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EXPERT EVALUATION OF THE TECHNICAL LEVEL OF NC-MACHINES

Ivan Vasiljevich ABRAMOV, Andrey Ivanovich ABRAMOV

Abstract

In this article, consider an approach to the formation of the base reference machine with the best performance, on the basis of expert evaluation of the technical level of CNC machine tools. The proposed approach makes it relatively simple to estimate the technical level of equipment to form a production strategy.

Key words

expert evaluation, CNC machine tools, technical level

Any decision regarding expediency and extent of intended modernization of the technological base of an enterprise depends on evaluation of technical condition and technological level of the available NC-machines. In turn, evaluation of technical condition of NC-machine relates more to repair and reconditioning (first of all, to the on-condition maintenance system), rather than to the modernization domain. The problem of technological level evaluation consists in comparison of quality indices of a real NC-machine with the ones of the basic model of NC-machine of the same group.

Russian standards of technical regulation define unified machine-oriented forms (maps) for evaluation of product technical level and quality in all industry sectors of national economy as well as the procedure of their construction and conduct. According to the standards, a special map of product technical level and quality evaluation (product technical level and quality map) is constructed for each product, which development and launch comply with standard requirements to Product Development and Pilot Production System (PDPPS) [26].

The standard includes terms and definitions related to construction of technical level maps and describes such concepts as “product quality index”, “product character” and “parameter of product”, “integral index of product quality”, ”product technical level evaluation”, etc. Product technical level evaluation consists of a number of operations, including:

- choice of indices describing the level of technical excellence of evaluated product,
- calculation of the indices
- and their comparison with the basic ones.

This approach means a basic specimen product to be used as a reference standard by product technical level and quality evaluation. The basic specimen product should characterize the latest scientific and technical achievements.

Set of indices used for evaluation of quality and technical level of NC-machines is regulated by a number of normative documents. The list of quality and technical level indices for turning lathes, available in the database, includes about 90 indices.

An integral index of technical level and competitiveness is defined as a ratio of a technical level change to the modernization costs having contributed to the change.

Examining the problem of NC-machines technical level dynamics, one should consider the concept of the objective function, which value, under specific conditions, may be regarded as an integral index of technical level. Analysis of technical level dynamics and subsequent calculation of the integral index of technical level come down to computation of the objective function value under given conditions. Use of machine- or machine group characteristics as input parameters of the objective function makes it necessary to calculate the factors and shifts of the objective function to some approximation.

The proposed approach to technical level evaluation consists in system analysis of NC-machines by a number of indices from the database and construction of objective function. For evaluation of technical level dynamics of NC-machines, it is reasonable to group machines according to the model modification. At that, a basic model of NC-machine is represented by a set of indices corresponding to predicted and best-case values for the present. Differences in technical level indices of model modifications allow to judge on technical level development.

It should be noted, that in case the compared index values differ in several orders, there arise a problem of the values normalization. Normalization implies database indices conversion from absolute to relative form. Relative index value is calculated as a ratio of the index value of NC-machine, which technical level is evaluated, to the index value of the basic model for respective machine group:

$$x_{rel} = \frac{x_{abs}}{x_{abs\ bas}} \tag{1}$$

where x_{rel} is a relative index value to be stored in the database, x_{abs} – an absolute index value, $x_{abs\ bas}$ – the absolute index value of basic model.

Conversion from absolute to relative values enables to avoid the use of dimension in the integral index of technical level, which, as has been said before, is a non-physical virtual index, and therefore has no dimension.

One may choose from a wide range of software applications designed for data storage and preprocessing. The preprocessed data form a table, with technical level- and quality indices of NC-machines being column values in respective rows. Table display is informative and enables calculation and plotting of some data dependencies.

Let us use the following formula as a first approximation of the integral index of technical level I_{tl}:

$$I_{tll} = \Sigma k_i \, \Sigma w_n P_n \tag{2}$$

where P_n is a technical level index of an NC-machine from the database, w_n – the weighting factor of respective technical level index, k_i – the weighting factor of respective group of technical level indices.

The given formula takes into account all indices of technical level and quality available in the database, as well as the weighting (correction) factors necessary for index ranking in calculation of the integral index.

As is evident, to make calculations by formula (2) one should know the weighting factors. We use the expert evaluation method to determine the values. The essence of the method consists in rational analysis of the problem by experts, quantitative evaluation of their judgments and analysis of results. This method may be used to estimate quantitatively the importance of each parameter in the database used for technical level evaluation.

	1	2	3	4	5	6	7
1	**Index name**	**16k20f3**	**16k20bf3**	**cke6130i**	**cke6136i**	**cke6136z**	**cke6140z**
2	**Functional parameters**						
3	Max turning length	900	1000	600	750	750	750
4	Max.turning diameter	320	320	300	360	360	400
5	X axis travel	210	210	175	205	205	200
6	Z axis travel	905	905	500	620	620	620
7	Spindle bore	55	55	40	40	52	52
8	**Performance parameters**						
9	Turret number of stations	6	6	6	6	6	6
10	Indexing time	5	5	2,1	2,1	2,1	2
11	Rapid traverse X	15	15	4	4	4	4
12	Rapid traverse Z	7,5	7,5	5	5	5	5
13	Cutting feed X	1	1				
14	Cutting feed Z	2	2				
15	Min. spindle speed	20	10	20	20	20	20
16	Max. spindle speed	2500	3500	2500	2500	2500	2500
17	**Accuracy parameters**						
18	Positioning precision	0,01	0,01	0,02	0,02	0,02	0,02
19	**Power characteristic parameters**						
20	Mainspindle motor power	11	11	4	5,5	5,5	5,5

Fig. 1: A fragment of a database table

	1	2	3	4	5	6	7	8
1	**Index name**	**base type**	**16k20f3**	**16k20bf3**	**cke6130i**	**cke6136i**	**cke6136z**	**cke6140z**
2	**Functional parameters**							
3	Max turning length	1000	0,90	1,00	0,60	0,75	0,75	0,75
4	Max.turning diameter	400	0,80	0,80	0,75	0,90	0,90	1,00
5	X axis travel	250	0,84	0,84	0,70	0,82	0,82	0,80
6	Z axis travel	905	1,00	1,00	0,55	0,69	0,69	0,69
7	Spindle bore	60	0,92	0,92	0,67	0,67	0,87	0,87
8	**Performance parameters**							
9	Turret number of stations	8	0,75	0,75	0,75	0,75	0,75	0,75
10	Indexing time	1,8	0,36	0,36	0,86	0,86	0,86	0,90
11	Rapid traverse X	15	1,00	1,00	0,27	0,27	0,27	0,27
12	Rapid traverse Z	10	0,75	0,75	0,50	0,50	0,50	0,50
13	Cutting feed X	5	0,20	0,20	0,00	0,00	0,00	0,00
14	Cutting feed Z	5	0,40	0,40	0,00	0,00	0,00	0,00
15	Min. spindle speed	10	2,00	1,00	2,00	2,00	2,00	2,00
16	Max. spindle speed	4000	0,63	0,88	0,63	0,63	0,63	0,63
17	**Accuracy parameters**							
18	Positioning precision	0,01	1,00	1,00	0,50	0,50	0,50	0,50
19	**Power characteristic parameters**							
20	Mainspindle motor power	11	1,00	1,00	0,36	0,50	0,50	0,50

Fig. 2: A fragment of a table containing normalized data

To process the expert judgments, the above-mentioned method is applied with the use of spreadsheets and spreadsheet editors. The weighting factor values assessed by experts are also stored in a database table. Their average values are used to calculate the first approximation of technical level index by formula (2).

If correlation factor of the expert estimates is large enough, i. e. if experts agree with each other, one may say, that the problem (assignment of weighting factors) has been thoroughly studied to date, and so the expert judgments do not differ much. If this is the case, further expert poll is not necessary, and one may content oneself with the already obtained data.

To create and populate the database of unnormalized technical level indices of turning lathes, performance and operational data of the following lathes (produced by domestic factories, such as public corporation "Krasny Proletary", public corporation "S. Ordzhonikidze Moscow Machine-Tool Plant", etc.) were used: 16К20F3, 16К20BF3, 1A616F3C2, 1B732F3, 1P717F3, 1P752MF3, 1P732MF4, 16A20F3C5, 1P756DF3, 1740RF3, 1P416F3, 1P732RF3. Performance and operational data of the following CKE series turning lathes produced by Chinese corporation "Dalian Machine Tool Group Corporation" (DMTG) were also used: CKE6130I, CKE6136I, CKE6136Z, CKE6140Z, CKE6140I, CKE6146Z, CKE6150I, CKE6150Z, CKE6156Z, CKE6163Z, CKE6166Z and CKE6180Z.

A fragment of a database table containing values of unnormalized technical level indices of NC-machines is shown in Figure 1. The table is opened in OpenOffice.org Calc 3.2.0 spreadsheet processor.

A fragment of a database table containing normalized (relative) values of technical level indices of NC-machines is shown in Figure 2. The table is opened in OpenOffice.org Calc 3.2.0 spreadsheet processor.Expert poll results are entered into a separate database table, on a new worksheet. The first column of the table is designated as "Index name", the next ones – "Expert 1", "Expert 2", etc., because experts were questioned on anonymous basis. The column values are weighting factors assigned by experts. A fragment of the database table is shown in Figure 3.

	1	2	3	4	5	7
1	**Index name**	Expert 1	Expert 2	Expert 3	Average	
2	**Functional parameters**					
3	Max turning length	20	30	20	23,33	
4	Max.turning diameter	30	30	20	26,67	
5	X axis travel	50	50	50	50,00	
6	Z axis travel	50	50	50	50,00	
7	Spindle bore	1	10	10	7,00	
8	**Performance parameters**					
9	Turret number of stations	50	50	50	50,00	
10	Indexing time	50	50	50	50,00	
11	Rapid traverse X	50	50	50	50,00	
12	Rapid traverse Z	50	50	50	50,00	
13	Cutting feed X	50	50	50	50,00	
14	Cutting feed Z	50	50	50	50,00	
15	Min. spindle speed	50	50	50	50,00	
16	Max. spindle speed	50	50	50	50,00	
17	**Accuracy parameters**					
18	Positioning precision	50	50	50	50,00	
19	**Power characteristic parameters**					
20	Mainspindle motor power	50	70	50	56,67	

Fig. 3: A fragment of a database table with averaged weighting factors

	1	2	3	4	5	6	7	8
1	**Index name**	**base type**	**16k20f3**	**16k20bf3**	**cke6130i**	**cke6136i**	**cke6136z**	**cke6140z**
2	**Functional parameters**							
3	Max turning length	1000	0,21	0,23	0,14	0,18	0,18	0,18
4	Max.turning diameter	400	0,21	0,21	0,20	0,24	0,24	0,27
5	X axis travel	250	0,42	0,42	0,35	0,41	0,41	0,40
6	Z axis travel	905	0,50	0,50	0,28	0,34	0,34	0,34
7	Spindle bore	60	0,06	0,06	0,05	0,05	0,06	0,06
8	**Performance parameters**							
9	Turret number of stations	8	0,38	0,38	0,38	0,38	0,38	0,38
10	Indexing time	1,8	0,18	0,18	0,43	0,43	0,43	0,45
11	Rapid traverse X	10	0,75	0,75	0,20	0,20	0,20	0,20
12	Rapid traverse Z	15	0,25	0,25	0,17	0,17	0,17	0,17
13	Cutting feed X	5	0,10	0,10	0,00	0,00	0,00	0,00
14	Cutting feed Z	5	0,20	0,20	0,00	0,00	0,00	0,00
15	Min. spindle speed	10	0,25	0,50	0,25	0,25	0,25	0,25
16	Max. spindle speed	4000	0,31	0,44	0,31	0,31	0,31	0,31
17	**Accuracy parameters**							
18	Positioning precision	0,01	0,50	0,50	0,25	0,25	0,25	0,25
19	**Power characteristic parameters**							
20	Mainspindle motor power	11	0,57	0,57	0,21	0,28	0,28	0,28
98	**Integral index of technical level**	53,26	44,46	46,45	36,01	37,40	37,47	37,66

Fig. 4: A fragment of a database table with calculation results of the integral index of technical level

There is one more column in the spreadsheet. It is designated as “Average value”. Values in this column are calculated using standard AVERAGE() function of spreadsheet processor. So the average values of weighting factors have been calculated. A fragment of the table containing averaged weighting factors is shown in Figure 3.

Having calculated the average values of weighting factors, one can calculate an integral index of technical level for any lathe as a first approximation using formula (2).

Figure 4 represents a fragment of a database table containing values of the integral index of technical level calculated as a first approximation using formula 2.

An integral index of technical level for the basic model of NC-machine is, in a first approximation, 53,26. All other NC-machines have smaller values of the integral index due to the approach to definition of basic model. So, technical level of the lathes under consideration should tend to the technical level of basic model but never reach it.

The proposed approach to expert evaluation of the technical level of NC-machines is rather easy to implement from engineering point of view. However it is labour- and time-consuming, as it takes time to choose experts and get their competent judgments. Nevertheless, this approach seems to be an essential constituent of correct learning in fast methods of technical level evaluation based on artificial neural networks and fuzzy logic.

Literature

1. NIKITIN Y.R., ABRAMOV I.V. CNC machines diagnostics Proceedings 13-th International Simposium on Mechatronics. – 2-4 June, 2010. – Trencinske Teplice, Slovakia – ISBN 978-80-8075-451-8, P. 89-91
2. RUCHKIN V.N., FULIN V.A. Universal'nyi iskusstvennyi intellekt i ekspertnye sistemy, BHV - Peterburg, 2009 г., 240 p, ISBN: 5-9775-0460-8

STRUCTURAL SYNTHESIS OF PRESSURE METAL FORMING PROCESSES

Sergey Alexandrovich MOROZOV, Olga Vasilevna MALINA

Abstract

Analysis of the variety of existing pressure metal forming processes allows to conclude, that the class of these processes can be related to complex structured processes according to the number of its characterizing parameters and criteria. The existing approaches to computer-aided design of such processes and CAD systems, implemented on their basis, permit to solve the synthesis tasks with an active participation of the production engineer. Development of the theory of characterization analysis allows to create the model of the synthesis process on the basis of an optimized combinatorial search, where the human influence on the design process is reduced and the automation level of the designer's intellectual activity is increased.

Key words

computer-aided design, pressure metal forming, structural synthesis, combinatorial search, allowed figures

Modern mechanical engineering is impossible without automation of all designing works, including the development of the product design and its production technique. Computer-aided design allows to reduce the time needed for the development and production of a new product, to increase its quality, to reduce the labor coefficient of production and the cost of its manufacturing and, therefore, to achieve a quick renewal of the range of products with account of market requirements.

The task of automation becomes especially urgent when developing the production technique, since the task itself is multiparameter and multicriterion, and its decision is multivariate. It is difficult and sometimes impossible for an expert to evaluate the influence of the set of parameters and criteria on the choice of the production technique without a computer. This determines the urgency of the task of automation of the pre-production engineering.

One of the main and the most progressive methods of producing blanks, semi-finished and ready parts in blank production is pressure metal forming (PMF). It is explained by the fact, that PMF provides a high quality of the part metal, it allows to correct defects of the cast structure of the initial blank and it reduces significantly the metal consumption due to maximum approaching of the blank configuration to the geometry of a ready part. Besides, PMF processes possess high productivity. The main processes of pressure metal forming are rolling, pressing, drawing, forging and stamping.

When any PMF process is considered in details, the set of parameters and criteria is determined; when the technique development is formalized and automated, they become the influence factors, determining the structure and contents of the manufacturing process.

Since any technique represents a finite number of operations and it is de-scribed by a finite number of parameters and evaluated by a finite number of criteria, then the manufacturing process can be represented by a finite set of discrete elements.

Three main techniques are applied in computer-aided design of manufacturing processes: the method of direct designing (active document), the method of analysis (addressing, analog) and the method of synthesis.

The method of direct designing means, that the preparation of the design document (the process chart) is assigned to the user, who chooses the typical decisions of different levels from the database in an interactive mode (for instance, the system “Compas-Autoproject” of “Askon” company (Saint-Petersburg). The manufacturing database is created and filled beforehand, it includes information about blanks, equipment, facilities, tools and so on, available at the enterprise. The database has a structured type, it involves sections, subsections, pages and separate fields. The user is given menus at different levels of design for the choice of blanks, operations, equipment, facilities, transfers, tools and so on. Information, chosen by the user from the database is automatically input into columns and lines of the process chart template. After that this information can be corrected if necessary and then printed in the form, specified by the corresponding standard GOST.

This level of design automation actually automates the preparation process of manufacturing documentation, while the development of production techniques is performed by a man. Therefore, the quality of the developed technique depends on the skill level of the process engineer.

Method of analysis is based on the choice of typical decisions. The structure of an individual manufacturing process is not created once again, it is determined by the composition and structure of the corresponding typical or group manufacturing process. Then the analysis is performed of the necessity of each operation and operating step with the consequent specification of all decisions at levels of decomposition “top-down”. Application of this method at the stage of the development and adaptation of the CAD system for manufacturing processes to conditions of a specific enterprise implies thorough preparation activities and it is justified for flexible manufacturing systems (the examples of such systems are CAD system “TechnoPro”, T-FLEX JSC “Top Systems” (Moscow)).

Within this approach to automation of techniques development, the expert only analyzes the proposed technological decisions and he has the possibility to correct them. The quality of design is again determined by the skill level of the production engineer.

The basis of the method of synthesis is automation of intellectual human activity on manufacturing process development. At present time CAD systems, applying the method of synthesis, are characterized by the high level of intellectualization of design processes due to programming of functional dependencies of the object domain [1-5]. All these systems are differed by designing techniques, accepted at various enterprises. Adaptation of such a system at the other enterprise is related in its essence to variation of the model of the system synthesis process, that is, to writing a new calculation module of the system, considering the development techniques of a specific production.

The method of manufacturing processes synthesis is the most progressive direction, if the approaches are developed to the creation of a design system with the algorithm of functioning, considering parameters and criteria of the object of designing, and also calculations related to the object domain as initial data for the design system.

What is the complexity to create such a system of computer-aided design of pressure metal forming techniques, implementing the synthesis method? First, it is the absence of production development techniques, common to all enterprises; second, it is the absence of development techniques, allowing to solve the synthesis task an any statement; third, it is the absence of a model of the synthesis process, free from dependencies of the object domain. Actually it means, that the developed CAD systems have, as a rule, a rigidly assigned set of initial data and a set of results, and the techniques, directed to features of a specific enterprise, determine the sequence of computations and constitute, in their essence, the model of the synthesis process of a technique.

It is evident, that in the present market situation it is urgent to create a system, free from the pointed drawbacks.

The solution of this task in the pointed statement is possible, if searching algorithms within the set of features are applied as the synthesis instrument, the features characterizing the techniques of pressure metal forming. Problems, appearing in implementation of these methods (called "damnation of dimension"), are solved by reducing the necessity in computational resources due to optimization of a combinatorial search.

The analysis of generalized models of complex structured objects, con-structed of discrete modules, showed, that the frame of the structure is practically absent, the set of features and their values, obtained by decomposition of the known structures as a result of an expert questioning, has a considerably greater cardinal, then the models of objects of a middle level of complexity. The cardinal number of the set of forbidden figures (reasons of unrealizable versions of the technique) is increased by one order. That is why, unlike the model of objects of a middle level of complexity, the first optimization stage of synthesis of complex objects is performed prior to the beginning of the process of a structural synthesis and it represents the reduction of the set of initial modules (features and outcomes). Implementation of the pointed reduction is possible by means of generating the set of allowed figures $R = \{r_i\}$ [6].

Allowed figures R can be absolutely allowed R_{ab} and relatively allowed R_{rel}, here $R = R_{ab} \cup R_{rel}$. Relatively allowed figures are those combinations of modules, which are obtained prior to giving the model of object class the restrictions resulted from the assignment of initial design requirements (for instance, combination of parameters of a specific equipment). Absolutely allowed figures R_{ab} are the combination of modules, assigned by the user as initial data.

Another classification of allowed figures divides their set into two subsets – precise and fuzzy. Precise allowed figures are combinations of outcomes ($R_{and} = \{r_{and}\}$, where $r_{and} = \{a_i\}$), fuzzy allowed figures are combination of outcomes and features $R_{or} = \{r_{or}\}$, where $r_{or} = \{a_i\} \cup \{P_j\}$, $i = \overline{1..N_{aror}}$, $j = \overline{1..N_{Pror}}$, N_{aror} is the number of outcomes of a fuzzy allowed figure, N_{Pror} is the number of features of a fuzzy allowed figure). Features, which have outcomes, unambiguously determining the presence of the subset of other features in the initial set of synthesis data, are precise allowed figures. Fuzzy allowed figures specify the set of features added to the synthesis process if the synthesized version contains some outcome or a group of outcomes called "key".

The third type of classification allows to divide the allowed figures into empirical and functional. Empirical allowed figures are obtained, first, by imposing the initial data on the design process, second, as a result of an expert inquiries as fixed and functionally undetermined dependencies of the object domain and they specify it. Functional allowed figures are one of possible displays of implementation of functional dependencies, available in the object domain during the synthesis process.

CONCLUSIONS

Classification of allowed figures allows to propose new approaches to optimization of the structural synthesis process: 1) it makes no sense creating and analyzing all the set of allowed figures, obtained as the set of all versions except for versions containing forbidden figures; 2) if the result of multiplication of n features is the set with the capacity N, with its subset presenting the set of forbidden figures with the capacity N_z, then allowed figures should be used as the data medium in case of $N_z > N - N_z$, and forbidden figures should be used in the opposite case; 3) fuzzy allowed figures divide all the set of features into subsets. Inclusion of the pointed sets into the synthesis process can be performed dynamically and is not the obligatory condition of the searching process; 4) generation of the set of allowed figures permits regarding each stable combination as one module, reducing the set of outcomes which participate in combinatorial search; 5) it is advisable to gener-ate the set of allowed figures within the set of features which are the conse-quence of a fuzzy allowed figure. Only in this case the allowed figure permits eliminating its constituent outcomes from the search during the synthesis process.

The task of optimization with introducing the allowed figures is divided into two stages:

1. reducing the set of outcomes participating in the search (by generating the set of allowed figures);
2. timely eliminating or preventing the appearance of forbidden versions (by analyzing the set of forbidden figures).

Owing to the classification variety of allowed figures, one should note, that unlike previously proposed algorithms, the set of outcomes under combinatorial search will be altered depending on the task assigned and restriction (initial data) imposed on the synthesis process.

Implementation of the proposed approach allows to generate the model of the structural synthesis process and create the system of synthesis of complex structured objects.

Literature

1. ALIYEV CH.A., TETERIN G.P. Computer-aided design system for hot die forging technique. – M.: Mashinostroeniye, 1987, 224 p.
2. WEINTRAUB D.A. Computer-aided calculation of the manufacturing process of deep drawing // Press-forging production. – 1971. – N5. – pp. 18-20.
3. CHESNOKOV V.S., VOZMISHCHEV N.E. Program systems of computer-aided design and simulation of forging and hot stamping// Proceedings of VIII Congress “Smith-2008”. – Ryazan: “Polytech” Ltd, 2008. – pp. 319-327.
4. BIBA N.V., STEBUNOV S.A. QForm-program of hot die forging simulation // CAD/CAM/CAE Observer #3(16), 2004. – pp. 2-4.
5. MOROZOV S.A. Computer-aided design systems for processes of pressure metal forming // Blank production in mechanical engineering. – 2004. - N11. – pp. 26-29.

6. MALINA O.V., MOROZOV S.A. Approach to structural synthesis of objects by complex structured models by the example of developing the technique of sheet stamping // Modern techniques: on the 50th anniversary of founding the department “Technology of robotized production”: proceedings /ed. by Dr. Tech. Sc., Prof. V.I. Goldfarb. – Izhevsk: ISTU Publishers, 2006, pp. 20-32.

INFORMATION PROCESSES MODELS OF MECHATRONIC SYSTEMS DIAGNOSIS

Yuri Rafailovich NIKITIN, Ivan Vasiljevich ABRAMOV

Abstract

The article reviews models of information processes of diagnosis, defining both the organization of diagnosis, analysis of diagnostic parameters and a decision on the technical state of modules, units and elements of mechatronic systems. The schemes of diagnostic devices are developed.

Key words

mechatronic systems, information processes, devices of diagnostics

The system of technical diagnostic of mechatronic system plays an important role in ensuring their reliability and high quality operation. For timely detection of defects in mechatronic systems, the organization of repairs and assess of the quality of repair work requires an effective diagnostic system. The use of technical diagnosis can significantly reduce maintenance costs; improve reliability of mechatronic systems and product quality.

The process of mechatronic systems diagnosing is considered as a set of two information processes. The first information process defines the organization of diagnosis. It defines the interval and the sequence of diagnostic modules, components and elements of mechatronic systems [1]. The second information process is used to analyze the diagnostic parameters and deciding on the technical condition of modules, units and elements of mechatronic system basic methods of artificial intelligence - Neural networks and Fuzzy logic systems [2, 3].

The feature of the first information process is to consider the degree of responsibility of mechatronic objects and the flow velocity in these degradation processes. In accordance with the above criteria, there are three proposed models for mechatronic systems diagnosing: parallel, serial and combined.

In parallel diagnosing all mechatronic systems modules are diagnosed at the same time. The continuous monitoring of technical condition is carried out. This method requires the maximum cost - each module has its own microsystem diagnosis. However, this method allows diagnosis in real time in the presence of degradation processes at high speed. It is appropriate to apply a parallel way of organizing the process of diagnosing when there is a threat to the human health and life and ahigh reliability is required.

The sequential diagnosis of mechatronic elements are diagnosed at a time. The periodic technical inspections are carried out. There is one controller for data processing, which consistently maintains information at regular intervals diagnosis. This method requires minimal cost, but it is necessary to calculate the intervals diagnostic of mechatronic elements and determine the sequence of their diagnosis.

In the combined diagnosis of the most critical mechatronic systems elements with high rates of degradation processes are diagnosed simultaneously, and the other - by turns at intervals of diagnosis.

The choice of intervals of diagnosis and sequence analysis of diagnostic parameters depends on the degree of responsibility of the mechatronic elements and the rate of degradation processes [1].

The feature of the second information process is the application of artificial intelligence - neural networks and fuzzy inference systems as diagnostic parameters (current, voltage, power, temperature, and temperature fields, vibration and acoustic parameters, the accuracy of positions, the stiffness, the motion parameters, power parameters, time intervals) have different physical nature and their analysis requires a single mathematical formalism.

To improve the mechatronic systems reliability the integration of information systems and diagnosis systems is required at the design stage of mechatronic modules. A mechatronic module should be composed of additional sensors to measure the diagnostic parameters. Computing core system diagnostics can be either a main controller to availability of computing resources, or a backup controller, which performs the diagnosis of all elements of mechatronic module and replaces the main controller, when it ceases to function properly.

Obviously, the diagnosing devices structural diagrams should match the way of the diagnosis process organization.

In parallel mode of organizing the process of mechatronic systems diagnosing collection, the information processing from sensors and decision on the technical condition are executed by parallel computing devices that are available in each mechatronic modules. Computing devices may be microcontroller or digital signal processors that transmit the results of solutions to the local network. The local network can be connected with a PC or CNC.

In the sequential method of organizing the process of mechatronic systems diagnosing collection, the information processing from sensors and decision on the technical condition are executed by one computing device, which may be a microcontroller, digital signal processor or industrial computer.

In the combined method of organizing the process of mechatronic systems diagnosing the most important and responsible modules are diagnosed simultaneously, and the remaining modules are diagnosed consecutively.

The authors propose to integrate the management and diagnosis system in each mechatronic modules. The diagnostic controller is the reserve controller and assumes the functions of management in case of violation of the normal functioning of the main controller. The block diagram of a mechatronic module with the built-in sequential diagnosis using a reserve controller, performing diagnostics, is shown in Fig. 1.

The block diagram of mechatronic system with the built-in parallel diagnosis is shown in Fig. 2. Each element has its own diagnosis controller. This implementation will have a maximum value.

Due to the upward trend in the level of intellectualization of technical systems, the mechatronic systems appear in all industries. If the existing mechatronic systems are diagnosed, it uses an external system of diagnosis. When designing a new mechatronic systems, it is advisable to use the built and integrated diagnosis system with the control system. If the designed mechatronic systems consists of mechatronic modules, the necessity is obvious to integrate the management and diagnosis system in each mechatronic module. The diagnostic controller is the backup controller and assumes the control functions in case of violation of the normal functioning of the main controller.

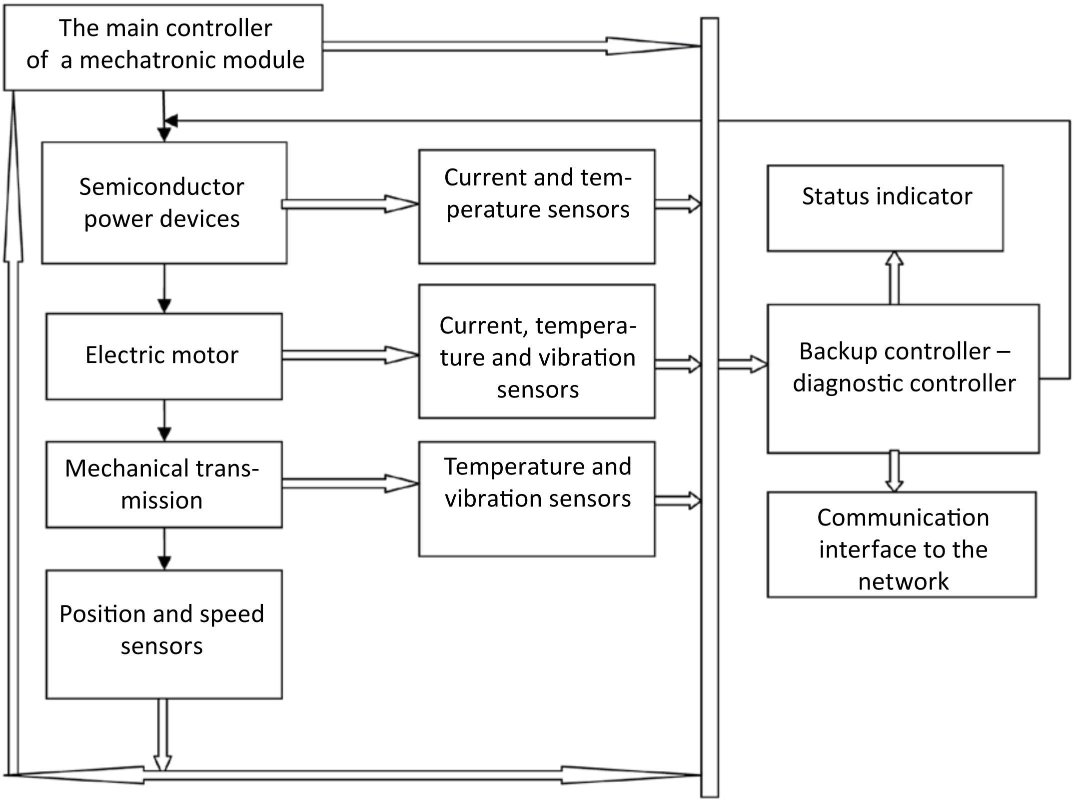

Fig. 1: Block diagram of mechatronic module with built-in sequential diagnosis using backup controller - the controller diagnostics

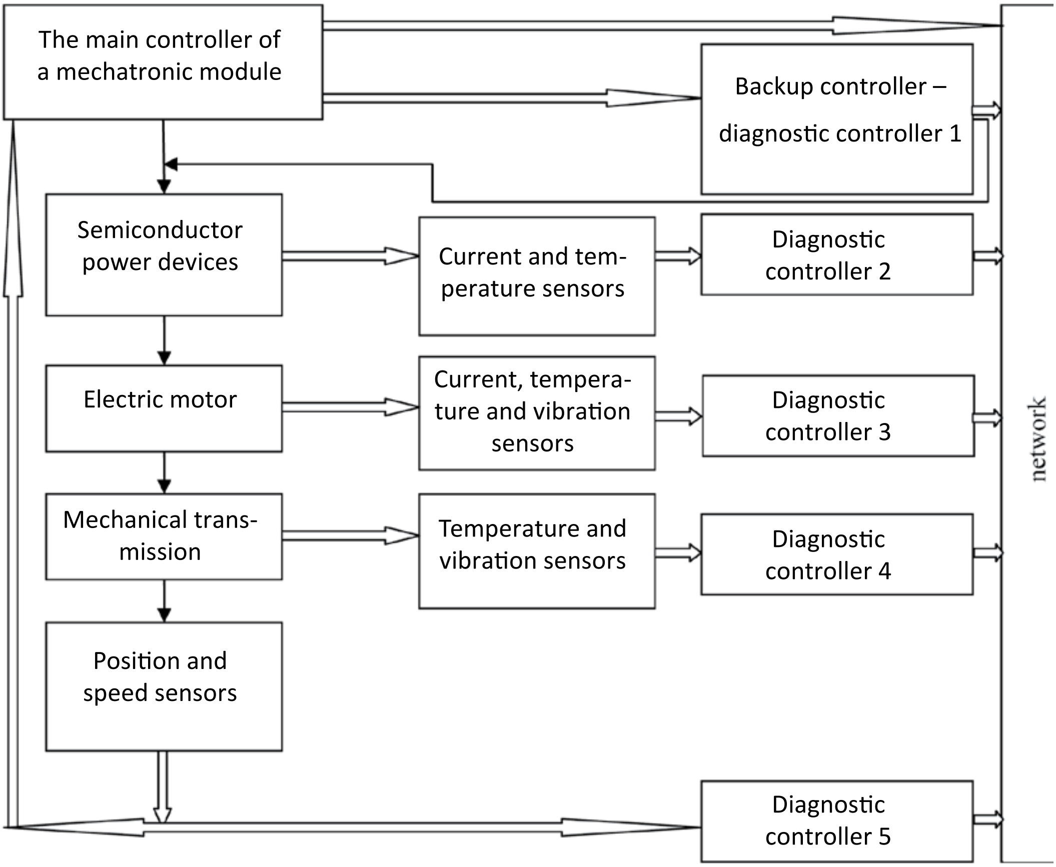

Fig. 2: Block diagram of mechatronic systems with built-in parallel diagnosis

CONCLUSION

The information processes of mechatronic systems diagnosis are reviewed. The structural scheme of a mechatronic module with the built-in sequential diagnosis using a backup controller that performs diagnosis is shown. The structural scheme of a mechatronic module with the built-in sequential diagnosis is given.

ACKNOWLEDGMENTS

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Literature

1. NIKITIN Y., ABRAMOV I.: Algorithms for mechatronic systems diagnosing. – Proceedings 5 International Symposium AiM 2010 Advances in Mechatronics. – 7–9 December, 2010. – Trencin, Slovakia. – P. 60–62.
2. Nikitin Y, Abramov I.: Diagnosis of mechatronic systems based on artificial intelligence methods. – Modern Technologies in Mechanical Engineering: Proceedings XIII International Scientific and Practical Conference. – Penza, 2009. – P. 204-206.
3. NIKITIN Y., ABRAMOV I.: Diagnosis of mechatronic systems. – Mechanics and Control. Proceedings XXXIX Ural Seminar on Mechanics and Control Processes. – Ekaterinburg, 2009. – P. 305-312.

DEVELOPMENT OF METHOD AND DEVICE FOR ROTARY BAND GRINDING OF HIGH-QUALITY WIRE

Sergey Alexandrovich SHILYAEV

Abstract

Durability and reliability of the most machines are limited by the work time of particular parts, for example springs. The fatigue resistance of a spring is influenced by the quality of a wire surface coating.

The machining efficiency can be greatly increased by applying new machining methods. The analysis of the existing technologies provides a device for the rotary band grinding whose work is based on a new scheme. The device designed renders possible wire machining, bar and piped stock. This increases the efficiency of the process.

The investigations performed show that the intense grinding regime of the rotary band grinding gives the high quality of a wire surface coating. This raises reliability and work time of the parts.

Key words

mechanical engineering, technology, grinding, wire, quality

One of the most essential problems of the modern mechanical engineering is increasing the reliability of the parts made of high-quality wire such as bearings, springs, etc. Such importance is provided by intensifying the temperature-power operating regime.

In actual practice, most springs made of a high-quality wire and properly tested prematurely lose their elastic characteristics or wreck. It especially concerns springs operating under the dynamic conditions. A great number of failure cases caused by breakage or loss of stability of power characteristics of a spring have been investigated to find out the reasons for the breakdown. Thus, the analysis of the breakage of the springs working under the repeated loading shows that the centre of the fatigue crack is on the outer surface ”fibers”. The crack can be caused by tangential or normal stress appearing on the stage of preliminary machining due to deep hairlines, cuts and surface roughness. It is also known that spring breakage is caused by the defects of a metallurgic wire, low quality of thermal processing and etc. However, about 30-40% reasons for such failures are congenital phenomena of the preliminary machining of high-quality wire.

The above facts prove that the technologies of spring production have some drawbacks and show the necessity of introducing some new methods increasing their load-carrying ability and stability of the elastic characteristics through time. The quality of a surface coating of a machined wire has an essential impact on the fatigue resistance of a spring.

A thorough examination of the works in the field of mechanical operation shows that the authors do not pay due attention to the subjects that concern the technology of machining long components of fragility and do not give unambiguous recommendations about the machining process itself. It means that still there are many possibilities for improving the methods and systems of control to increase quality and machining efficiency.

The main methods of machining a high-quality wire are such kinds of mechanical operation as wire drawing through special filters, lathe machining with cutter bits, machining with grinding tools and etc.

One of the advanced machining methods is grinding with a band. This type of grinding is widely spread among operations that are essential for the final machining, for forming roughness and physical and mechanical properties of a surface coating. The investigations performed by some scientists show that the band grinding has ample opportunities and some advantages.

The main advantage of this method is presented by better conditions of cutting in the area of machining due to stretchability and spring power of a band, diminution of cutting strength, lower heat density of machining, in comparison with the grinding disks, balance problems and adjustment of a tool and etc.

New machining methods always greatly modify the machining technology and construction of the existing equipment, thus, developing the production of their most progressive types.

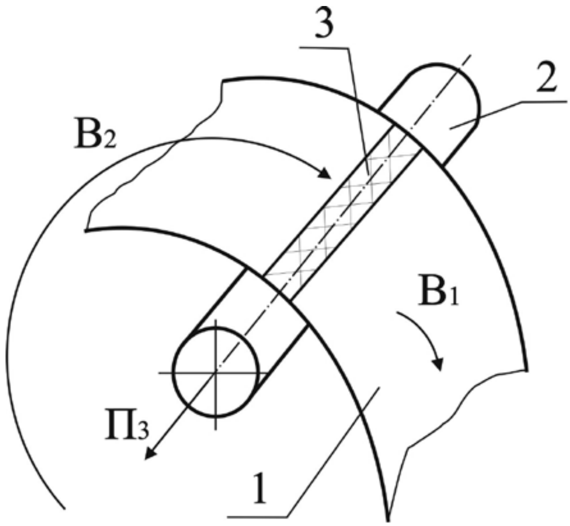


Fig. 1: Machining high-quality wire: 1 – grinding band, 2 – wire, 3 – contact area; shape-generating movements: B_1 – rotational movement – cutting speed, B_2 – rotational movement – circular feed of a band with a circuit plate, $П_3$ – straight movement – line feed of a wire

Therefore, increasing the efficiency must be followed with designing and applying the activities aimed at improving the product quality with technological methods.

The analysis of the existing machining patterns, patent search as well as recommendations about applying band grinding and obtaining the needed quality of machining contribute in designing a device for machining high-quality wire with band grinding – machining with a free branch of a grinding band rotating around the part (Fig. 1).

Applying such machining is the most acceptable since an increased spanning angle enables to enlarge the contact area that leads to increasing mechanical compliance of a grinding band and improving the operating conditions. An increased contact area also causes the increasing of the number of active grains on a unit of the working surface of the band, which is the most important characteristics of the abrasive tool and allows to present the size of a cut made by one grain, thus, the possibility to define the load per one grain. Hence, the durability of a tool increases greatly while applying rotary band grinding.

The given scheme served as a basis for designing the engineering samples of the devices of rotary wrap-round band grinding with one and two grinding bands used.

A distinguishing feature of the production prototype of the device of the rotary band grinding (Fig. 2) is that the drive component of a grinding band made of belt-driven wheels and grinding head that provides planetary movement; the device is supplied with a mechanism for permanent band pull-up and a widget for pull-up and centering control of a workpiece that provides pull-up and centering control of a wire that are necessary for failure-free operation of the device. The main motion drive takes the rotation from the polyphase induction motor that is driven by electrical and control system with the rate speed 1400 rot/min. Line feed of a wire is performed by a broaching widget.

For studying the main laws of the process of machining of a high-quality wire with the device of the rotary band grinding some investigations were held concerning the phenomena that take place at metal removal and the band wear that are determined by the parameters of the grinding regime.

The needed parameters of the detail quality are specified by using a required type of the band and changing the pull-up of the band. This increase of the pull-up leads to the increase of the specific pressure in the area of machining and, then, to the worsening of the quality of the surface. The optimum effort of the pull- up for the cloth tape is 60-80 H.

The durability of the abrasive band and the efficiency of the grinding process are determined by the proper selection of the characteristics of the abrasive material and the machining regime. The efficiency of the machining process and the quality of the surface are mainly determined by the speed of the line feed of a wire and some constant parameters. The cleanliness of the machined surface is increasing with the cutting speed increased. The data of the experiment give the following optimum values that determine the high efficiency and the cleanliness of the surface: the speed of the band is 18-20 m/sec with the line feed of the machined wire 4 m/min.

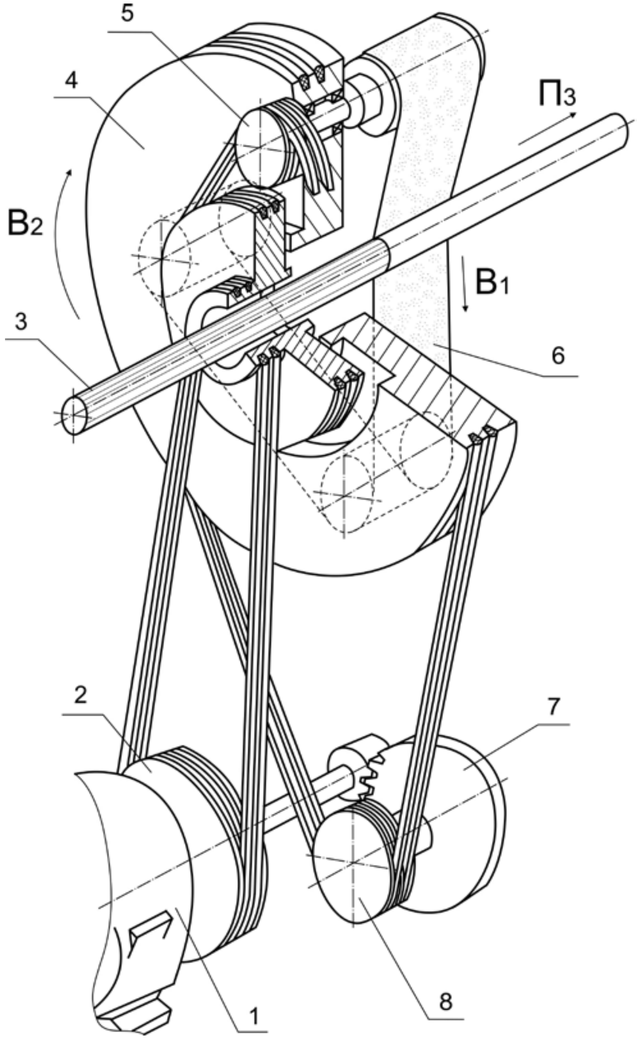


Fig.2: Scheme of a device of rotary band grinding:
1 – electric motor, 2 – driving wheel of a grinding band, 3 – wire, 4 – circuit plate, 5 – contact rotary wheel of a grinding band, 6 – a grinding band, 7 – reducing gear, 8 – driving wheel of rotating circuit plate

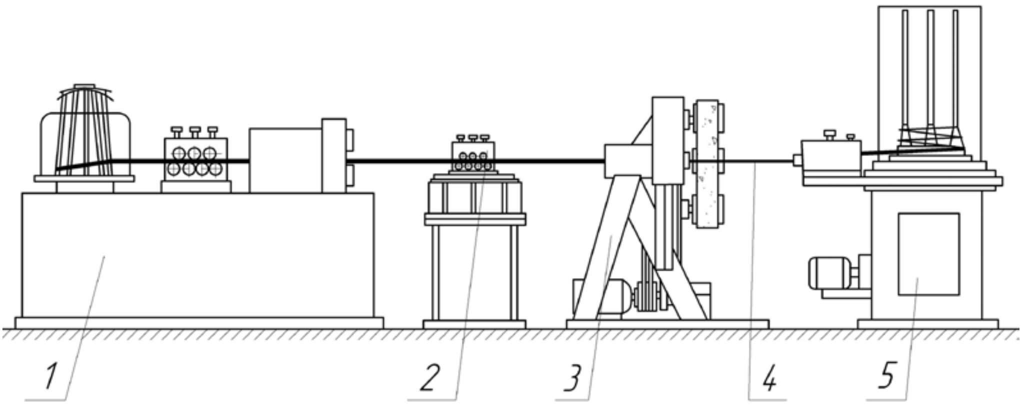


Fig. 3: The scheme of line for machining high-quality wire:
1 – full-automatic lathe, 2 – widget for fitting and pulling up a wire, 3 – rotary band grinding device,
4 – machined wire, 5 – winding up widget.

The grinding of a high-quality wire is supposed to be performed with a newly designed line for high-quality wire machining that includes an unwinding widget, a widget for control and pull-up of a wire, a device of rotary band grinding and winding widget with winding-up roll (Fig.3).

The line operates in the following manner. A grinded wire is given from the unwinding widget through the pull-up widget and the device of rotary band grinding into the pilot bore of the pickup which was substituted for the winding widget of a drawbench, and then onto the winding-up roll. Before that a pull-up roller is removed apart to decrease the band stretching. After that, a needed band stretching is adjusted with the winding-up roll moved counter clockwise and a standard dynamometer reading the stretching value. Line energization drives the rotary band grinding device as well as the winding-up roll that regulates needed wire feed though the cutting area. In addition, the rotation from the electric motor is directed onto the drive-shaft of the pickup through a worm reduction gearbox and onto the drive-shaft of the winding-up roll via a chain. Therefore, the rotation movement is given onto the roll.

The winding widget gives a workpiece from the unwinding widget through the pull-up widget in the machining area and is meant to wind ready (grinded) wire and providing the finished product with coiled shape (market condition).

Introducing rotary band grinding into the industry solved the problem of machining optimization and showed optimum machining regimes that give top performance under the given requirements for the surface quality.

For studying the main laws of the process of machining of a high-quality wire with the device of the rotary band grinding some investigations were held concerning the phenomena that take place at metal removal and the band wear that are determined by the parameters of the grinding regime.

The investigations were performed with the abrasive band of graininess 40. The influence of the following process factors was studied: the intensity of loading the pulling-up roller $P_н$,H; speed of the abrasive band V_A, m/sec; the speed of the line feed of high-quality wire $S_{np,}$ m/min. The following values were determined: metal removal per time unit mg/min; band durability T_C, min; surface roughness R_a, mkm.

Nowadays the mathematical theory of planning the experiments gives a great number of plan types and matrixes of planning. Therefore, the research task is to choose the plan that suits the particular task.

The dependences q = f (P_H, V_L, S_{np}), Tc = f (P_H, V_L, S_{np}), R_a = f (P_H, V_L, S_{np}) were to be approximated with the quadric polynomial. The experiment was performed according to the

Tab. 1: Variability Levels and Intervals

Factors	Coded Identification	variability interval	Natural Factor Levels corresponding with the coded ones		
			lower «-1»	basic «0»	upper «+1»
$P_н$, H	x_1	10	60	70	80
$V_л$, m/sec	x_2	2	16	18	20
$S_{пр}$, m/min	x_3	1	2	3	4

programme of the central composition rotatable planning of the second order. The levels and intervals of factor variation that are accepted in the research are shown in table 1. The central composition rotatable plan of the second order for the three factors consists of the plan of the complete factorial of 2^3-type (experiments 1-8), six experiments in the "star points" (experiments 9-14) and six experiments in the center of the plan (experiments 15-20).

The calculations performed with the given data, with reference to the coordinates of the centers of the response surfaces and the values of the angles of axes rotation, we draw the boundary curves of the response surfaces (ellipse) in Microsoft Excel, applying the equation of ellipse in parametric form (Fig. 4).

To ease the analysis and search for optimum values, the optimization planes were sorted at the criteria of the line feed for each separate level. Fig.5. shows the cutting of the response surface under the fixed value of the line feed at the upper level.

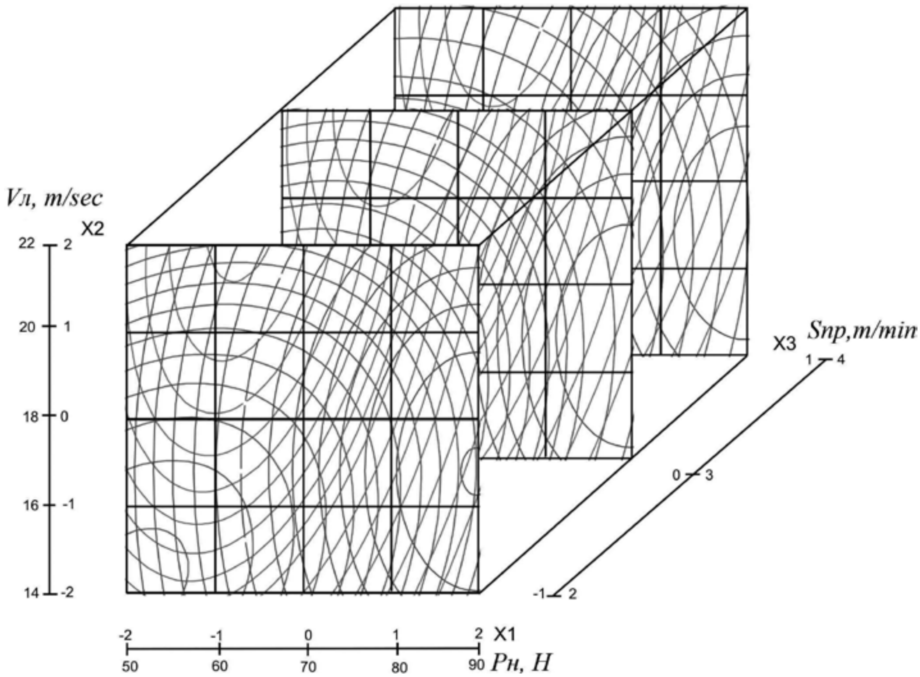


Fig. 4: The System of Cuttings of the Response Surfaces

For instance, the required roughness is Ra = 0. 84 mkm under the line feed 4 m/min. This can be obtained with combination of the grinding regimes – the abrasive band speed and intensity of loading the pulling-up roll. However, to find the optimum combination, it is essential to include some other process parameters such as abrasive band durability and material removal (table 2). The given combinations do now influence the surface roughness, but the last combination is the most preferable.

To ease the calculations, selection of the variable parameter and drawing the boundary curves, the programme of optimization of

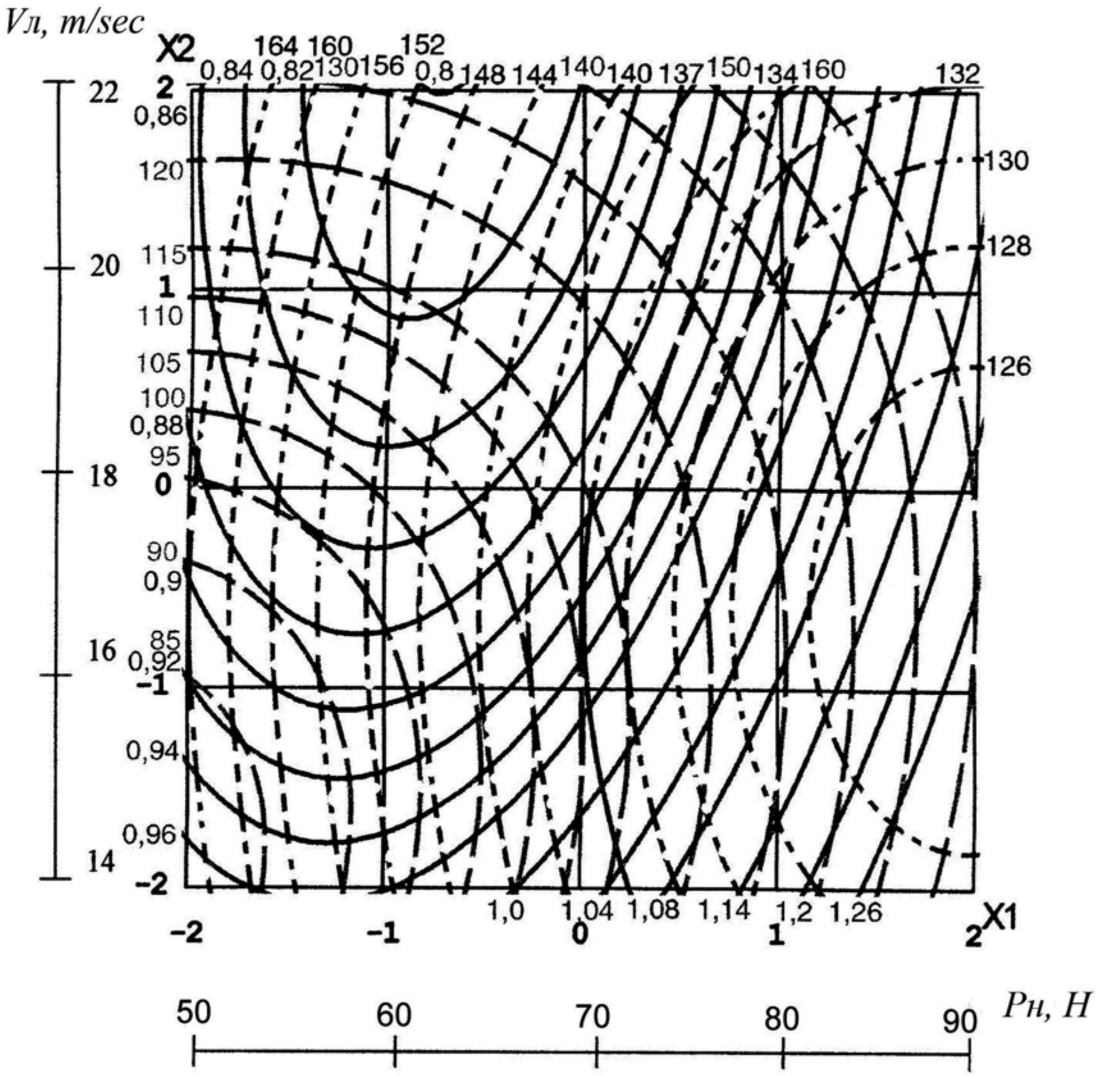


Fig. 5: The cuttings of the response surfaces Y_q, Y_{Tc}, Y_{Ra}, if x_3 = 1 (S_{np} = 4m/min):

– – – – Material removal, mg/ min;

- - - - - Abrasive band durability, min;

------------ Surface roughness, mkm.

Tab. 2: The results of the analysis of the curved response surfaces for S_{np} = 4 m/min and Ra 0,84 mkm

№	Vл,m/sec	Pн, H	T, min	q, mg/min
1	21,2	52	164	120
2	19	55	156	105
3	19	66	140	115

the rotary abrasive band grinding of the high-quality wire has been presented (Certificate of official registration of the computer programme №2007613532 (Russia), applied 22.06.2007, registered 21.08.2007). This programme allows to study the complex systems with the multifactor experiment according to the programme of the central composition rotatable planning of the second order, that is the planning and the machining of the whole three-factor experiment of the machining process.

CONCLUSION

Rotary band grinding with the band moving around the part is one of the most perspective and advantageous fields in machining non-rotating parts.

The distinguishing feature of the technology presented is that the centreless grinding is substituted at the stage of the final machining of a spring wire for the rotary band grinding followed by drawing of a wire. In this case the rotary band grinding provides the required roughness and the drawing – a required diameter of the high-quality wire.

The industrial use of the rotary band grinding has solved the problem of optimization of the machining process and offered some optimum machining regimes that provide the maximum efficiency under the requirements for the surface quality

The designed device provides the grinding of the high-quality wire and piped stock. It gives the roughness of the surface within the 7-8th class, material removal 120-130 mg/min, abrasive resistance of the band 140-160 min (the length of the band L=1240 mm) and 250-300 min (L=2500 mm).

Literature

1. Shilyayev, S. Industrial Application of the Rotary Band Grinding of a High-Quality Wire. Current State and Innovations in Transport Complex: Materials of International Scientific and Technical Conference. Perm, April 17-18, 2008 – Perm: PSTU press, 2008. – P. 204-207.
2. Calculation of Device for Highly-Productive Coiled Wire Grinding from Difficult Material. Scientific Proceedings of the Scientific-Technical Union of Mechanical Engineering / Third International Congress Mechanical Engineering Technologies ’01. Republic of Bulgaria – 2001. – Volume 2 (57). – C.424-427.
3. Svitkovskii F.; Shilyayev S.; Ivanova T.; Syursin S.L., Galchik A.I. Device for Band Grinding / Certificate №11503, 6B24B21/02. Russia.
4. Svitkovskii, F.Y.; Shilyayev, S.A. Ivanova, T.N., Belt grinding Machine/ Patent of Invention №2228831, 7B24B 21/02. Russia.
5. Shilyayev S. A. Optimization of the Process of the Rotary Band Grinding with the Free Branch of the Abrasive Band of High-Quality Wire // collected scientific works by graduate students and teachers. – Izhevsk: ITN and PRP, 2000. – P. 37-41.

BENDING MOMENT AND ROTATING FREQUENCY INFLUENCE ON INTERFEFENCE FIT BEARING CAPACITY

Ivan Vasiljevich ABRAMOV, Andrey Ivanovich ABRAMOV,
Anton Nikolaevich SINITSYN, Vasilya Vasilevna SINITSYNA

Abstract

Influence of rotating frequency and bending moment on bearing capacity of interference fit is investigated. Theoretically proved, that bending moment and rotation simultaneous action leads to the greater contact pressure decreasing, than the separate action of the factors. It is showed, that for constant rotating frequency relationship between bending moment and contact pressures is nonlinear. It is stated that when bending load increases, the contact pressure in the middle part of contact zone decreases to zero at the lower rotating frequency.

Key words

interference fit, pressure coupling, contact pressure, bearing capacity, bending moment, finite element method (FEM)

Interference fit is widely spread in mechanical engineering. One of the coupling application is shrink-fit holder for tool fastening during high-speed processing. Shrink-fit holder and tool coupling is affected by complex force action while processing. Axial force, rotational and bending torques affect the coupling. Considering that spindle rotary axis speed of modern machining center reaches several thousand revolutions per minute, it is worth to give special attention to the problem of ensuring bearing capacity of pressure coupling.

Interference fit bearing capacity in axial and tangential direction is roughly estimated by the equations:

$$F = f_{oc}\pi d l p_k \tag{1}$$

$$M_{KP} = f_{KP}\pi d^2 l p_k/2 \tag{2}$$

where f_{oc} and f_{KP} - friction factors for torsion and axial shears, d respectively l - diameter and length of mounting surface, p_K- contact pressure.

Bearing capacity of coupling loaded with bending moment is assessed by the equation:

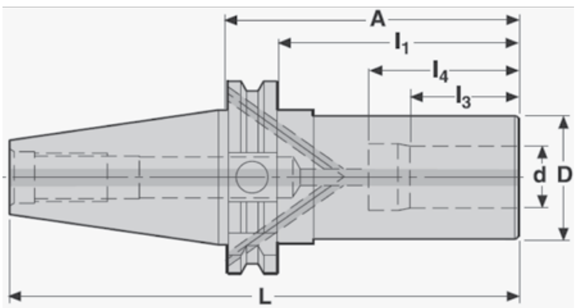
$$M = 0{,}2\, p_k dl \qquad (3)$$

Thus, bearing capacity of coupling depends on effective coupling area and contact pressure. According to (1) and (2) friction factor impacts only on strength in axial and tangential direction and is not considered by evaluation of coupling strength under bending load.

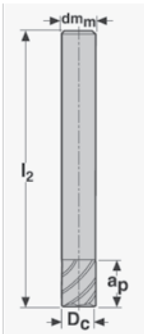
There are some doubts about applicability of equation (3) for evaluation interference fit strength under bending load. Firstly, in contrast to equations (1) and (2) it does not contain friction factor. Secondly, equation (3) does not take into consideration loading conditions. Probably, coupling strength differs for static and dynamic bending stress because of occurrence of slide on joint face parts under bending loads [1]. Thirdly, it does not take into account influence of centrifugal forces that appear when rotating. Fourthly, equation (3) does not take into consideration contact pressure redistribution that appears under bending load while estimating strength during loading. Influence of bending moment on pressure redistribution is considered in paper [2].

Influence of rotating frequency on bearing capacity various interference and coupling lengths is investigated for in paper [3]. In that paper it is noted, that contact pressure and interference decrease with increase of rotating frequency. For every conjunction there is a certain value of rotating frequency at which interference decreases to zero and failure occurs. Under the conditions of force couplings rotation without external load the coupling length does not affect the behavior of contact pressure decrease. In that paper is also indicated, that under the conditions of force couplings rotation without external load the coupling length does not affect the behavior of contact pressure decrease.

Complex impact of bending load and rotation on interference fit bearing capacity is considered in this article. Finite element analysis is used as a method of testing. A subject of inquiry is coupling of shrink-fit holder and end mill. Geometry of conjunction components corresponds to shrink-fit holder DIN69871-ADB 5800 with outer diameter d_2 = 28 mm and end mill with shank diameter dm_m = 10 mm, length l_2 = 62 mm produced by SECO (fig.1) [4]. Research was carried out for interference fits N = 6µm having coupling length l_c = 10 mm. Yield stress for the material of shrink-fit holder is σ_T = 1480MPa, ultimate strength is σ_B = 1750MPa, modulus of elasticity is $E_1 = 2.10^{11}$Pa, Poisson's ratio is μ_1 = 0,3, density is ρ = 7750 kg/m^3. Hard alloy is used as a material of the end mill. Its bending strength is 1200 MPa, modulus of elasticity is $E_2 = 5{,}2.10^{11}$Pa, Poisson's ratio is μ_2 = 0,3, density is ρ = 11500 kg/m^3.



(a)



(b)

Fig. 1: Shrink-fit holder (a) and solid carbide mill (b)

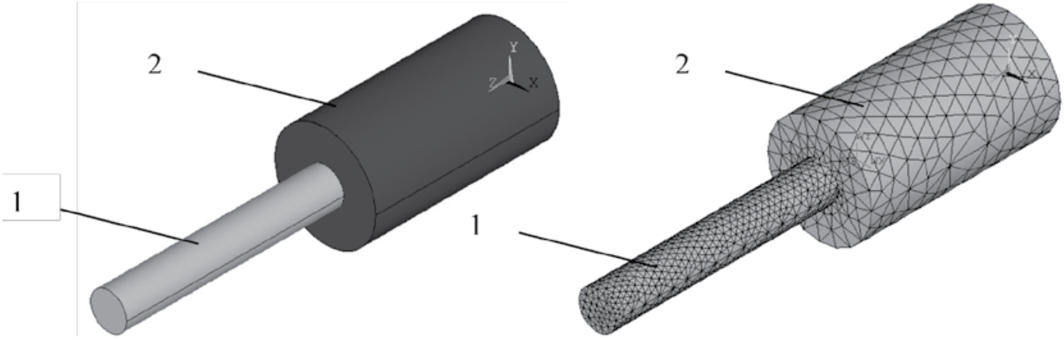
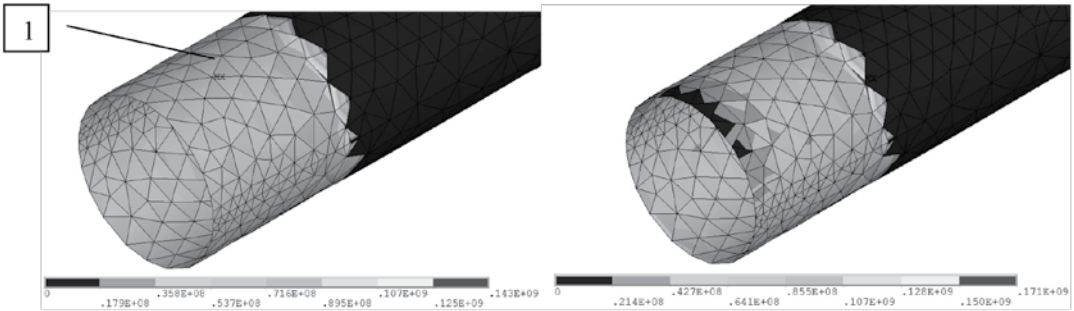


Fig. 2: Finite element model of pressure coupling parts for simulations of bending load and rotation:
1 – end mill, 2 – shrink-fit holder



(a) (б)

Fig. 3: Contact pressures for different bending moment without rotation: a) M = 0 ; б) M = 11,4 H.m

To investigate the effect of simultaneous bending load and rotation action on bearing capacity of interference fit a grid of 29059 solid elements is used. To optimize calculation time we consider only clamping part 2 of shrink-fit holder (fig. 2).Compaction of finite-element mesh is carried out at the supposed stress concentration zone. Boundary conditions are presented by end fixation, restricting parts X and Y axial rotation and all nodes displacements along Y axis.

Contact pressures in the centre of the fit (point 1 on fig.3) are analyzed. From figure it becomes apparent, that bending load action on pressure coupling causes contact pressure redistribution. Contact pressure redistribution may lead to joint opening, i.e. to gap appearance as a result of contact pressure decrease to zero.

Results of the computation are presented on figure 4. On the figure we may see that contact pressure in the middle part of contact zone decrease when bending moment increase even without rotation (w=0). It can be explained by contact pressure redistribution.

For constant rotating frequency relationship between bending moment and contact pressures in the middle part of contact zone is nonlinear. Thus, for rotating frequency 20000 rpm contact pressure decreases 19,44 times while bending load increases 4 times.

When bending load increases, the contact pressure in the middle part of contact zone decreases to zero at the lower rotating frequency. Thus, for bending moment M = 11,4H.m failure came at rotating frequency 80000 rpm, while for bending moment M = 45,6H.m at 40000 rpm.

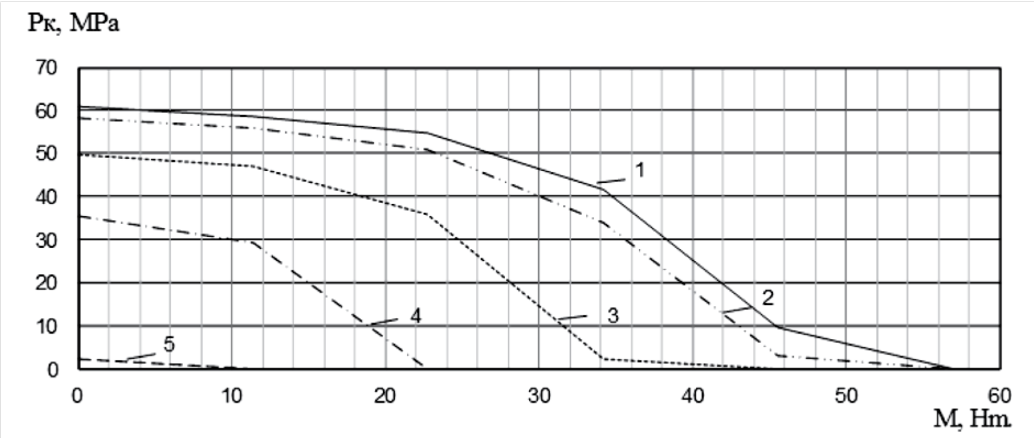


Fig. 4: Relationship between contact pressures (in the middle part of contact zone) and bending moment for different rotating frequency: 1 – w = 0; 2 – w = 20000rpm ; 3 – w = 40000rpm ; 4 – w = 60000rpm ; 5 – w = 80000rpm

This diagram may be used for optimum high-speed mill condition definition. For example, knowing nominal contact pressure it is possible to select optimum rotating frequency and feed in terms of coupling strength criterion. Thus, to guarantee the contact pressure 40 МПа in characteristic point of the interference fit involved, one may choose three loading conditions: for rotating frequency w = 40000rpm maximum permissible bending moment is M = 18Hm, for rotating frequency w = 20000rpm - M = 30Hm, for the loading without rotation - M = 32,5Hm.

Contact pressures in characteristic point $Pk_{x.m}$ for four type of loading are presented in table 1. Contact pressure variations $\Delta Pk_{x.m}$ for three type of loading relative to state of rest are calculated.

Table data show that bending moment and rotating frequency simultaneous action leads to the greater contact pressure decreasing, than the separate action of the factors. Bending moment increasing from 0 to 22,8 Нм causes contact pressure decreasing in characteristic point on $\Delta Pk_{x.m}$ = 6,21 МПа Rotating frequency increasing from 0 to 20000 rpm causes contact pressure decreasing on 2,84 MPa. Bending moment and rotating frequency simultaneous action decreases contact pressure on 10,15 MPa.

CONCLUSIONS

1. Theoretically proved, that bending moment and rotating frequency simultaneous action leads to the greater contact pressure decreasing, than the separate action of the factors.
2. It is showed, that for constant rotating frequency relationship between bending moment and contact pressures is nonlinear. It is stated that when bending load increases, the contact pressure in the middle part of contact zone decreases to zero at the lower rotating frequency.

Tab. 1

	Rest state	Bending M = 22,8Hm	Rotating w = 20000rpw	Bending+ Rotating w = 20000rpw M = 22,8Hm
$pk_{x.m}$, МПа	61,09	54,88	58,25	50,94
$\Delta pk_{x.m}$, МПа	0	6,21	2,84	10,15

Literature

1. GRECHISHCHEV, I.S. AND IL'YASHENKO, A.A., Soedineniya s natyagom: Raschet, proektirovanie, izgotovlenie (Tight Joints: Calculation, Design, Manufacture), Moscow: Mashinostroenie, 1981.
2. I.V. ABRAMOV, A.I. ABRAMOV, A.N. SINITSYN, and V.V. SINITSYNA. Stress–Strain State of Tight Joints under a Bending Moment. Russian Engineering Research, 2010, Vol. 30, No. 8, pp. 759–762. ISSN 1068_798X.
3. I.V. ABRAMOV, V.V. SINITSYNA. Rotating frequency influence on interference fit bearing capacity // Materials of third post-graduate student research conference of "Quality management" faculty of ISTU – Izhevsk: ISTU, 2010. – c.209-212. ISBN 978-5-7526-0455-3.
4. Seco «Machining Navigator», Seco tools, 2008
5. TURYGIN Y.V., KULISH E.V. Load capacity and mode of deformation of press fit polyjoints. 11-th International Symposium on Mechatronics "Mechatronika 2008", Trencianske Teplice, Slovakia, 2008. – p.41-44. ISBN 978-80-8075-305-4.
6. ANSYS 12.0 Academic Research. ANSYS User's Guide. // ANSYS, Inc. 2009

TRAINING OF SPECIALISTS IN THE PROGRAM "MECHATRONICS AND ROBOTICS" AT ISTU

Yuri Vasiljevich TURYGIN, Andrey Ivanovich ABRAMOV

Abstract

The paper describes the approaches to complying with requirements of State educational standards on training the high-skilled specialists in the field of mechatronics and robotics. Implementation of the leveled training of specialists according to the principles of Bologna process is considered.

Key words

mechatronics and robotics, leveled training of specialists, basic educational program, international accreditation

The problems in manufacturing modern automated and intellectual types of products in RF can be resolved at modern stage of science and technology only on the condition of special training of highly skilled human resources able to conduct researches, design mechatronic and robotic systems, technological processes of their production and operation.

Specialists in mechatronic systems are in high demand in all hi-tech areas where the breakthrough modules, systems, machines with intellectual control are designed, manufactured and operated.

Training of engineers in robotics at Izhevsk State Technical University started in 1987 to meet the demand of enterprises in Udmurtia and Ural region in the frameworks of the specialty "Robots and robotic systems". In accordance with the development of scientific and technological progress and needs of industry, the specialists in "Mechatronics and robotics" have been trained from 1996.

Following the transition to 2-level training, the bachelor and master programs "Technology, equipment and automation of machine-building plants" have been additionally introduced.

In accordance with state educational standards the specialists in robotics and mechatronics are trained only full-time.

The mission of the Department of Mechatronic Systems that teaches students in the program considered – training of specialists under the conditions of integration of new knowledge fields (information technologies, microsystems, theory of automatic control with artificial intelligence elements) and fundamental and traditional sciences (mechanics, hydro-pneumatics, electrical engineering).

The aims of main study program (MSP) "Mechatronics in machine-building and instrumentation engineering" for training masters in "Mechatronics and robotics" are as follows:

- creation of intellectual medium based on fundamental (mechanics, hydro-pneumatics, electrical engineering) and applied sciences, modern information technologies in research and educational process for the preparation of bachelors and masters – graduates of the study program "Mechatronics and robotics" – for professional activities;
- participation of highly skilled teachers of ISTU and other higher educational institutions, including international ones, specialists of research institutions and well-known firms in the field of machine-building and instrumentation engineering, students' representatives in the formation of study program content;
- formation and publication of competence base that allows implementing the career plans, improve professional knowledge and skills through life-long learning, including Candidate and Doctor of Science studies.

Highly qualified academics of ISTU (Professors, Doctors of Science, Associate Professors, Candidates of Science) teach the students humanitarian, social-economic, natural science, general professional and special subjects. 70% of academics teaching bachelor students have Candidate and Doctor of Science degrees, 100% – those teaching master students. Two members of International Academy of Informatization, 8 Professors, Doctors of Science, 12 Associate Professors are involved into the education process. To teach special subjects the academics and specialists of the Institute of Applied Mechanics of Ural Division of Russian Academy of Science, leading experts of the enterprise IzhMash and Izhevsk Electrical-Mechanical Plant "Kupol" are invited.

To provide the high quality of specialists' training, the Department (University) is constantly developing its laboratory base. There are 3 computer classrooms for informatics and automated design (CAD, CAM, CAE) with licensed software AutoCad, PiCad, Assembler, Microsoft Access, Simatic, Delphi, ICS-05, MPLAB-IDE, Ansys, simulation and control laboratory with licensed software Pro/Engineer, Adam, Компас, Robostudio, high-precision robot produced by ABB, laboratory of electronics and microprocessor engineering with work places for fitters of electronic devices and debugging of electronic devices equipped with modern instruments, laboratory of robotics and mechatronics (robots НТЦМ01, НТЦМ03, НТЦМ25, М-20П40.01).

Hi-tech equipment, such as LOM 1015 – machine for solid modeling, graphical stations for 3D and technological modeling, unique machine – vibration stand for hardness testing, 4-axis CNC machining center BM-501; high precision CNC lathe ИТ-42; high precision milling and drilling machine LPKF C-60 for producing printed circuit boards; multichannel logic-analog oscillograph Agilent-54621D, etc is applied in study process.

To solidify the knowledge obtained and get the practical skills, the students have trainings and internships at local and foreign enterprises (Germany, Slovak Republic, Czech Republic, Hungary).

The researches of the Department in the frameworks of scientific school headed by the Honorary Worker of Science and Technology, Prof., Doctor of Technical Science Abramov I.V. significantly influences the training of specialists in mechatronics and robotics. The researches are conducted in the following main fields: investigations in the fields of mechatronics and robotics (adaptive robotics based on stereo vision systems; parallel and group control of mechatronic system drives; mechatronic systems for energy recuperation; unpiloted aircrafts; transportation and mobile robots), investigation of complex mechatronic (technical) systems (reliability, operational effectiveness, strategy and systems of maintenance and repair), technical diagnostics of mechatronic systems and their components, information-measuring and controlling systems of mechatronic machine-tool modules, pressure coupling modeling (theory, designing, technology); modeling of high speed machining of materials based on the application of mechatronic modules, engineering calculations based on modern methods (numerical methods, including finite-element method; solid modeling, solid media strength calculations, contact tasks, frequency areas, dynamic analysis, solution of the tasks of hydro- and gas dynamics and heat fields). The Department comprises the Board for Doctoral Dissertation Defense chaired by Prof. Abramov I.V.

The Department staff is actively involved in international programs of all levels, they prepare applications in accordance with scientific areas of the Department and priority fields in the development of science and technology. As a result of the participation in the integrated project of 6^{th} European framework program, in which mainly young researchers of the Department were involved, the unique experience to work in international team was obtained, undergraduate and postgraduate students of the Department approved themselves and evaluated the possibilities of such projects.

The students are actively involved into the research process. Every year they present the results of their research at scientific-technological and scientific-methodological conferences, including international ones. The student team participated in International student Olympiad of users of CAD-CAM-CAE systems in the process of engineering designing and analyzing and took the 11^{th} place in the nomination “Modeling of parts in the system Compass-3D”.

For the last three years undergraduate and master students and teachers of the Department have been awarded 11 gold medals and 6 diplomas for the best works in the contests for the best research organized by the Ministry of Education and Science of the Russian Federation and at International specialized exhibitions “Robotics”. In 2007 the Ministry of Education and Science awarded the teachers fo the Department the badges “For the development of students’ research”.

After the graduation, the master students having revealed the abilities for research and obtained the recommendations of State Attestation Committee continue their education at PhD school. At the moment, there is 1 student pursuing Doctor of Science degree and 11 – Candidate of Science degree. The PhD school of ISTU trains PhD students in the specialty 05.02.05 “Robotics, mechatronics and robotic systems". There are specialized Boards for defending Candidate and Doctor of Science dissertations in the specialties connected with the theory and practice of the development and operation of mechatronic and robotic items and complexes at ISTU: 05.13.01 "System analysis, control and data processing", 05.13.18 "Mathematical modeling, numerical methods and program complexes", 05.02.02 "Machine science, drive systems and machine parts", 05.13.12 "Systems of design automation in machine-building", 05.02.18 "Theory of mechanisms and machines". At present, 11 graduates of the specialty 220400 and master programs 150900.68 and 220100.68 study at PhD school. Conduct researches in the Department's research areas.

Only Professors and Associate Professors train future specialists in master programs. Each master student has the research supervisor who supervises research, designing or technological works in accordance with the master thesis subject.

International cooperation in the field of education and research contributes to training specialists in tune with modern requirements of science and production. Such cooperation is based on the agreements between ISTU and partner universities, including: Leuphana University (Germany), A. Dubcek University in Trencin (Slovak Republic), Slovak University of Technology in Bratislava (Slovak Republic), Brno University of Technology (Czech Republic).

In 2009 the program "Mechatronics and robotics" was accredited by ROSOBRNADZOR of the Russian Federation. In 2008 the bachelor and master programs 150900 were accredited by Central Evaluation and Accreditation Agency ZEvA, Hannover, Germany.

Literature

1. TURYGIN YU.V., ALEKSEYEV V.A. Developments of Master's training at ISTU / Technical universities: integration with European and world educational systems: Proceedings of the IV International conference (Russia, Izhevsk, April 21-23, 2010) In 3 vol., Vol.1 – Izhevsk, ISTU publishers, 2010, pp. 300-305. ISBN 978-5-7526-0437-9 (Vol. 1). – ISBN 978-5-7526-0436-2.
2. TURYGIN YU.V., KLEKOVKIN V.S., MAGA D., KHARTYANSKIY R. Developemnt of cooperation in education and scientific-research works / Technical universities: integration with European and world educational systems: Proceedings of the IV International conference (Russia, Izhevsk, April 21-23, 2010) In 3 vol., Vol.1 – Izhevsk, ISTU publishers, 2010, pp. 96-99. ISBN 978-5-7526-0437-9 (Vol. 1). – ISBN 978-5-7526-0436-2
3. http://www.osu.ru/docs/bachelor/fgos/221000b.doc FEDERAL STATE EDUCATIONAL STANDARD OF HIGHER PROFESSIONAL EDUCATION FOR TRAINING THE SPECIALTY 221000 MECHATRONICS AND ROBOTICS (QUALIFICATION (DEGREE) "BACHELOR"
4. http://base.consultant.ru/cons/cgi/online.cgi?req=doc; base=LAW; n=97630 FEDERAL STATE EDUCATIONAL STANDARD OF HIGHER PROFESSIONAL EDUCATION FOR TRAINING THE SPECIALTY 221000 MECHATRONICS AND ROBOTICS (QUALIFICATION (DEGREE) "MASTER"

HYDRODYNAMICS OF JET GENERATORS IN HIGH-PRESSURE AUTOMATED SYSTEMS OF ABLUTION

Valentin Alexejevich TENENYEV, Anatoli Alexandrovich KALINKIN, Yuri Vasiljevich TURYGIN

Abstract

The paper presents the statement of the task and the mathematical model of the high-pressure liquid jet outflow to the airspace. Results of numerical calculations of flow parameters and the consumption coefficient are given.

Key words

high-pressure jet, ablution, mathematical simulation, numerical methods

In modern manufacturing equipment hydraulic devices are widely used, applying the method of jet ablution of different materials with a liquid, forced under high pressure (up to 5-10 MPa and more). These devices and techniques are most widely spread for hydrocutting of different materials, and also for cleaning and ablution of manufacturing equipment and auxiliaries from contaminations.

A large number of these ablution devices is used, for example, in paper-making industry and they are the essential influencing factor of the paper-making equipment efficiency on the whole and the quality of the manufactured paper products [1, 2].

The manufacturing scheme of the clothes ablution of paper-making machines is given in Fig. 1.

Digit 1 in the scheme denotes the feed (collector) pipe, which supports on rollers 2 and can move along them. The pipe with nozzles 3 functions as a generator of a multi-jet flow, acting on the surface of a moving ablution cloth (manufacturing clothes) 4. During ablution, the feed pipe is displaced perpendicularly to the direction of the cloth motion by means of a control unit 5 and a drive module 6. The drive is produced on the basis of a pneumatic motor with the feed supplied by means of a pipeline 7.

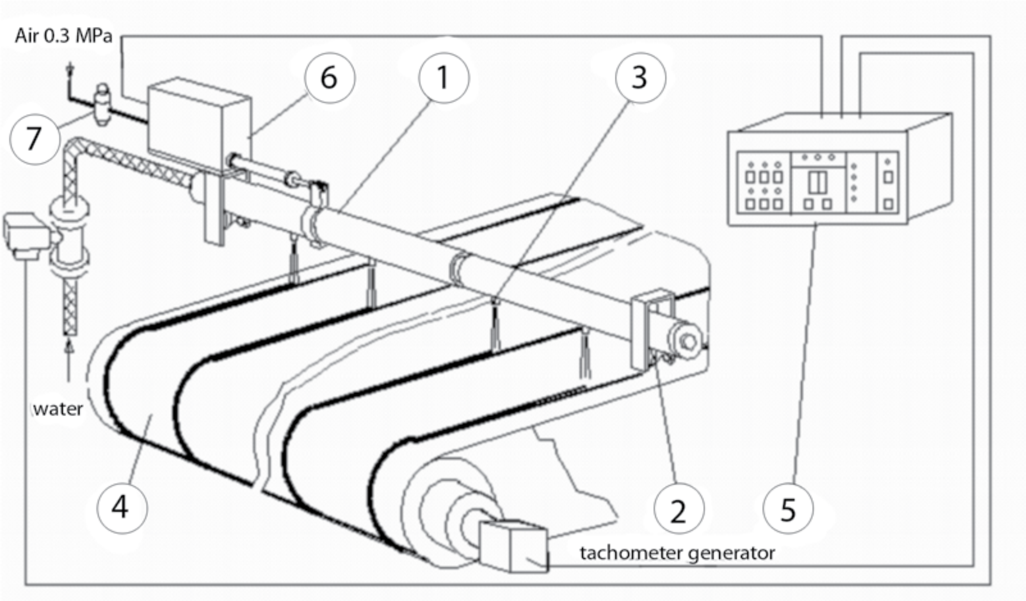


Fig. 1: Scheme of automated system of manufacturing clothes ablution of paper-making machines

The first automated ablution devices, appeared at Russian enterprises of pulp and paper industry, were equipped with a pneumatic mechanical drive, which did not allow to ensure the accurate enough displacement and positioning of the jet ablution unit [3].

The authors of this paper, supported by the department "Mechatronic systems" of IzhSTU, created an advanced ablution system at the scientific-production enterprise "BIFOR" (Izhevsk), applying a mechatronic drive module of the feed pipe displacement and positioning (see Fig. 2).

A mechatronic module allows to measure the step within a wide range, to assign various typical ablution cycles, to handle typical auxiliary displacements (transition to "zero" after the stop) and so on.

Development and application of a new ablution equipment enabled to advance also the ablution process itself.

In order to provide the qualitative ablution, the motion drive must ensure the accurate displacement and positioning of the feed pipe across the cloth motion, and to perform the shift precisely for each step in a definite place during the cloth motion. Moreover, the value of the step must be optimal, in order to eliminate, from one side, the unwashed areas between separate strips of each step, and, from the other side, to the overlap of adjacent strips. In order to implement such a system successfully, it is necessary to choose the value of jet displacement at each step. The value of each step is mainly determined by jet parameters at the outflow from nozzles. It is important to know not only the dimension of jet diameter here, but also the level of its narrowing or widening at different segments of outflow, distribution of velocities along the cross-section, the presence of turbulence and so on. Solution of this task was performed applying the hydrodynamic simulation of processes of jet outflow with account of its interaction with the air environment.

When calculating the parameters of processes of liquid jet outflow into the airspace, it is necessary to solve the joint task of liquid flow generation in the head-piece (in ablution equipment this element is called "nozzle") and in a liquid jet, interacting with the gaseous environment. Parameters of outflow and motion were calculated on the base of numerical solution of hydrodynamic equation in axisymmetric statement.

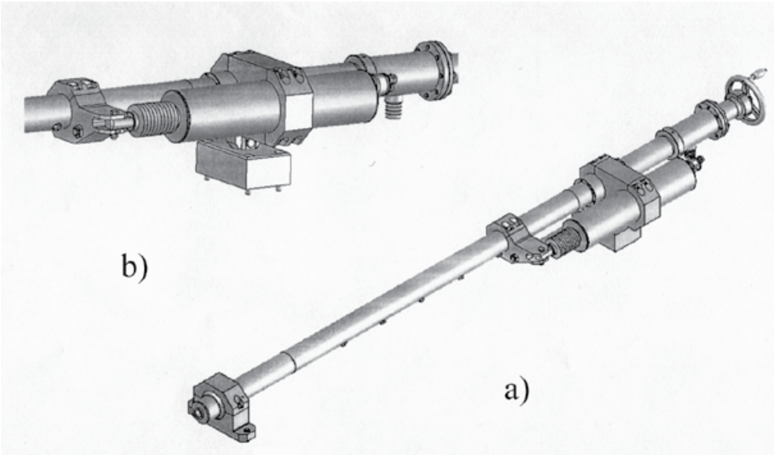


Fig. 2: Ablution device (a) and mechatronic module (b) of the step motion drive

A finite-difference mesh, covering the calculation area completely, was created for numerical solution of the task. The fragment of marking the calculation area, adjacent to the outlet (canal of the nozzle), is shown in Fig. 3.

Equations, describing the stationary viscous isothermal outflow of incompressible liquid, written in a curvilinear coordinate system, is as follows:

$$\mathbf{F}_{\xi} + \mathbf{G}_{\eta} = \mathbf{P} + \mathbf{R}_{\xi} + \mathbf{H}_{\eta} + \mathbf{S}$$

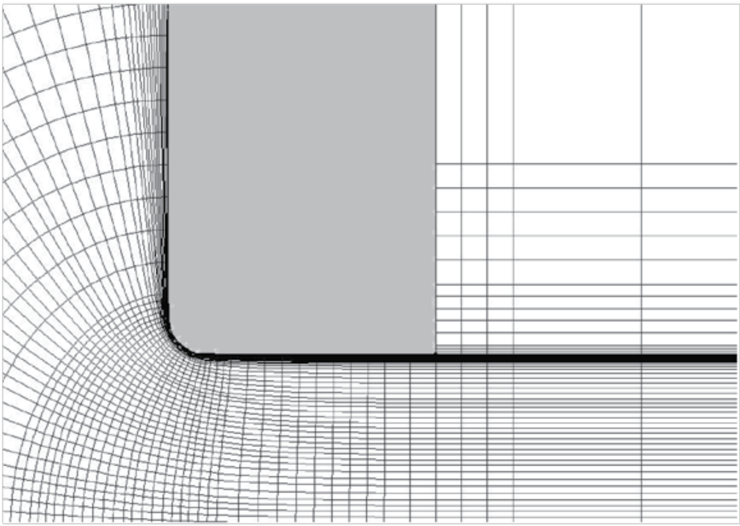


Fig. 3: Finite-difference mesh for the nozzle with the edge rounded radius R=0.2 mm

$$\mathbf{F} = yDU\begin{bmatrix}\rho\\ \rho u\\ \rho v\\ \rho E\\ \rho\varepsilon\\ f\end{bmatrix},\ \mathbf{G} = yDV\begin{bmatrix}\rho\\ \rho u\\ \rho v\\ \rho E\\ \rho\varepsilon\\ f\end{bmatrix},\ \mathbf{P} = -y\begin{bmatrix}0\\ p_\xi x_\xi - p_\eta y_\xi\\ p_\xi y_\xi + p_\eta x_\xi\\ 0\\ 0\\ 0\end{bmatrix},\ \mathbf{R} = y\mu\begin{bmatrix}0\\ u_\xi\\ v_\xi\\ E_\xi\\ \varepsilon_\xi\\ 0\end{bmatrix},\mathbf{H} = y\mu\begin{bmatrix}0\\ u_\eta\\ v_\eta\\ E_\eta\\ \varepsilon_\eta\\ \end{bmatrix},$$

$$\mathbf{S} = yD\begin{bmatrix}0\\ -\mu_\xi\left(vx_\xi + yv_\eta\right) + \mu_\eta\left(vy_\xi + yv_\xi\right)\\ \mu_\xi\left(-vy_\xi + yu_\eta\right) - \mu_\eta\left(vx_\xi + yu_\xi\right)\\ \mu_T Q - \rho\varepsilon\\ c_\mu c_1 QE - c_2\rho\dfrac{\varepsilon^2}{E}\\ 0\end{bmatrix},$$

$$U = \frac{1}{D}\left(ux_\xi + vy_\xi\right),\ V = \frac{1}{D}\left(-uy_\xi + vx_\xi\right),\ D = x_\xi^2 + y_\eta^2 .$$

Here p is the pressure; u, v are components of the flow velocity along axes x, y; U, V are contravariant components of velocity along axes ξ, η; D is the Jacobian determinant of transformation of the initial coordinate system x, y into the orthogonal curvilinear system ξ, η ; $\mu_0 + \mu_T$ is the sum of molecular and turbulent viscosities.

The latter equation of transferring the value f (the feature of the transferred substance) is written in the presence of two phases in the flow (f = 1 – water; f = 0 – air). The density and viscosity in the calculation area were determined with application of the value f [4]:

$$\rho = \rho_1 f + (1-f)\rho_0,\quad \nu = \nu_1 f + (1-f)\nu_0,\quad \mu = \rho\nu .$$

The subscript 0 corresponds to air, 1 – to water.

In order to account the turbulent mode of flow in the boundary layer, a two-parameter model of turbulent viscosity is considered (the turbulence energy E, the dissipation velocity ε) [5]. In equations of turbulence: $c_1 = 1.44$, $c_2 = 1.92$, $c_\mu = 0.09$ are empirical constants;

$$Q = 2\left(\left(u_\xi\xi_x - u_\eta\eta_x\right)^2 + \left(v_\xi\xi_x + v_\eta\xi_x\right)^2\right) + \left(u_\xi\xi_x + u_\eta\xi_x + v_\xi\xi_x - v_\eta\xi_y\right)^2 + \left(\frac{v}{y}\right)^2$$

generation; $\mu_T = c_\mu \dfrac{E^2}{\varepsilon}$.

Boundary conditions are as follows: on the hard surface U = 0, V = 0. With account of logarithmic distribution of the average flow velocity, the boundary conditions for E and ε in the first node of the difference mesh (point y_1), located outside the viscous sublayer, are taken as follows:

$$E_1 = \frac{u_*^2}{\sqrt{c_\mu}}, \ \varepsilon_1 = \frac{u_*^3}{\chi y_1},$$

where u. is the dynamic velocity, determined by the friction stress on the wall τ_0 ($\tau_0 = \sqrt{u_*}/p$); x = 0.41 is the Karman constant.

At the symmetry line $U_\eta = V = E_\eta = \varepsilon_\eta = 0$. ; at input and upper boundaries $U = D^{-1/2}u_\infty$, V = E = ε = 0, u_∞ is the flow velocity; at the output boundary $U_\xi = V_\xi = E_\xi = \varepsilon_\xi = 0$, $p = p_\infty$, p_∞ is the pressure of the undisturbed flow.

The algorithm SIMPLE [6, 7] was applied for numerical solution of the system of equations (1). Calculations were performed for various configurations of nozzles. The abundant pressure inside the feed pipe was taken 2 MPa. Water at the temperature 20ºC was considered as the liquid. The diameter of nozzles was chosen to be equal to 2 mm, the edge rounded radius in the canal outlet - R=1 mm and R=0.2 mm.

After performing the numerical simulation, the main hydrodynamic parameters of the jet flow have been determined and consumption characteristics have been obtained for versions of edge rounding of the nozzle canal from R=1 mm up to R=0.075 mm.

The vector flow field (velocity field) in the nozzle and at the initial (outer) segment of the jet is shown in Fig. 4 and 5.

For the big rounded radius (R=1 mm) the flow in the nozzle is without separation, as it is shown in Fig. 4. The consumption coefficient for these conditions of outflow is 0.96.

When the rounded radius is increased, a ring detached area is generated (Fig. 5). Contraction of the cross-section leads to reduction of the consumption coefficient down to 0.87.

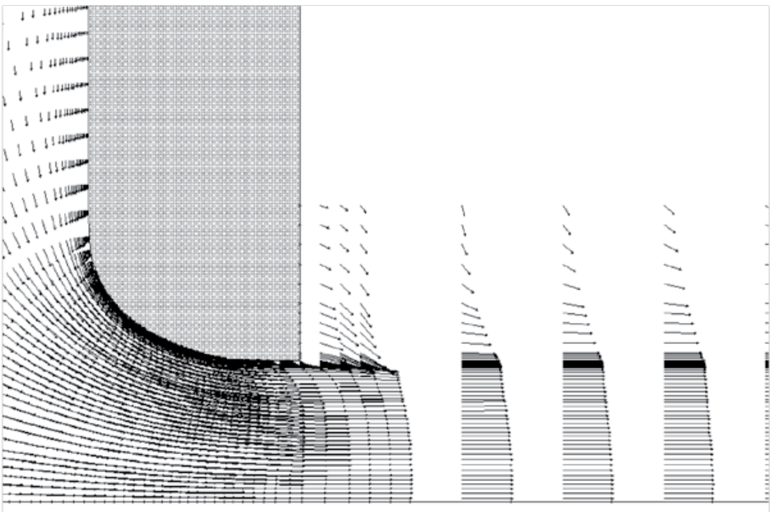


Fig. 4: Flow field at the segment of jet generation (R=1 mm)

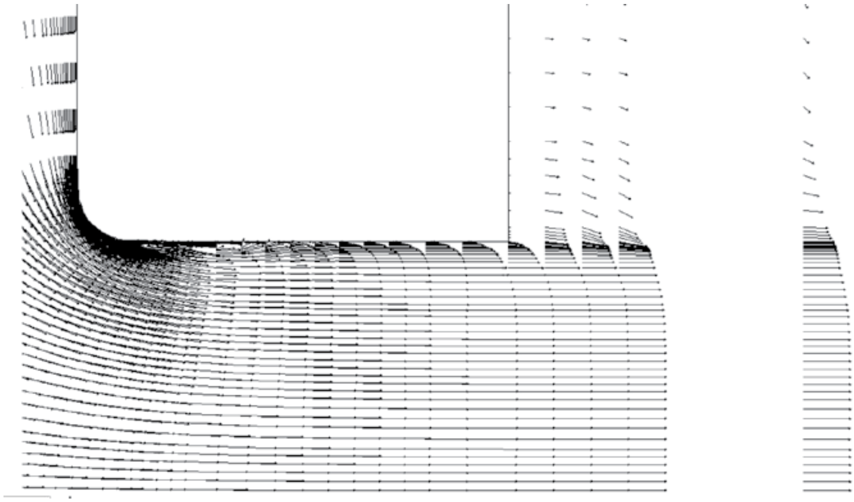


Fig. 5: Flow field at the segment of jet generation (R=0.2 mm)

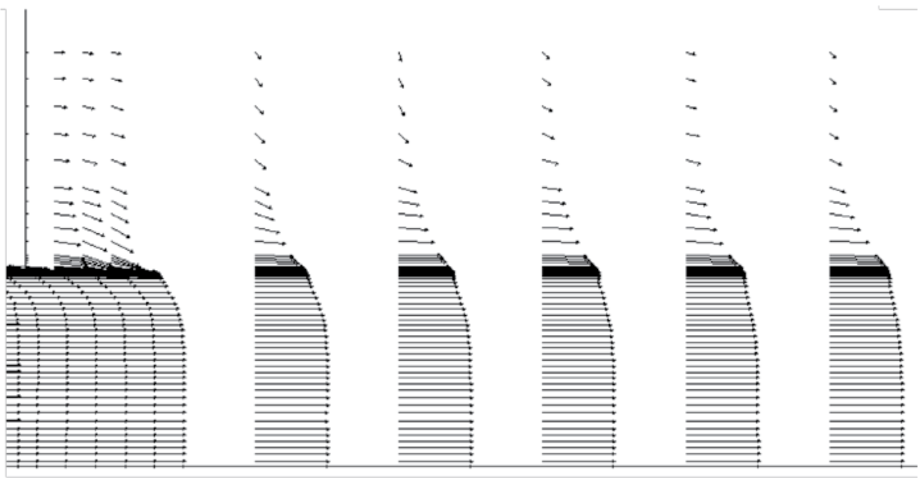


Fig. 6: Flow field in the area of jet interaction with air

The pattern of a liquid jet interaction with the air environment is shown in Fig. 6. It is evident, that the air is involved into the motion when interacting with the jet surface and profile configuration of jet velocity vectors remains invariable at a rather big distance from the nozzle cut. Moving away from the jet, the environment remains undisturbed.

In case of a smooth flowing of a liquid into the nozzle (R=1 mm), the flow field in the area of jet generation is rather uniform. At smaller radius of the edge rounding at the nozzle inlet (R=0.2 mm), a great non-uniformity of distribution of jet parameters is observed. It is proved by the position of lines of equal pressures (isobars) within the area of jet generation and by the field of velocity vectors (Figures 7 and 8).

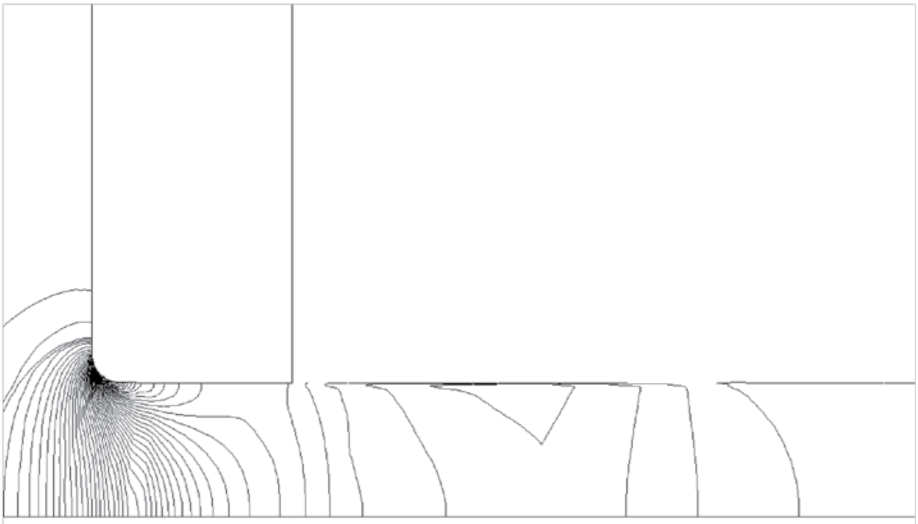


Fig. 7: Isobars in the area of jet generation (R=0)

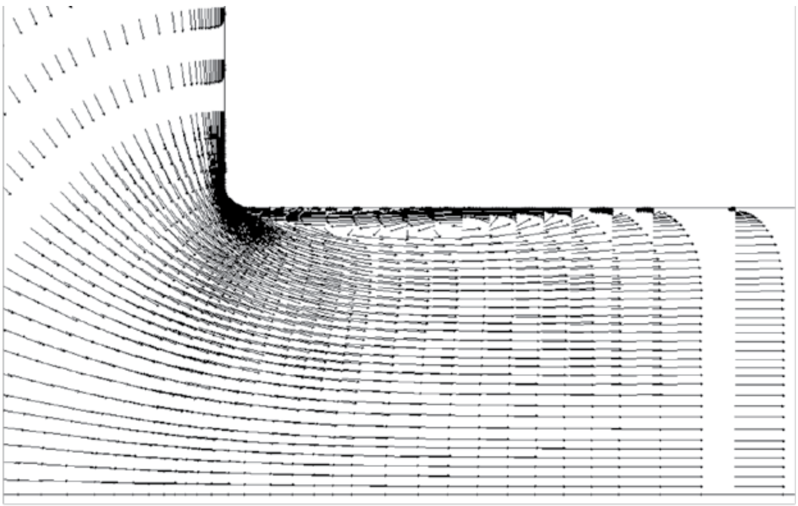


Fig. 8: Vector field of flow (R=0.075 mm)

The calculation result in Fig. 8 for the rounded radius R=0.075 mm (almost sharp edge at the inlet of the nozzle) denotes the length increase of the detached area of the flow with decreasing the radius at the edge. The relation of the length of this area to the radius R is given in Fig. 9.

The non-uniformity of flow parameters leads to variation of the consumption coefficient. As for the considered nozzles, the consumption coefficient has been calculated, equal to the ratio of the section-average velocity   to the velocity of the ideal outflow V_a:

$\eta = \dfrac{V}{V_a}$ where $V_a = \sqrt{2\dfrac{p_0 - p_a}{\rho}}$ $p_0 - p_a$ - is the abundant pressure in the pipe.

The dependence of the consumption coefficient on the rounded radius is shown in Fig. 10. The detached area is generated for the value of the rounded radius under 0.5 (Fig. 9). Within the range R=0.5 – 1.0 the value of the consumption coefficient varies insignificantly.

Up to the value R=0.2 the length of the area of the reverse flow is increased steadily. When values of the radius R are under 0.2, a more abrupt increase of the flow field non-uniformity appears

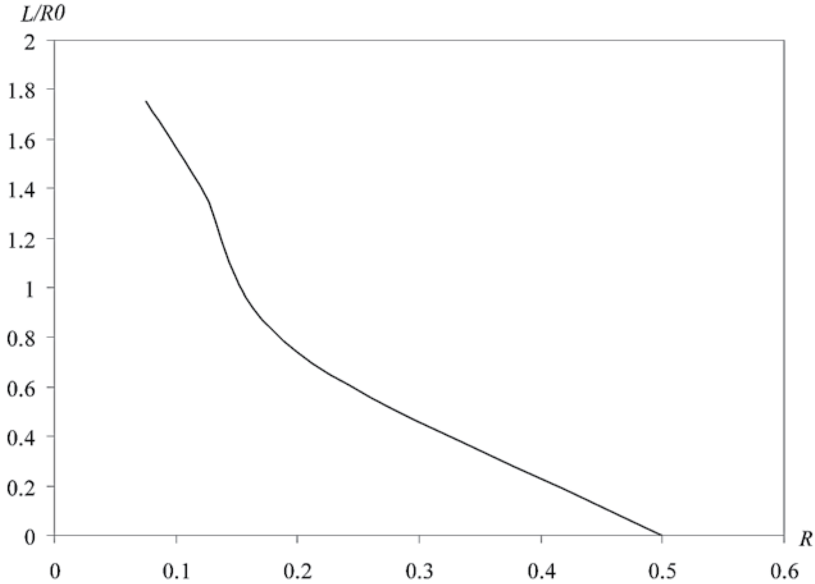


Fig. 9: Dependence of the length of the detached area of the flow on the radius of the edge rounding at the inlet of the nozzle canal

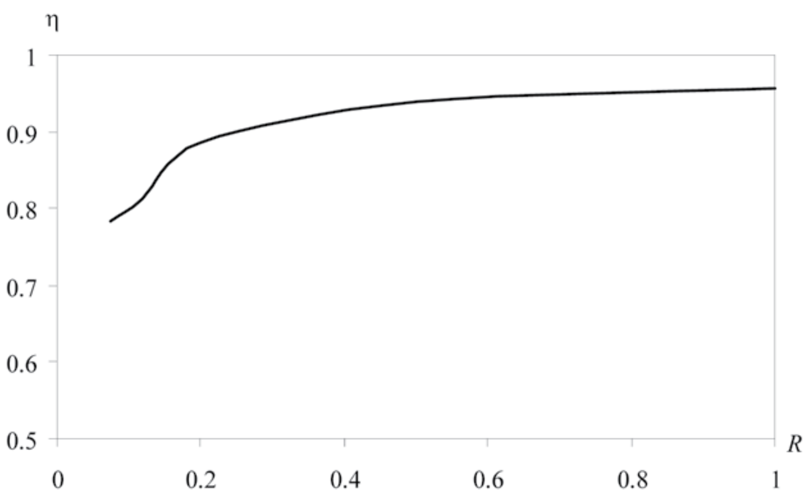


Fig. 10: Dependence of the consumption coefficient on the value of the rounded radius R

at the input part of the nozzle. Within this range of the rounded radius values the consumption coefficient tends to the value 0.8, which agrees with the known experimental results [8].

Analyzing the obtained results as a whole, one can conclude, that the features of the jet generation do not have an essential influence on the process of a high-pressure jet motion in the air. The behavior of a liquid jet in the air does not depend on the shape of a nozzle canal, if the ring detached area is located inside the canal prior to the output cut. The jet keeps the shape, close to cylindrical at the distance up to

$$\frac{x}{r_a} = 200.$$

Literature

1. CHICHAYEV V.A. et al. Pulp and paper industry equipment. Vol. 2. Paper-making machines – M.: Timber industry, 1981.- pp. 112-117 (in Russian).
2. Paper-making reference-book / A.A. Alekseyev and oth., in 3 volumes, vol. 2. Publishers "Timber industry", 1965. – pp. 583-595 (in Russian).
3. AVERKIN V.V., KALINKIN A.A., TURYGIN YU.V. Hydraulic cleaning of clothes of paper and cardboard making machines by high-pressure sprinkles (HPS) // Hydraulics and pneumatics. 2004, N16. – pp. 25-28 (in Russian).
4. HIRT C.W., NICHOLS B.D. Volume of fluid (VOF) method for the dynamics of free boundaries //J. Comput. Physics.- 1981, vol. 39. - P. 201-225.
5. LOYTSYANSKIY L.G. Mechanics of liquid and gas. – M.: Nauka, 1987. – 840 p. (in Russian).
6. PATANKAR S. Numerical methods of solving the tasks of heat exchange and dynamics of liquid. – M.: Energoizdat, 1984. – 150 p. (in Russian).
7. BENDERSKIY B.YA., TENENEV V.A. Spatial subsonic flows in areas with complex geometry. // Mathematical simulation, Vol. 13, N8, 2001. pp. 47-52. (in Russian).
8. SIOV B.N. Outflow of liquid through nozzles. Moscow: "Machine building", 1968. – pp. 9-28 (in Russian).

ENGINEERING OF DESIGN AND CONTROL ALGORITHM OF PASSENGER CAR COMBINED POWER PLANT

Vladimir Alexejevich UMNYASKIN, Nikolay Mikhailovich FILKIN

Abstract

In the article herein a control algorithm for passenger car combined power plant consisting of internal-combustion engine and electric motor connected by means of matching reduction gear and operating to one output shaft, as well for electric energy storage is considered.

Key words

hybrid car, combined (hybrid) power plant, electric motor control algorithm

One of the latest trends in global automobile manufacturing aimed to settle the problems regarding ecology and fuel efficiency of vehicles is to build combined (hybrid) power plants (CPP) in vehicle design. Moreover, special attention is given to development and establishment of systems and algorithms for CPP control, since their reasonable choice has influence on efficiency of electric motor, used as part of CPP, and electric energy storage to a large extent. CPP control system provides operation, matching, supervision and control of each power plant component according to the programme (control algorithm) predetermined in a certain control element (logical control unit, intelligent electronic modules, microprocessor, etc.). The control algorithm is based upon needs of a driver which are specified by the element of control of fuel supply to internal-combustion engine cylinders and vehicle state, along with upon analysis of various road and climatic & natural operating conditions.

Scientific researches directed to establish control systems for CPP make it possible to select and substantiate the most rational (optimal) control method, operational principle and control algorithm for CPP, as well as the areas of CPP control systems developed earlier to be improved. Optimization of CPP control system provides a means for enhancement of fuel efficiency, environmental safety and haulage & speed capacity of the car in the course of its operation as much as possible.

In State Educational Institution of Higher Vocational Education “Izhevsk State Technical University” together with OAO “IzhAvto’ there was built IZH-2126-based hybrid passenger car

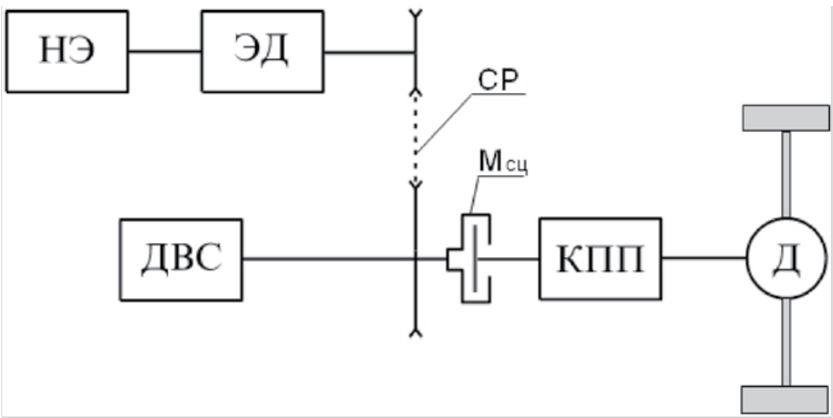


Fig. 1: Structural & kinematic diagram of hybrid CPP-powered car

Legend to Fig. 1: НЭ – electric energy storage; ЭД – electric motor; СР – matching reduction gear; ДВС – internal-combustion engine; $М_{сц}$ – clutch coupling; КПП – change gear box; Д – cross-axle differential

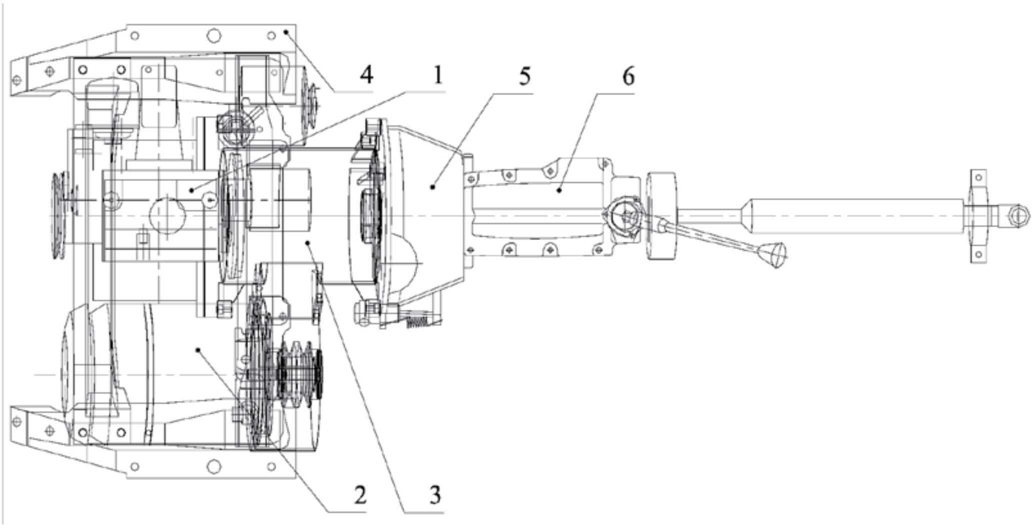


Fig. 2: Design of combined power plant
Legend: internal-combustion engine of VAZ-1111 type with capacity of 22 kW; 2 – electric motor of PT-125-12 type with capacity of 10 kW; 3 – matching belt reduction gear; 4 – power plant frame; 5 – clutch coupling; 6 – change gear box

with CPP executed with parallel construction arrangement [1]. Structural & kinematic diagram of CPP-powered car is shown in Fig. 1.

Hybrid passenger car consists of the major components as follows:

1. Combined power plant made up of combined power generating system (internal-combustion engine and electric motor connected by means of matching reduction gear) and power train units (Fig. 2). Matching belt reduction gear is designed to transfer torque from internal-combustion engine and electric motor to one output shaft of combined power plant. Its reduction ratio for coordination of speed of internal-combustion engine and electric motor shafts (max. possible shaft speed of electric motor of PT-125-12 type equals to 8,400 rpm, that of VAZ-1111 type - to 5,600 rpm) is equal to 1.4. According to structural & kinematic diagram shown in Fig. 1 there has been

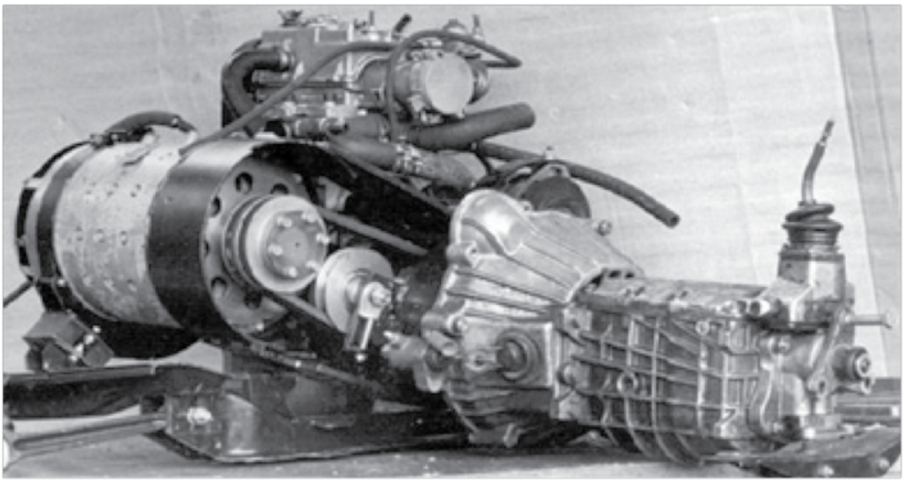


Fig. 3: Combined power plant

developed CPP design based on which experimental CPP has been produced and implemented in IZH-2126 car. Physical configuration of the established CPP is shown in Fig. 3.

2. Start-control devices (SCD) which primary function is matching the operation of both motors of the power plant while transferring torques according to the programme which simulates real-life conditions of hybrid car driving.
3. Electric energy storage involving two packages of lead-acid batteries of 6ST-55 type, four batteries in each package.
4. Carrier car IZH-2126.

It is common knowledge that internal-combustion engine is characterized by high torques at high crankshaft speeds, whereas electric motor – by high torques at low shaft speeds. Therefore, during acceleration of internal-combustion engine-powered car the required additional energy can be received from electric energy storage through electric motor while keeping the driving with steady-state speeds and close to them (at low accelerations) using only internal-combustion engine, which is to be provided in the algorithm of CPP control. The control algorithm shall provide special operation modes (start of internal-combustion engine, car acceleration, regulation of driving speed, braking) of CPP-powered car required for the driver to drive the car. Moreover, CPP control algorithm shall provide the required control of electric motor as a part of CPP (matching of internal-combustion engine and electric motor operation) at various conditions of car driving, etc.

Depending on the required mode of car operation the driver controls CPP by means of ignition switch and accelerator pedal when starting internal-combustion engine and accelerator pedal only when accelerating, regulating driving speed and decelerating.

All car driving conditions provide control of internal-combustion engine through accelerator pedal, i.e. the higher throttle angle, the more air-fuel mixture is supplied from carburetor to internal-combustion engine cylinders; and the higher speed of internal-combustion engine crankshaft. When starting the internal-combustion engine as starter an electric motor can be used which is controlled by means of supply of corresponding voltage and current to electric motor windings and their adjustment which is necessary in order to provide the required operation conditions of electric motor, and, therefore, of hybrid car as a whole.

With a view to substantiate the most rational control of electric motor [2] some calculation researches have been carried out resulting that designed speed-torque characteristics of the used electric motor of PT-125-12 type have been obtained, i.e. relationship between supply voltage $U_{эд}$ and exciting current $I_{эд}$ required to receive torque at output shaft $Í_{ýä}^{ðàñ}$ (Fig. 4).

In an initial stage of electric motor operation when its torque remains constant the supply voltage is to be smoothly adjusted (increased) under the constant exciting current. After that in order to receive zero torque at max speed of electric motor shaft which is equal to 863.5 rad/sec (8,224 rpm) it is required to decrease exciting current at constant max supply voltage under a certain law. If at any time exciting current is stopped at any level or fails to be changed under a certain law, electric motor switches to partial characteristic when output torque will be decreasing faster and will be equal to zero at speed lower than 863.5 rad/sec (8,224 rpm). These electric motor characteristics are shown in Fig.4 by dashed lines.

Smooth adjustment of supply voltage at initial stage of electric motor operation is a challenging task. Therefore, the developed engineering prototype of CPP is controlled by means of stepwise variation of supply voltage:

1. Supply voltage of 48 V is supplied to electric motor which accelerates to as high shaft speed as 177.9 rad/sec (1,694 rpm) with resistor of 0.13 Ω in resistance brought into armature circuit and exciting current adjusted as appropriate.

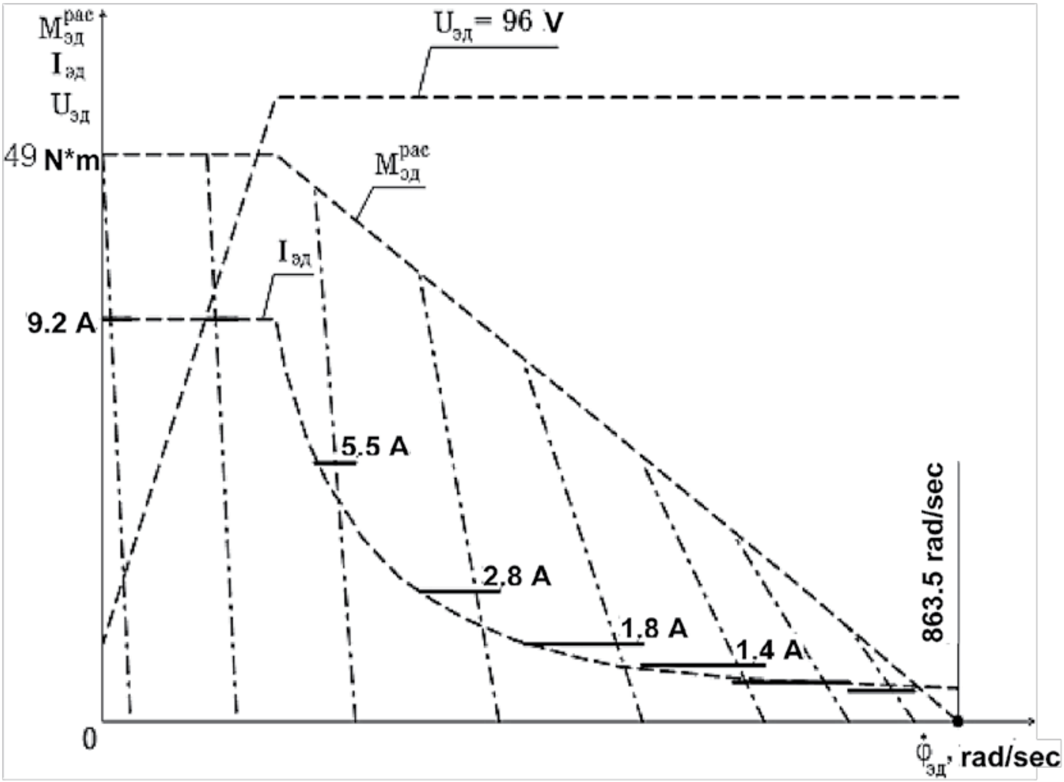


Fig. 4: Designed set of load characteristics of electric motor of PT-125-12 type

2. Then supply voltage of 96 V is supplied to electric motor which accelerates and at rated speed of 261.7 rad/sec (2,492 rpm) in armature circuit a resistor shunting takes place. At shaft speed of 4,200 rpm electric motor switches from traction conditions into generator ones to recharge electric energy storage, since quantity of energy supplied from electric motor decreases sharply when electric motor operates at high shaft speeds.

Objective external speed-torque characteristic under such control of electric motor of PT-125-12 type as above is shown in Fig. 5, where also shown external speed characteristic of internal-combustion engine of VAZ-1111 type and total external speed characteristic of CPP (sum of internal-combustion engine and electric motor capacities) taken from output shaft of combined power plant.

For CPP control an algorithm of hybrid car driving was developed as follows:

1. Start and idle. By means of matching reduction gear an electric motor starts internal-combustion engine which switches to idle conditions (800 to 900 rpm), whereas electric motor starts operating under conditions when it doesn’t consume electric energy from the storage and doesn’t generate torque on output shaft, i.e. it is being at the boundary of switching into generator or motor operating conditions. Should crankshaft speed increase, electric motor will switch into generator conditions and start transferring energy to storage which decelerates an internal-combustion engine.
2. Start of driving (speeding up) and acceleration. When opening throttle of internal-combustion engine carburetor, the driver wants to obtain speed of the car as desired. Since the car speed will be lower

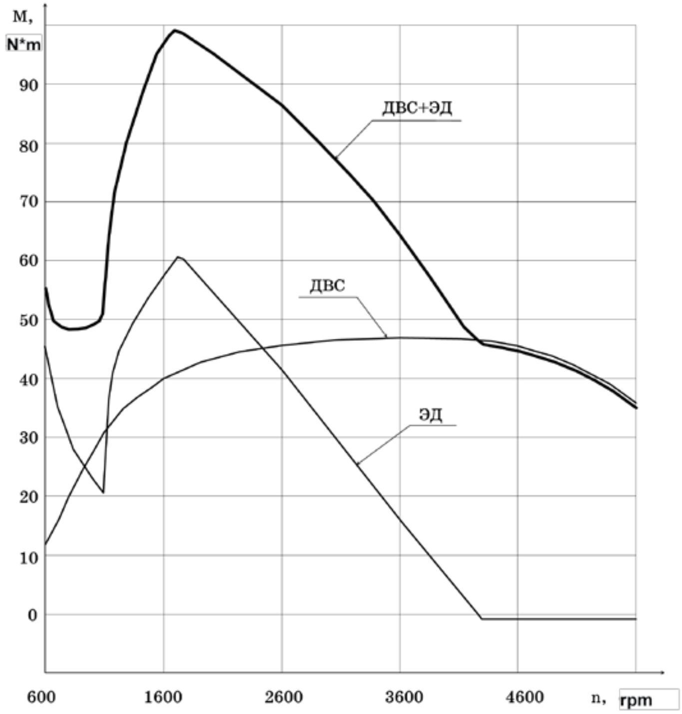


Fig. 5: Objective external speed characteristics of electric motor of PT-125-12 type, internal-combustion engine of VAZ-1111 type and combined power generating system

than that specified in the algorithm for the certain throttle angle, in order to reach the required speed as predetermined in electronic control unit during that period total torque is transmitted to drive wheels of the car from internal-combustion engine and electric motor. Electric motor is fed exclusively by electrical energy storage. When the car speed determined by internal-combustion engine capacity and driving resistance corresponds to the throttle angle predetermined by the driver or close to it, electric motor switches into conditions when it doesn't generate torque or to generator conditions in order to charge electric energy storage. These driving conditions are represented by a diagram in Fig. 6. The CPP-powered car driving resistance power $N_{сопр}$ when driving with steady-state (uniform) speed on horizontal bituminous concrete road is equal to:

$$N_{соПр} = (N_f + N_w)/\eta_{tp}$$

where N_f – power required to surmount rolling resistance force while car driving with steady-state (uniform) speed on horizontal bituminous concrete road, kW; N_w – power required to surmount air resistance while car driving with steady-state (uniform) speed, kW.

The CPP-powered car driving resistance power $N_{сопр}$ is equal to internal-combustion engine capacity provided CPP-powered car is driving with steady-state (uniform) speed.

Let us consider a special case (Fig. 6) when driver opens the throttle for example by 50 per cent. In this case internal-combustion engine and electric motor accelerate the car and upon reaching the speed of 77 km/h which corresponds to the throttle angle predetermined by the driver (as per the curve No. 3 shown in Fig. 6), electric motor switches to operating conditions when it doesn't

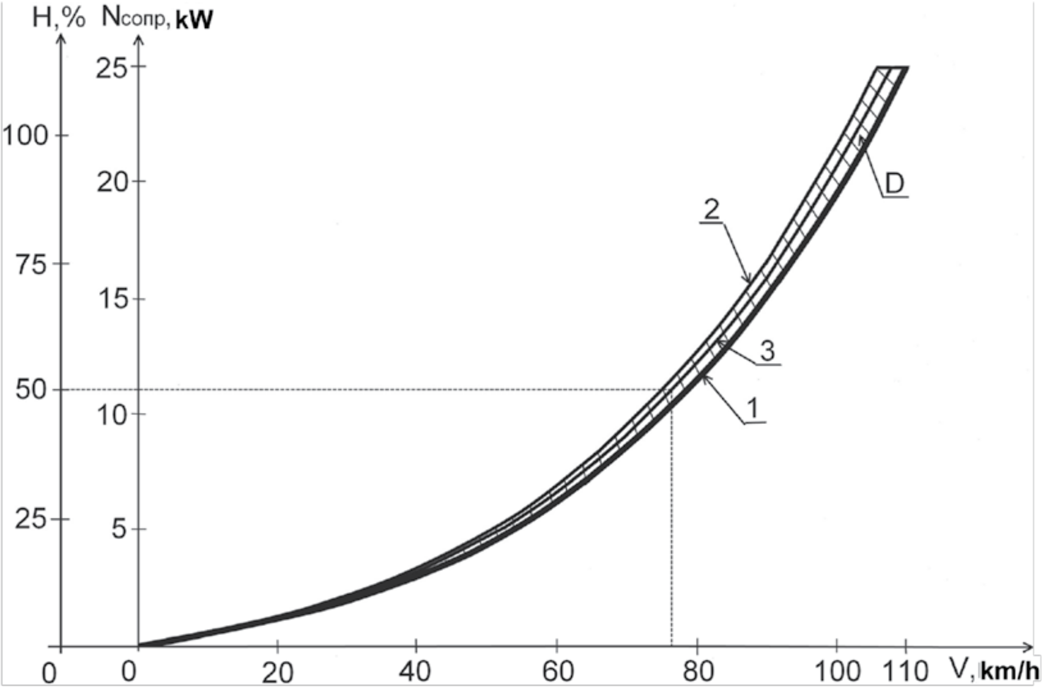


Fig. 6 – Load and CPP-powered car driving resistance power vs. car uniform driving speed curve

Legend to Fig. 6: H – load or throttle angle, %; $N_{сопр}$ – CPP-powered car driving resistance power while driving with steady-state (uniform) speed on horizontal bituminous concrete road, kW; V – uniform speed of the car, km/h; 1 – designed relationship between CPP-powered car driving resistance power and car uniform driving speed; 2 – relationship between resistance power which takes into account the growth in driving resistance and deterioration of internal-combustion engine operating characteristics (deterioration of internal-combustion engine characteristics and increasing of losses by 10 per cent are acceptable) in the course of operation of CPP-powered car; D – area which determines a set of objective characteristics between characteristics No. 1 and No. 2 which can be used for electric motor control (switching off); 3 – objective characteristic implemented in the developed CPP control system for switching the electric motor off while car accelerating under predetermined throttle positions.

generate torque or to generator conditions to charge electrical energy storage. The car will be driving with uniform speed only by means of operation of internal-combustion engine which capacity equals to 11.5 kW. Therefore, the relationship between CPP-powered car driving resistance power and car uniform driving speed No. 3 as shown in Fig. 6 describes switching of electric motor from motor conditions into generator ones and vice versa.

3. Conditions creating additional driving resistance force. Uphill driving, cross wind or other conditions which create additional driving resistance force when car speed will be lower than that predetermined in algorithm for specified throttle angle; internal-combustion engine and electric motor operate under traction conditions.
4. Conditions decreasing rolling resistance force. Downhill driving, favoring wind or other conditions which decrease rolling resistance forces when speed will be higher than that predetermined for specified throttle angle according to curve No. 3 as shown in Fig. 6; electric motor starts operating under generator conditions.

5. Forced idle. Electric motor operates under generator conditions when car speed is reducing at the time of throttle angle decreasing with the clutch engaged, i.e. under forced idle conditions (deceleration-braking). That is electric energy recuperation process at work.

Electric-powered drive control system has to provide execution of the developed algorithm. The required algorithm has to be programmed in a certain control unit which receives data by means of sensors from the controlled variables while the car is at rest or during its driving, then analyses them and provides CPP operation as required. The following parameters were taken as key parameters in the developed CPP control system: speed of output shaft of the combined power generating system, value of throttle angle and driving speed.

In conclusion it shall be noted that CPP-powered cars executed with parallel construction arrangement of internal-combustion engine and electric motor are comparable to conventional cars equipped only with internal-combustion engine with regard to dynamic behavior. However, this arrangement succeeds in increasing of fuel efficiency by as high as 30 per cent and more, while emission is reduced by more than 40 per cent, that was shown during experimental investigations of IZH-2126 car equipped with CPP, with almost no change in its basic design parameters. The established control system provides execution of the developed algorithm and maintains driving conditions predetermined by driver.

Literature

1. Design of energy-efficient engines and drives for vehicles, for the task of “Design of combined power plant for urban passenger car”: Interim (1st stage) report on pilot-scale scientific research carried out within the framework of activity No. 1.2.2 “Making investigations by science teams under the supervision of Candidates of Science” of the federal purpose-oriented program “Scientific and academic & teaching staff in innovative Russia” for 2009 to 2013” / Government contract No. P1449 as of Sep 03, 2009 / Izhevsk State Technical University; Project Manager V.A. Shilyaev – Izhevsk: IzhSTU, 2009. – p. 102 – Executive Manager D.A. Kopotev; Participants: A.I. Starkov, K.S. Bratukhin, A.R. Imangulov.
2. UMNYASHKIN V.A., FILKIN N.M., MUZAPHAROV R.S., KOPOTEV D.A. Mathematical modeling of dynamics of vehicles equipped with combined power plants. – Izhevsk: Scientific and publishing center “Regular and disordered dynamics”, 2009. – p. 74.

THE RESEARCH OF REPETITION CODE CORRECTING EFFICIENCY IN HIGH FREQUENCY OFDM COMMUNICATION SYSTEM

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Abstract

Repetition code correcting efficiency in the presence of burst error, which is quite typical for high frequency data transfer, is investigated. Data transfer is provided by OFDM signals within 3.1 kHz bandwidth on 2400 bps and 1200 bps data rates. Repetition codes are constructed on the base of Reed-Solomon codes. The task of the article is to compare two schemes of coding development: repetition codes and non-repetition codes.

Key words

OFDM, Reed-Solomon code, repetition code, signal-coded sequence, HF channel, burst error

It is well known fact that data transmission through the high frequency (HF) channel is complicated because of multipath propagation. Multipath propagation becomes a reason for intersymbol interference (ISI) and burst error appearance as well. Nowadays high demands of reliability of information transfer are made to modern communication systems. There are some most promising ways of solving this requirement. One of them is to use the orthogonal frequency division multiplexing (OFDM) in communication systems. On the one hand OFDM technology allows to avoid intersymbol interference by including cyclic prefix to the signal, and on the other hand it allows to use selected bandwidth more effective. Another way is to use error correcting coding (ECC). Among all types of correcting codes we have chosen Reed-Solomon code because it effectively corrects burst error, which is typical for HF channel. The main idea of error correcting coding is to add some redundancy data to the information data [1, 2]. The number of errors that code can correct directly depends on redundancy. Codes with huge redundancy correct more errors, but contain less information therefore the data rate slows down. If we want to provide high speed data transfer, we should choose correcting code with smaller redundancy. In any case if error becomes more than code is able to correct, the whole block of information is lost. Taking into account the fact that burst error is typical for HF channel, we can offer useful decision to reduce information losses. The main idea is to divide information block into several parts and encode each part separately by code with less redundancy. So if a part of coded blocks will be affected by burst error, only part of information will be lost. Such coding scheme can essentially increase data transfer reliability therefore our research is an urgent problem.

DEFINITION OF REPETITION CODE

In this section we will define a term repetition code and explain the difference between repetition code and non-repetition (usual) code.

In the case of usual coding information block of length K is encoded by (N,K) code. As a result we have a coded block of length N (fig. 1).

In the case of repetition coding information block of length K is divided into some blocks of length k and each one is encoded by (n,k) code so that total length of all codes is equal to N or Σn = N. Depending on data rate and value of redundancy respectively, repetition encoding scheme can be organized in two ways: repetition of information or distribution of information. In the first case short (n,k) code many times encodes the same information block of length k. In the second case short (n,k) code encodes different parts of a single block K (fig. 2).

Now let's take a look at correcting efficiency of both schemes. We presume that repetition code includes x composite (n,k) codes, each one corrects t errors. It is obvious that repetition (N,K) code corrects T = xt errors. Single error and burst error can appear together in HF channel and if total error is larger than (N,K) code can correct, we lose the whole information block. But if we use repetition encoding, only some part of information is lost. This situation is clearly described on fig. 3. However error may be located in such way, that usual coding scheme will be more effective. So the task is to compare two types of coding schemes.

Now we consider how to decode the repetition code. As it is said above repetition codes are constructed on the base of Reed-Solomon codes. The usual Reed-Solomon code is decoded by Peterson Gorenstein Zierler (PGZ) algorithm [1, 2]. To decode repetition code constructed by distribution of information, each composite code block of length n should be decoded separately by PGZ algorithm. And then all information blocks of length k are summed up making a final information block of length K (fig. 4a). To decode repetition code constructed by repetition of information, each composite code

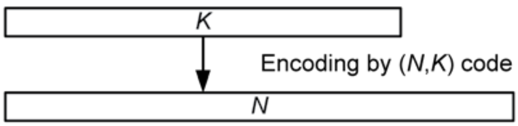


Fig. 1: Non-repetition encoding scheme

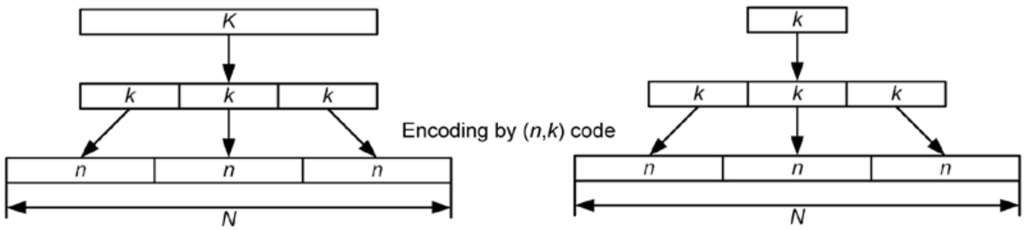


Fig. 2: Repetition encoding scheme: a) distribution of information; b) repetition of information.

block of length n should also be decoded separately by PGZ algorithm. The difference is that we store each information block of length k and erase flags correspondingly. Then all information blocks and erase flags come into the block of erase flag analysis. If one of the erase flags is set to zero (this means that decoder has successfully decoded information), then we choose corresponding information block. And it is the final information block (fig. 4b). If all of the erase flags are set to one (this means that decoder has failed to correct all errors), then we choose any information block.

BASIC CHARACTERISTIC OF OFDM COMMUNICATION SYSTEM

Conception and development methods of OFDM communication system are well described in [3, 4]. We just consider basic characteristic of OFDM system, which are necessary for further construction of codes:

- Duration of OFDM symbol: T_{OFDM} = 20 ms;
- Duration of cyclic prefix: 4 ms;
- Sampling rate: 8 kHz;
- Signal bandwith: 3.1 kHz;
- Number of carriers: N_C = 48;
- Type of carrier modulation: DQPSK;
- Data rate: 2400 bps, 1200 bps.

Main principles of repetition code construction

To construct coding scheme on the base of Reed-Solomon code for communication system, which transfers data at some rate, we should define following parameters:

- code block length N;
- information block length K;
- power of Galois field m.

Code block length N depends on number of carriers NC in OFDM signal spectrum and number of points in signal constellation m_C of carrier modulation. This dependence can be described by equation (1):

$$N = N_c \log_2 (m_c) \tag{1}$$

Taking into account that in our OFDM system and for DQPSK, we get following results:

- N = 96 bits in case of DQPSK;

Information block length K depends on data rate V_D and O_{FDM} symbol duration T_{OFDM} as:

$$k = VdT_{OFDM} \tag{2}$$

Taking into account that T_{OFDM}= 20 ms and V_D = 2400 or 1200 bps, we get following results:

- K = 48 bits in case of V_D = 2400 bps;

- K = 24 bits in case of V_D = 1200 bps;

Since Reed-Solomon code is nonbinary code, it operates with symbols containing m bits in the Galois field GF (2^m). Therefore first we should calculate code block length N_{RS} and information block length K_{RS} in symbols, using following equation:

$$N_{RS} = \frac{N}{m} \quad K_{RS} = \frac{K}{m} \tag{3}$$

So value m should be chosen in such way, that N_{RS} and K_{RS} possess integral value. Taking into account that N = 96 and K = 48 or 24, we arrange following series: m = 3,4,6.

Necessary requirements to construct repetition code are as following:

- Total length of all composite code and information symbol length (n_{RS} and k_{RS}) must be equal to code and information length (N_{RS} and K_{RS}) correspondingly:

$$\Sigma\, n_{RS} = N_{RS}$$
$$\Sigma\, k_{RS} = K_{RS} \tag{4}$$

- Redundancy (n_{RS} - k_{RS}) should be even and positive.

Designation of repetition code is as following:

$$M \times (n_{RS}, k_{RS}) \text{ RS GF } (2^m) \tag{5}$$

i.e. repetition code includes M (n_{RS}, k_{RS}) Reed-Solomon codes over Galois field GF (2^m).

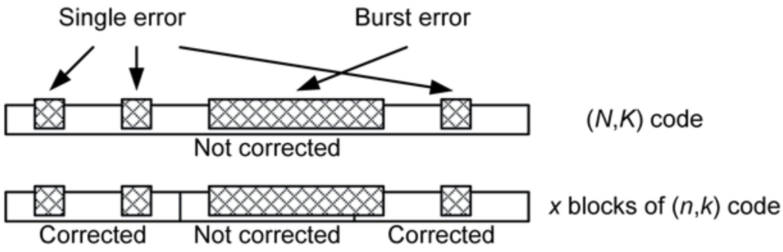


Fig. 3: Probable error location in code block

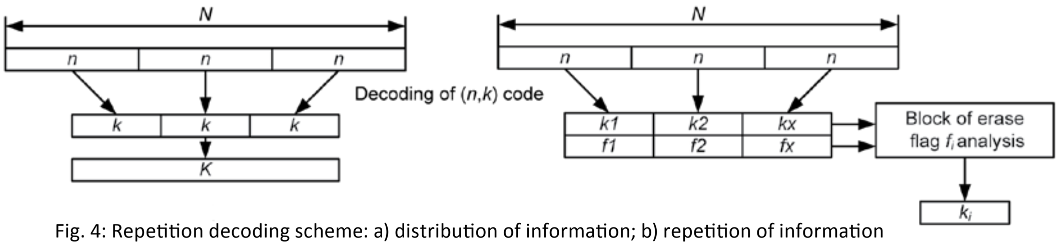


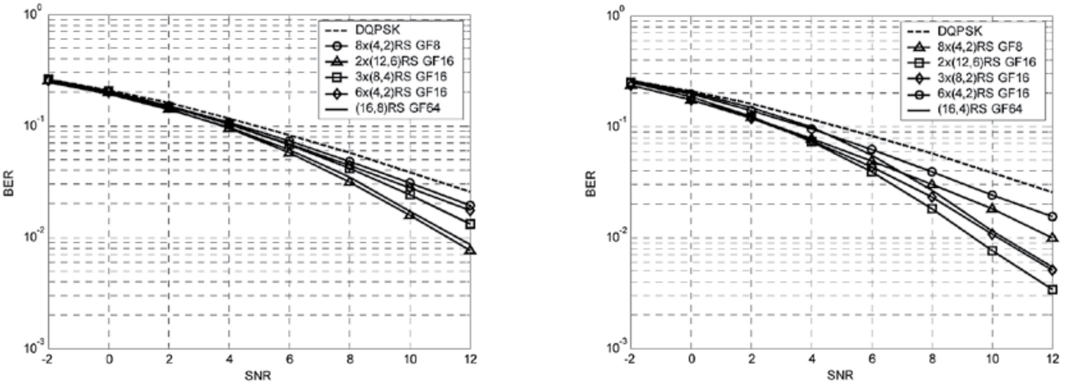
Fig. 4: Repetition decoding scheme: a) distribution of information; b) repetition of information

Tab. 1: Signal-coded sequences for 2400 bps data rate

№	Type of signal-coded sequence	Type of carrier modulation	Note
1	(16,8)RS GF (2^6)	DQPSK	non-repetition code
2	2x (12,6)RS GF (2^4)		repetition code (distribution of informatio
3	3x (8,4)RS GF (2^4)		
4	6x (4,2)RS GF (2^4)		
5	8x (4,2)RS GF (2^3)		

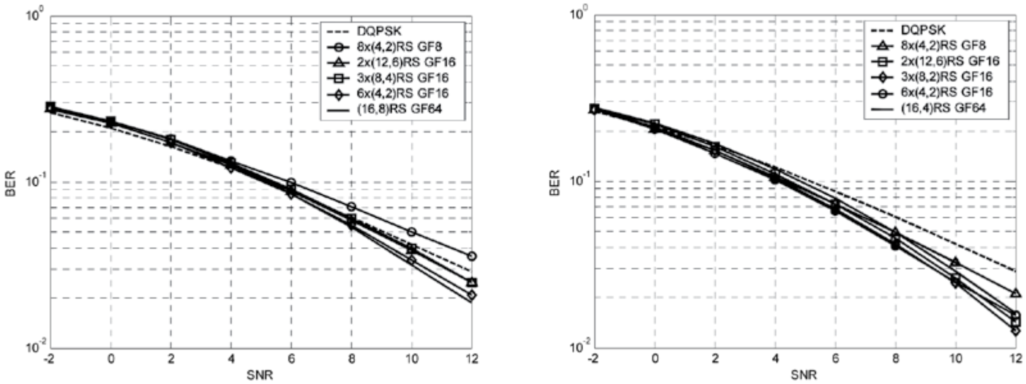
Tab. 2: Signal-coded sequences for 1200 bps data rate

№	Type of signal-coded sequence	Type of carrier modulation	Note
1	(16,4)RS GF (2^6)	DQPSK	non-repetition code
2	2x (12,6)RS GF (2^4)		repetition code (repetition of information)
3	3x (8,2)RS GF (2^4)		repetition code (distribution of information)
4	6x (4,2)RS GF (2^4)		repetition code (repetition of information)
5	8x (4,2)RS GF (2^3)		repetition code (repetition of information)



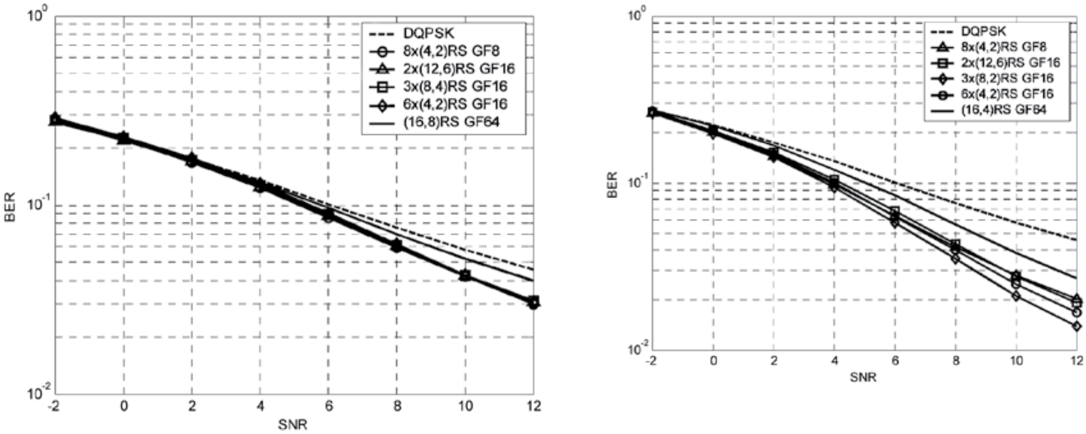
(a) (b)

Fig. 5: Noise immunity of OFDM system in Good channel for 2400 bps (a) and 1200 bps (b)



(a) (b)

Fig. 6: Noise immunity of OFDM system in Moderate channel for 2400 bps (a) and 1200 bps (b)



(a) (b)

Fig. 7: Noise immunity of OFDM system in Poor channel for 2400 bps (a) and 1200 bps (b)

Coding schemes for 2400 bps and 1200 bps data rate

We constructed different types of signal-coded sequences for 2400 bps and 1200 bps data rate. They are presented in following tables.

SIMULATION RESULTS

We tested noise immunity of OFDM communication system for both data rates in three standard simulation channels termed Good, Moderate and Poor, which are implemented in accordance with CCIR recommendation [3]:

- Good channel: time delay spread is 0.5 ms, fade rate is 0.1 Hz;
- Moderate channel: time delay spread is 1 ms, fade rate is 0.5 Hz;
- Poor channel: time delay spread is 2 ms, fade rate is 1 Hz.

The results are shown on figures below as a dependence between bit error rate (BER) and signal-to-noise ratio (SNR).

CONCLUSION

We developed two schemes of repetition coding on the base of Reed-Solomon codes, tested noise immunity of OFDM communication system using repetition codes for 2400 bps and 1200 bps data rate. Also we compared correcting efficiency of repetition codes and non-repetition codes and found out next results:

- Using of repetition codes is more effective in any channel and for both data rates.
- Repetition codes are also effective and sometimes extensively effective in the view of computational complexity.
- Different repetition coding schemes provide different correcting efficiency depending on channel conditions. So we unfortunately can't say which of them is most optimal at all.

Literature

1. WICKER B., BHARGAVA V.K. Reed-Solomon Codes and Their Applications. New York: IEEE Press, 1994.
2. R.H. MORELOS-ZARAGOZA. The Art of Error Correcting Coding. Wiley, 2002.
3. GILL M.C. Coded-Waveform Design for High Speed Data Transfer over High Frequency Radio Channels. /PhD Thesis, February, 1998.
4. BINGHAM J.A.C. Multicarrier modulation for data transmission: an idea whose time has come.- IEEE Commun. Mag., May 1990.

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