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APPLICATION OF DIFFERENTIAL EQUATIONS SOLUTIONS FOR MODELING OF METAL WORKING PROCESS AS THE MEANS OF FUNDAMENTAL TRAINING OF FUTURE ENGINEERING

The paper illustrates the application of the method of mathematical modeling on the example of application of differential equations solutions to show one of the approaches of project method usage in the process of fundamental training of future engineers.

***Key words**: modeling, based on differential equations, machining, pieces deformation.*

Introduction

Problem set-up. In modern production presentation of data in the form of graphic dependences as the most economic, descriptive and conceptual is more widely used. Graphic tools for data presentation are applied in various spheres of visual communication to induce the processes of thinking, based on the models, and pictures, drawings, graphics are the tools, by means of which thoughts are transmitted in the form of graphic utterances. The important approach to the study of the approximate solutions of differential equations is their visualization, i.e., saturation of educational material with illustrations, construction of the proofs of mathematical statements, based on insight and visualization. Geometrical approach in modern mathematical modeling is not only the tool for problems solution but also the method of their description.

The best geometrical approach to the solution of the problem, based on complex usage of the methods of computational mathematics is presented in the works of V.I. Klochko.

In spite of a great amount of modern CAD systems, that enable to simulate and describe almost all the processes of pieces machining, modern engineer often faces the problem of the description of mathematical model of the process. The process of the surface plastic deformation can be described by means of differential equations. Application of MathCAD system enables not only to solve differential equations but also visualize the results obtained on the example of phase portraits, flow curves, surfaces of ultimate strains, etc.

Analysis of recent research and publications. The essence of research approach, using information-communication technologies(ICT), particularly, while studying mathematics, was considered by M. I. Zheldak, Yu. V. Goroshko, S. A. Rakov and others. They studied various aspects of research – investigation activity of the students, however sufficient attention was not paid to organization of this kind of activity, with the
emphasis on mastering fundamental knowledge. In research of O. S. Zakutniy [5] it is stated that in case of considerable changes of machining processes operation of certain systems is accompanied by worsening of statistic accuracy of results processing, that is why, it is necessary to apply new methods of research results processing.

Aim of the paper: show one of the approaches to the usage of mathematical modeling in the process of fundamental training of future engineers of subject modeling on the example of metal working.

The aim of research method is improvement of students engineering knowledge and skills. Construction of training and educational process on condition of development of creative abilities provides its construction in such a way that the student performed the role of the researcher. One of possible ways of research method realization is method of the projects.

Method of projects may be considered as a set of techniques, operations, directed at reaching didactic aim by means of detailed processing of the problem, that must be finished by real practical result, arranged in this or that way. Method of projects always provides the solution of a certain

problem, that, on one hand, requires the usage of the set of various methods and tools for study, on the other hand – integration of knowledge and skills form various spheres of science, engineering, technology. We will consider the specific example of the method of projects [4].

The aim of the project realization is practical mastering by the students of scientific principles, gaining the methods of experimental data processing and construction mathematical models, i.e., conversion of the obtained knowledge into tooling for solution of educational, research and real experimental and practical tasks, close to production problems.

Mathematical models, describing real production processes, can be introduced to students in all sections of higher mathematics course.

Problems, solution of which contains qualitative characteristic of the phenomenon being considered, are the most interesting. Solution of any applied problem by means of mathematical methods is mathematical modeling. Writing down the conditions by means of mathematical expressions, we construct mathematical model of the real physical process. While composing and solving the equations, there appears the necessity to make certain assumptions regarding the parameters. That is why, any model has certain degree of approximation and error in calculations.

Title of the project: modeling of metal processing using the solutions of differential equations.

Concise description of the project: During execution of the project task, students must get familiar with mathematical models, which correspond to elements of the scheme, its possible simplification and with mathematical models, which correspondent to simplified schemes of the given project. **Full description of the project**: one of the project most efficient ways of increasing failure – free performance and longevity of pieces is application of the methods of volumetric surface machining. Volumetric hardening increases static strength of pieces, where operating stresses are distributed along the section rather uniformly

For pieces, failure of which starts on the surface, numerous methods of surface hardening methods have been developed. In machine- building branch methods of surface hardening by means of surface plastic deformation (SPD) are most widely used.

While studying the technology of hardening processing by means of SPD methods two problems occupy an important place: revealing the regularities of SPD mechanics of elastic plastic body and development of the principles of technological processes of pieces machining control , applying SPD methods. The solution of the given problems enables to improve the processes, create CAD systems of technological operations of hardening machining of pieces, applying SPD methods. Metals in the course of deformation display elastic and plastic properties. For modeling of similar complex systems it is convenient to use structural elements [6, 7], that describe this or that physical mechanism of deformation. Elastic mechanism of deformation can be modeled by means of structural element in the form of linear or non-linear spring, motion resistance of which depends on the coefficient of dry friction.

Considering various combinations of structural elements, structural models of the body with different deformation properties may be constructed. After construction of structural model of the body the relations can be obtained which establish functional dependence between stressed and strained state of the whole unit, that is one of the most comlex problems in the mechanics of rigid strained body.

To find the dependence of the deformation in the process of tool contract with the surface of the blank, being machined and dependence x on prior spring tensioning – the problem of dynamic modeling of surface plastic deformation of the piece with fixed liquid damper in the centre during mechanical machining is considered (Fig. 1).

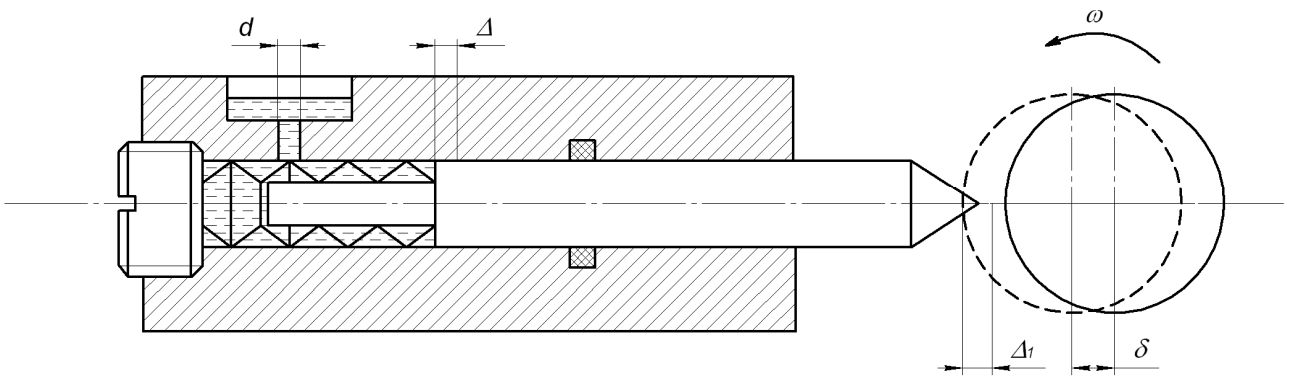


Fig. 1. Diagram of the process of dynamic modeling of surface plastic deformation with liquid damper

Differential equation, describing the process of surface plastic deformation of the piece, fixed in centers with beats b has the form

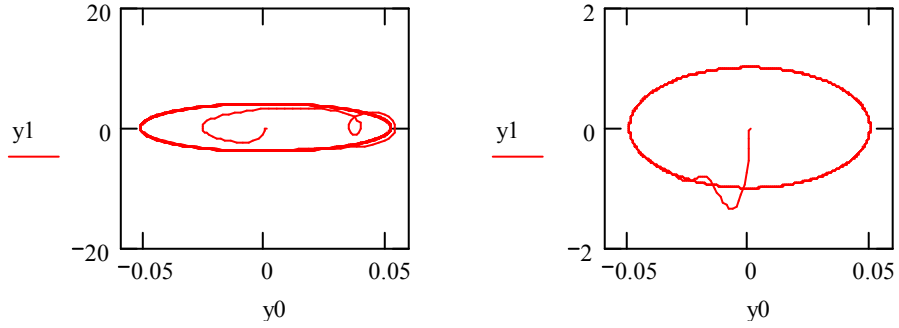
$$mx'' = -Cx' - k(\Delta + x + \delta\sin(wt)) + Es(\Delta_1 - x - \delta\sin(wt))\cdot\mathrm{sgn}(\Delta_1 - x - \delta\sin(wt)),$$

where m – reduced mass of the tool – kg; b – beat of the piece – mm; C – tension of the spring - H/(mm/s); k – spring rigidity, H/mm; Δ – previous tension of the spring, mm; δ - beat of the piece, mm; ω – angular velocity of the piece, rad/s; E – rigidity of piece material per unit of deformation surface, H/mm^2; S – area of piece-tool contact, mm^2; Δ_1 – initial static tension of the tool into piece – mm; sgn( ) – single function, describing force influence of piece surface on the instrument in case of contact and its absences in case of tool separation from the piece.

In the above-mentioned equation, the function Sgnx describes force influence of piece surface on the tool in case of the contact and if the contact is absent. Availability of computer modeling system(CMS) MATHCAD gives the students the possibility to analyze these modes and compare the results.

The task is to choose such integration step, that the best information result could be obtained; study the dynamics of tension change for w=10 rad/s, 100 rad/s. To make a conclusion, regarding the impossibility of operation on certain frequencies, find optimal frequency (Fig 2), carry out the research in case of Cx' substitution by $C(x')^2$, if liquid dampers are used; study the case, when the piece is machined by toroidal or spherical tool with a small radius ($r \le 3$ mm) assume

$S = k_1\cdot(1 + B_1 - x - b\cdot\sin(wt))^3$, where $k_1 = 1$, $k = 1000$, w=100 rad/s, b=0,01 mm, C= 200 H(mm/s), B_1=0,01 mm, ES=100 kH/mm, B= 1 mm.



a) b)

Fig. 2. Phase portraits of the problem 1-2
Phase portrait at critical frequency ω=76.03 rad/s (a) and at ω=20rad/s (b)

Analysis of phase paths shows, that dynamic system has stable equilibrium. This is limiting cycle. Initial conditions are in the middle of the cycle and phase path is a helix, that turns to the cycle. Limiting cycle is characterized by the presence in the system of stable periodic oscillations. In Figs x(t) (y0)- variation of piece position, x′(t)(y1) – linear speed of piece motion are shown

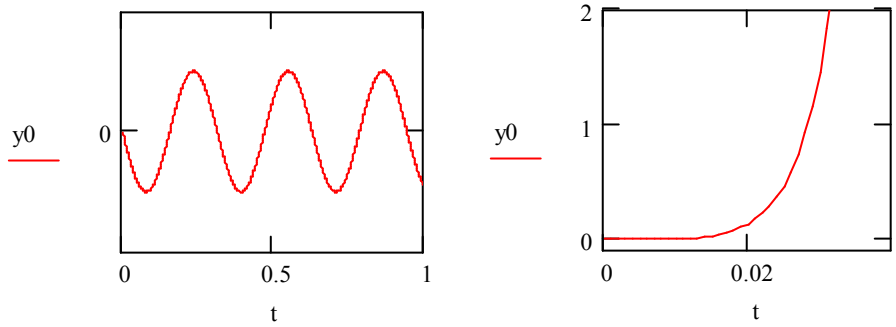


Fig. 3. Piece deformation
a) ω=20 rad/s, b) 76.03 rad/s<ω<100 rad/s

The suggested mathematical model gives the possibility to obtain necessary quality of the surface as a result of substantiated choice of parameters of technological system.

Participants of the project: students of academic group of machine – building specialty.

Term of realization: two weeks after the obtaining of the task.

Aims of the project: continue to form in the students skills of CMS application; continue to form the students skills of composing and solving differential equations; continue to form the students skills of analysis of differential equations solutions; continue to form in students skills of distinguishing essential features; continue to form the students skills of using the Internet for the search of necessary information.

Realization of the project provides:

1. Motivation of independent educational-cognitive activity of the students and project presentation.
2. Formation of groups of 3-4 persons, in each group the expert is nominated to help other students.
3. Formulation of the task for the groups: choose model equation, find solution, construct the graphics of the solutions and evaluate errors in points, far from Ox, solve equation by numerical methods, for the comparison of the results make use of isoclinic line, carry out computational experiments, be ready for the control.

Analyzing tension curves at various values of *w,* students make conclusion regarding the dynamics of the process. Analysis of the piece position change in Fig. 3 in case of angular velocity from the interval 76.03 rad/s<ω<100 rad/s, shows the impossibility of operation on such frequencies of piece rotation, as contact of the tool and piece is not permanent but periodically repeats.

Hence, changing the parameters of differential equation, the shift of these curves may be changed and influence directly the change of the piece shape. Let us compare the conventional and information technologies of projects method realization from the subject: “Approximate methods of the solution of differential equations of the first and second orders”. In accordance with the conventional technology projects method can realized in such an order: first, the students individually prepare to project execution, study necessary theoretical material. The teacher gives the task, formulates the goals. Then, the students do the work and defend the results. Students, by means of computational facilities, solve the equation, using the suggested method. The work of a teacher is to control the course of work execution, consulting and evaluation of the results, formation of skills and experience of individual analysis of the obtained data.

The technology of project method execution, using technical and programming facilities of ICT can be described in the following way. Students individually prepare to work execution, apprehend the task, study theoretical material, perform previous calculations, obtain exact solution of the equation. The teacher sets up the problem, formulates the aims of the task and their motivation.

Function of the computer is tasks generation, verification of students knowledge, necessary for research execution. At the second stage machine control of the exercise of the first stage execution is realized. The students enter the results of the calculations, carried out at the first stage, obtain approximated solutions of equations, evaluate the error. The teacher controls the course of work execution, consults students. The computer, on students request, gives the solution of the equation, performed by the set method and also by other methods, prints out the results of the calculations. Then, the study of the obtained approximate solutions, comparison with the exact solution is carried out. The teacher forms skills and experiences of the students for independent analysis of the results, develops skills of creative thinking. Computer generates the question of problematic character, prints out the graph of error change. Student in dialogue mode enters answers to the question, in order to carry out the research, changes the value of task parameters, analyzes the results of calculations, makes conclusions.

Conclusions

During realization of projects method using new technology the amount of knowledge elements, mastered by students increases. The student gets skills of comparison of experimentally obtained dependences with known, accepted mathematical models for the given process. Characteristic feature of CMS MATHCAD usage is that the student has the possibilities to obtain the results of application of various methods, compare them, evaluate errors, student has the possibility to answer the problem question.

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