system of ordinary differential equations, function interpolation, approximate integration by the Gauss or Simpson method, and many programs that are available in the computer's operating system form a library of subprograms.

In addition, standard equations are used to derive equations: analytical differentiation and integration, simplification, substitution, variation. Various variants of sweep (difference, stream, differential, matrix, orthogonal), recognition of arbitrary areas, programs for solving basic problems and other programs are included in the library of modules of the application bank.

Let us explain what a basic problem is. For example, the splitting methods reduce the solution of the original problem to the successive solution of some elementary (one-dimensional) problems, each of which has an independent designation. It is natural to call these tasks a basis, but a sequence of them. solution, which ensures the solution of the original problem, by the representation of the latter in this basis. The basis for such a definition of the basis is the fact that within a certain fixed basis a fairly wide class of different tasks. On the other hand, the completion of the class of problems under consideration can be made at the expense of an insignificant extension of the basis [1].

10 Operating Bank B_7

Monitor B_7 to control the sequence of work B and has a simple structure, which was possible in view of the hierarchical construction of the system, because each B is essentially an independent package with its own monitor, which controls all the functions of the modules inside B [2].

In the operating bank B_7 logical, symbolic and arithmetic operations are performed. The bank's work consists of three stages: output of models, choice of algorithms and account. In the process of the system, B_7 from other banks consistently rewrites the necessary data and provides a strict procedure for processing the rewritten words. In accordance with the work stages in B_7, the order of output, choice of algorithms and counting [1] are introduced.

The software consists of symbolic and arithmetic procedures. Symbolic procedures - input, census, substitution, differentiation, variation, integration, integration by parts, reduction of similar terms, model analysis, choice of algorithms, series, construction of grid equations, direct method, construction of variational equations, Chaplygin and Dorodnicyn methods,.

The order of the output is related to the sequence of operation of the specified operators.

The operation of the operating bank begins with the procedure Enter (B_0, B_7). Further, according to the words from B_0, a census of laws and signs from banks B_2 and B_3 in B_7: Per (B_2, B_3, B_7). This rewrites a subset of words from the following names of laws and quantities included in these laws [1]:

The order of the output depends on the type of systems and the names of the unknown quantities. In the algorithmic system, the following types of systems are considered:

For all these systems, you can build an order of output in the form of networks. We give examples [1].

A. Aerodynamics (one-component) in [1].

1) The corresponding equations of condition B are given. Elastic-deformable body (the principle of possible displacements):

2) $\int_V (P : \delta D)dv = \int_V (\overrightarrow{F} - \rho\frac{\partial\vec{v}}{\partial t})\delta\overrightarrow{U}dv + \int_\Omega \overrightarrow{P}_n\delta\overrightarrow{U}d\Omega = 0$

7) $P = \varphi_0 U + \varphi_1 D,$

12) $D = \nabla_i U^j + \nabla_j U^i + \nabla_i U^K \nabla_j U^K$

16) $P : \delta D = \sum_i \sum_j \sigma^{ij}\delta\varepsilon_{ij},$

18) $\frac{d\overrightarrow{V}}{dt} = \frac{d^2\overrightarrow{U}}{dt^2},\ \nabla_i u^j = \frac{\partial u^j}{\partial x_i} + \Gamma^K_{ij}U_K,\ U^{(1)} = -z\frac{\partial w(x,t)}{\partial x},\ U^{(2)} = 0,\ U^{(3)} = w(x,t)$

19) (Cartesian coordinates $\Gamma^K_{ij} = 0$

21) Field: prism.

The order of output is shown in Fig. 41 in [1]. Here we introduce the following notation: M is a mathematical model; DP is a differential operator; $\int M$ integral; $\int$ integro-differential; OD - ordinary differential; GD - is hyperbolic; PD – is parabolic; ED - is elliptical; SD – displaced; $P\int$ regular; $C\int$ - singular.

11 Output order

The set of general MS equations makes up a set of words in a given alphabet and is written out in a bank of laws B_2. For brevity, this set will be called the "array"of laws!

1	Conservation of mass	$[\rho, \overrightarrow{v}]$
2	Preservation of Concentration	$[c_i, \overrightarrow{j}_k, v_i, j]$
3	Persistence of momentum	$[\overrightarrow{v}, \overrightarrow{p}, F]$
4	Variations of displacement	$[P, D, \overrightarrow{F}, \overrightarrow{u}, p_n]$
5	Variations in voltage	$[P, D, \overrightarrow{F}, \overrightarrow{P}_K, \overrightarrow{u}]$
6	Energy	$[u, \overrightarrow{j_a}, \overrightarrow{j_k}, \overrightarrow{u_\varepsilon}, P, \overrightarrow{V}]$
7	Stress tensor	$[P, D, C, \varphi_i]$
8	The flow of substances	$[\overrightarrow{J}_k, T, c_i, \overrightarrow{F}_i]$
9	Heat flow	$[\overrightarrow{J}_q, T, c_i, \overrightarrow{F}_i]$
10	Speed reaction	$[J_i, c_i]$
11	Volumetric force	$[\overrightarrow{F}, \overrightarrow{F}_\in]$
12	The strain tensor	$[D, \overrightarrow{u}]$
13	The strain rate tensor	$[C, \overrightarrow{v}]$
14	Electrodynamics	$[\overrightarrow{H}, \overrightarrow{E}, \overrightarrow{D}, \overrightarrow{P}, z, \overrightarrow{I}, \overrightarrow{i}]$
15	The tensor of operators	$Grad\overrightarrow{v}\, DivP, div\overrightarrow{v}\, gradp$
16	Operation Tensor	$:, \cdot, ^o$
17	Differentials	$\frac{d}{dt}, \nabla_i$
18	Symptoms	$[\overrightarrow{u}, \overrightarrow{v}]$
19	Metrics	g_{ij}, Γ_{ij}^k
20	Dimension	$\frac{\partial}{\partial x_i}$
21	Region	
22	Border conditions	
23	Solution method	
24	Constants	

system1: aerohydrodynamic	
One-component	$[\widetilde{v}, T, \rho, p]$
Mixture	$[\overrightarrow{v}, R, \rho, P, c_i]$
Electrodynamic	$[\overrightarrow{v}, R, \rho, P, \overrightarrow{E}, \overrightarrow{H}]$
System 2: Solid (moving)	$[\overrightarrow{v}, D]$
System 3: Solid (voltage)	$[P, \overrightarrow{v}]$

The MS task classes are formed using the feature space. A lot of features of tasks in the bank fit into the bank of signs. A set of characteristics of tasks fit into a bank of characteristics B_3, which is later called an array of characteristics.

The formulation of tasks is carried out with the help of the formulation bank (B_0), where all the main terms of the MS fit in.

Building banks B_0 and B_3 - the main task of this item.

When solving specific problems, taking into account their characteristics, chosen from the data of bank B_0 from general laws, mathematical models of problems that are solved by methods of computational mathematics are derived. Since in the algorithmization of the output of mathematical models of tasks is carried out on the computer, it is necessary to establish a strict order of output, that is, a sequence of standard transformations. On the order of output depends the structure of the formulation banks and attributes.

The derivation of the equation is carried out in the operational bank. To do this, first, according to the bank statements from the bank laws and signs in the operating bank consistently correspond necessary for the word output. Then the operation operation is performed in the operating bank in a certain order. Such an order of output is formalized in the form of successive steps.

Earlier, schemes of formalized derivation of task models were outlined. Analysis of these schemes leads to the following conclusions:

1. The choice of MS laws is ambiguous. For example, in aerodynamics use a differential recording of the equations of conservation of momentum, and in the mechanics of a deformable solid - a variational record (in displacements or stresses). If there are no electrodynamic phenomena, Maxwell's equations are not applied at all.

The equations for the conservation of matter for the k-th component are used only in the study of mixtures. Equations of energy conservation are considered in the presence of temperature phenomena.

The same applies to the summand equations. For example, in the absence of electromagnetic or diffusion phenomena, only the term associated with the thermal conductivity remains u_q in the energy equation.

2. Formally, the derivation of the model is related to the simplification of the equations of general MS laws, written out in tensor symbolism. This simplification is primarily achieved by means of conditions imposed on the parameters of the systems and on the connections between them. For liquid, for example $p = const$, and $\frac{\partial p}{\partial t} = 0$ for statics $\overrightarrow{v} = 0$; for an ideal gas $P = pU$ and $DivP = gradp$. Such simplifications can be carried out directly in the equations of general laws.

3. The next stage of simplification begins with the discovery of tensor quantities. In this case, a coordinate system is first defined, metrics (g_{ij}, g^{ij}, g_i^j), Christoffel symbols (Γ_{ij}^{γ}) and covariant derivatives (∇_i) are calculated. The obtained values are substituted into the formulas for the operations of the tensor calculus (grad, div, rot. Grad, Div, and etc.).

4. After the transition to coordinates, simplifications are again made on the conditions imposed on the components of the system parameters. For example, for a plane flow $v^{(3)} = = 0$, for a plane stress state

$$P = \begin{Bmatrix} \sigma^{11} & \sigma^{12} & 0 \\ \sigma^{21} & \sigma^{22} & 0 \\ 0 & 0 & 0 \end{Bmatrix}.$$

Thus, in the derivation of models, the selected laws are successively simplified by terms, tensor quantities, coordinates, scalar quantities, that is, simplification operations are applied several times.

Since in algorithmization the derivation of models and their investigation, the choice of the algorithm and the numerical solution of the problem constitute an unbroken chain, then in constructing the corresponding banks, it is necessary to take into account the experience of solving problems of MS, that is, to formulate the signs of problems of algorithms.

In algorithmization, all stages of output are formalized in the form of output steps. We list these steps.

The laws. The choice of terms and laws is realized with the help of words like "liquid "gas "deformable solid body "mixture etc. The form of recording laws is adapted to implement this step.

The parameter T. The choice of constraints on the tensor quantities is carried out with the help of the words "statics "real "elastic,"and so on.

Coordinates. The coordinate system is selected, the dimensionality of the space is set. In this case, the words "decart "cylindrical "one-dimensional "two-dimensional etc. are used.

Parameter C. In this step, the values of the scalar parameters are refined.

Borders. Characteristics of the area of motion of systems and its boundaries are specified when formulation the task and from the bank of the statement are directly entered into the operational bank.

Initial data. Here, the initial, boundary conditions and conditions on discontinuities are fixed. When the task is formulated, these conditions are transferred to the operational bank in a formalized form.

Coefficients. When formulation a problem, numerical values of the coefficients are set or their signs are fixed, according to which the data bank is searched.

Algorithm. When formulating a problem, it is possible to outline in advance the general ways of its numerical solution and the scheme of the account. From these data, a decision algorithm is chosen.

The required quantities. In many cases, when formulation the task, the list of the main and production sought values is additionally fixed. This circumstance is formalized in the last (ninth) step of the first stage of conclusions.

Let us dwell on the list of parameters determined as a result of solving the problem. In the general case, the main parameters of the system are found from the MS equations ρ, c_k, p, T, z, $\overrightarrow{\upsilon}$, $\overrightarrow{u}$, $\overrightarrow{E}$, $\overrightarrow{H}$ (density, concentration, pressure, temperature, charge, speed, displacement, electric and magnetic fields) and the derivatives of the quantities u, s, w, Q, P, D, $\overrightarrow{N}$, $\overrightarrow{M}$, $\overrightarrow{J}$, I_σ, I_ε, $\overrightarrow{B}$, $\overrightarrow{D}$, $\overrightarrow{I}$, V, G, S (energy, entropy, resistance, flow, tension, deformations, forces, moments, flows, invariants of stress tensor and deformation, electric and magnetic inductions, electric current, volume, weight and cost).

This is the order of derivation of the MS equations. To implement the described scheme, it is necessary to form a statement bank and a feature bank.

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АЛГОРИТМИЗАЦИЯ МЕХАНИКИ СПЛОШНЫХ СРЕД

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В статье поставлены и решены основные проблемы алгоритмизации механике сплошных сред. Рассматриваются проблемы автоматизации исследований механике сплошных сред. Автоматизации всех этапов исследований названа алгоритмизацией в механике сплошных сред, методы формализации в механике сплошных сред - алгоритмическими методами. Приведены этапы алгоритмизации: опыт-законы-задачи-математические модели-алгоритмы-программные обеспечение-вычислительный эксперимент. Дано практическая реализация этапы алгоритмизации осуществляющий при помощи шести основных B_1 - данные, B_2 - законы, B_3 - признаки, B_4-модели,B_5-алгоритмы, B_6-прикладные и двух вспомогательных B_0-постановка,B_7-операционные алгоритмических банков.

Ключевые слова: механике сплошных сред, автоматизация, методы формализации, система, законы, признаки, модели, алгоритмы.

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