

Computer realization of research into the dynamics of mechanical systems

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Abstract. The article considers the application of methods of component modeling and of object-oriented technologies in automated construction of dynamic models of mechanisms in their program realization.

1. Dynamic processes in mechanical systems (mechanisms)

A mechanical system is a set of bodies with elastic and inertial properties making it possible to transform the movements of some bodies into the required movements of other bodies, which is widely used in technological machines for obtaining both the necessary form of the product [1] and the required parameters of surface quality [2]. Dynamic processes are mechanical oscillations in mechanical systems. The method of calculating dynamic processes is known [3, 4]. It is based on the substitution of the real mechanism with a system of concentrated masses, which are connected by inertialess, elastic-dissipative and kinematic connections (a dynamic model). In practice, however, this method is not widely spread. The main reasons are as follows:

- low degree of accuracy and high labor intensity of calculating the model's parameters, primarily its elastic and inertial characteristics;
- high labor intensity of work connected with the development of the dynamic model of the mechanism, its mathematical description (a mathematical model), and the subsequent program realization of calculations on the basis of the mathematical model;
- impossibility to assess the reliability of the obtained results without further experimental research of the ready mechanism.

2. Objective representation of mechanical systems.

Any mechanism can be regarded as a set of several elements connected among themselves by various connections. Through these connections, the elements of the mechanism interact with each other, thus providing its functioning. The term 'element' will designate a separate part of the mechanism, a fragment of a part, or, on the contrary, several details at once. Such definition of the element corresponds to the concept of an object – a basic concept in the theory of component modeling of complex dynamic systems and object-oriented technologies [4].

We will compare each element of a mechanism with an object according to the above-mentioned definition. Any processes in such object can be modeled in any way and, according to the principles of encapsulation and polymorphism of object-oriented technologies, at this stage, their nature and mathematical, program or physical description are disregarded.



Such approach is of interest in solving tasks dealing with development of both dynamic and mathematical models of mechanisms [5, 6] and, which is singularly important, their program realization in further computer processing [1].

Let us imagine a real mechanism as a set of objects connected among themselves by transfer functions. Such objects can be represented by both separate links and sets of links forming elementary mechanisms. Let us connect five sets of characteristics with each object (Figure 1):

- Properties, including masses, moments of inertia and stiffness, dissipation coefficients, parameters of transfer functions and others defining an object as a closed system.
- Responses to disturbances from other objects.
- Power disturbances from other objects.
- Input parameters including kinematic and power.
- Output parameters (kinematic, power, values of criteria of quantitative assessment of dynamic processes in an object).

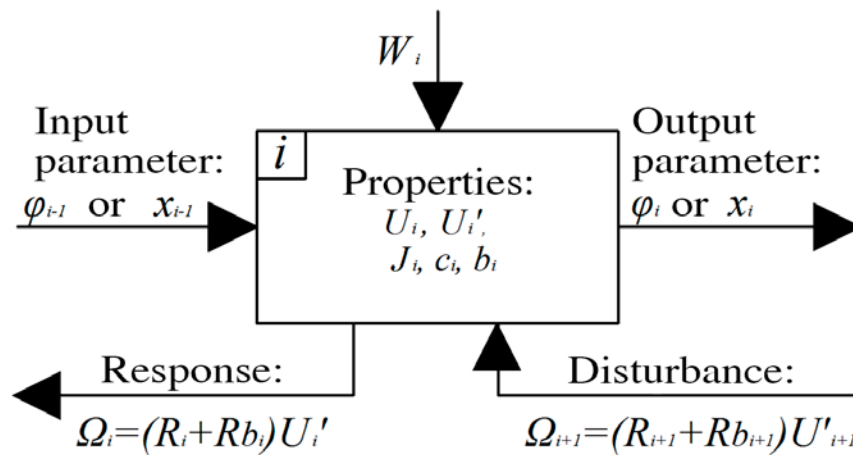


Figure 1. The object's parameters and features

Properties and responses (labels 1 and 2) are values entirely depending on the object. The first constants are independent of external conditions, the second ones depend on the environment in which the object is placed. Power disturbances and input parameters (labels 3 and 4) are the environment of the object. Output parameters (label 5) are a set of the resulting data making it possible to estimate the processes inside the object after it is placed in a certain environment. It should be particularly noted that a set of objects representing a mechanism (object representation) and the mechanism itself completely fit each other. Reality can be substituted with a model only on the level of an object. It means that the accuracy of the results of dynamic research is largely determined by the 'high quality' of the objects which are used in this research. An object and an object model, as is understood from the above, are different concepts. However, in further discussion, the term 'object' will designate its model.

The input parameters of an object are the function of the (angular or linear) relocation of the object preceding it (φ_{i-1}) and external loads W_i on this object (e.g., forces and moments of friction, constructional and technological ones). The output parameter, respectively, is the function of the relocation of the output link. Properties are a set of constants determining the quantitative characteristics of the model corresponding to this object. Among them there are parameters of position functions and transfer functions (for the entrance link they are U_i and U_i'), elastic-inertial and dissipative characteristics. Response, which is in fact an output parameter, is the influence of elastic forces R_i and dissipation forces R_{b_i} in the first fragment of the entrance link on the previous object. Disturbance is a response from the following object(s) to the influence of the given object.

3. Computer simulation of dynamic processes in mechanical systems

The system of computer simulation of dynamic processes in mechanisms has been developed in order to decrease the labor intensity of dynamic research of mechanical systems and to increase their reliability. It is based on methods of solid-state modeling [6], methods of component modeling and of object-oriented technologies [4, 5].

The complex of programs combined in a single system (*dam* – dynamic analysis of mechanisms) includes a number of modules the basic of which is as follows:

1. The creation and opening of the project. A project is a specifically organized set of various files storing information on objects, connections among them and their parameters, as well as the description of the mechanism being researched.

2. The constructor of an object model allows the user in the interactive mode to create an object model of the mechanical system using the database of the existing object models of standard mechanisms and their elements.

3. Modules of input, editing and testing object parameters. The characteristics of these modules (their number is equal to the number of objects) are:

- Determination of the number of masses (complexity) of the model and the output weight. Already at the stage of determining the parameters of the object, its dynamic characteristics, those depending on the complexity of the model, as well as those at different values of its elastic-inertial parameters in the field of their acceptable values can be determined. In fact, such procedure makes it possible to substitute the natural experiment with the numerical one and, thus, to check “experimentally” each of the objects of the object representation of the mechanism for “high quality”, which to some extent removes the question of the reliability of the results of dynamic research in the *dam* system.
- Input of elastic-inertial and dissipative parameters of the model. The values of these parameters can be determined with a sufficiently high accuracy in designing the mechanism in a system of solid-state modeling [6].
- Availability of the library of standard position functions making it possible to realize the following scheme of the ideal movement of the object’s entrance link in various options: rising (forward stroke) – upper dwell – lowering (reverse stroke) – lower dwell.
- Data input on gaps and manufacturing errors.
- Wide opportunities for determining the functions of external loads for each mass of the dynamic model of the object and their division into three groups: friction forces, constructional and technological loads.
- Storing various versions of data separately according to elastic-inertial characteristics, position functions, gaps, manufacturing errors, and external loads for each object.
- A possibility to test the entered data.

4. The dynamic analysis of the mechanism. This module of the application is a set of dynamic models corresponding to the object representation of the mechanism; it transforms systems of differential equations into the mathematical model, solves them with certain results. A reference should be made to wide opportunities in connection with the object data management:

- Managing the productivity of a mechanism.
- Excluding (or changing) different types of loads, dissipative forces, gaps from the simulation model during their calculations.
- Determining the reliability and operability of the mechanism (or its separate object) by a number of criteria and graphic dependences.
- Preserving the results for the purpose of their further comparison in selecting the most rational constructive decision at the stage of designing the mechanism.

4. Practical application of modeling dynamic processes in the *dam* system

Figures 1 and 2 present a solid-state model of the transfer mechanism of the AB1818 cold upsetting machine and its object model created in the *dam* system.

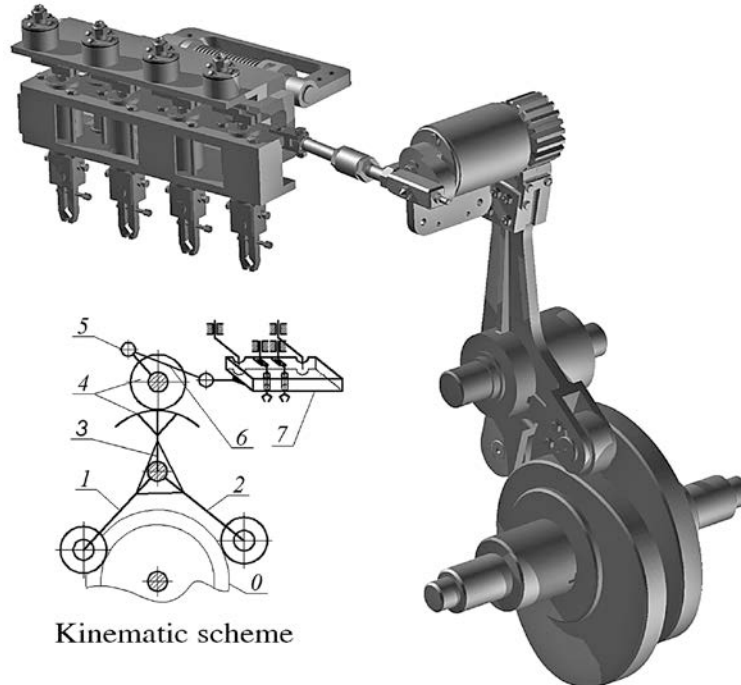


Figure 2. The transfer mechanism of the cold forging machine
(a solid state model and a kinematic scheme):

0 – cam unit, 1, 2, 3 – direct and reverse strokes levers, 4 – gear transmission, 5 – crank, 6 – rod, 7 – transfer carriage

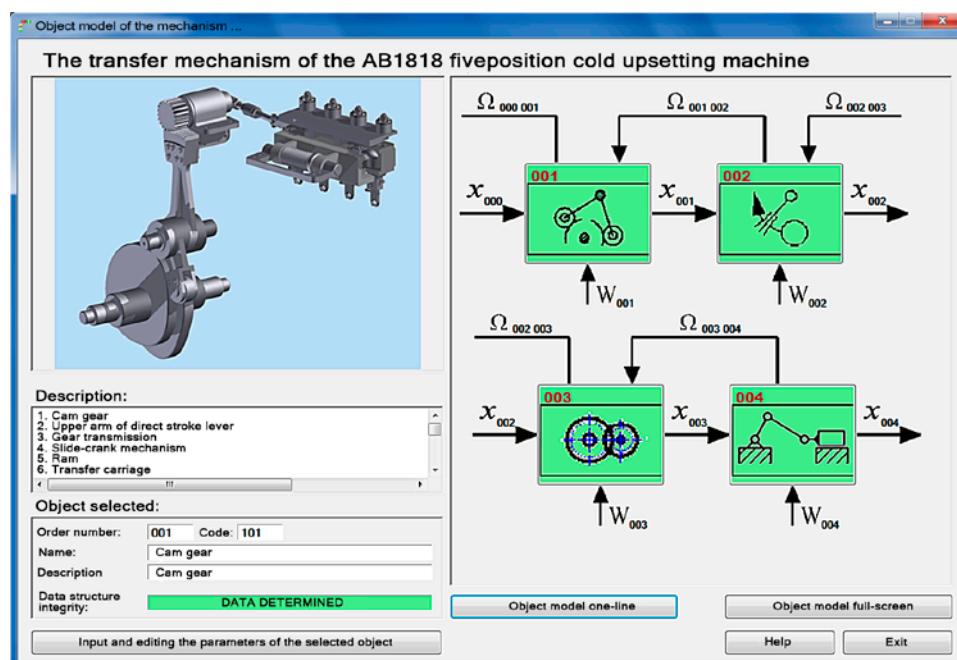


Figure 3. An object model: a constructor of the object model (a render window)

Figure 4 shows a render window for the research of the dynamics of the transfer mechanism of the cold forging machine. What is determined here is the researched object - in Figure 4 it is the slide-crank mechanism of transferring the carriage, the operation speed of the mechanism, its mode of work (single-stroke or automatic), the initial and final positions of the input link. Values of these objects: a number of masses, kinematic, elastic-inertial and dissipative characteristics, loads, parameters of gaps and the manufacturing error are assigned to development of the object model of the mechanism. Some of these data (gaps, manufacturing errors, forces of dissipation and friction, constructional loads and technological efforts) can be excluded from the modeling process.

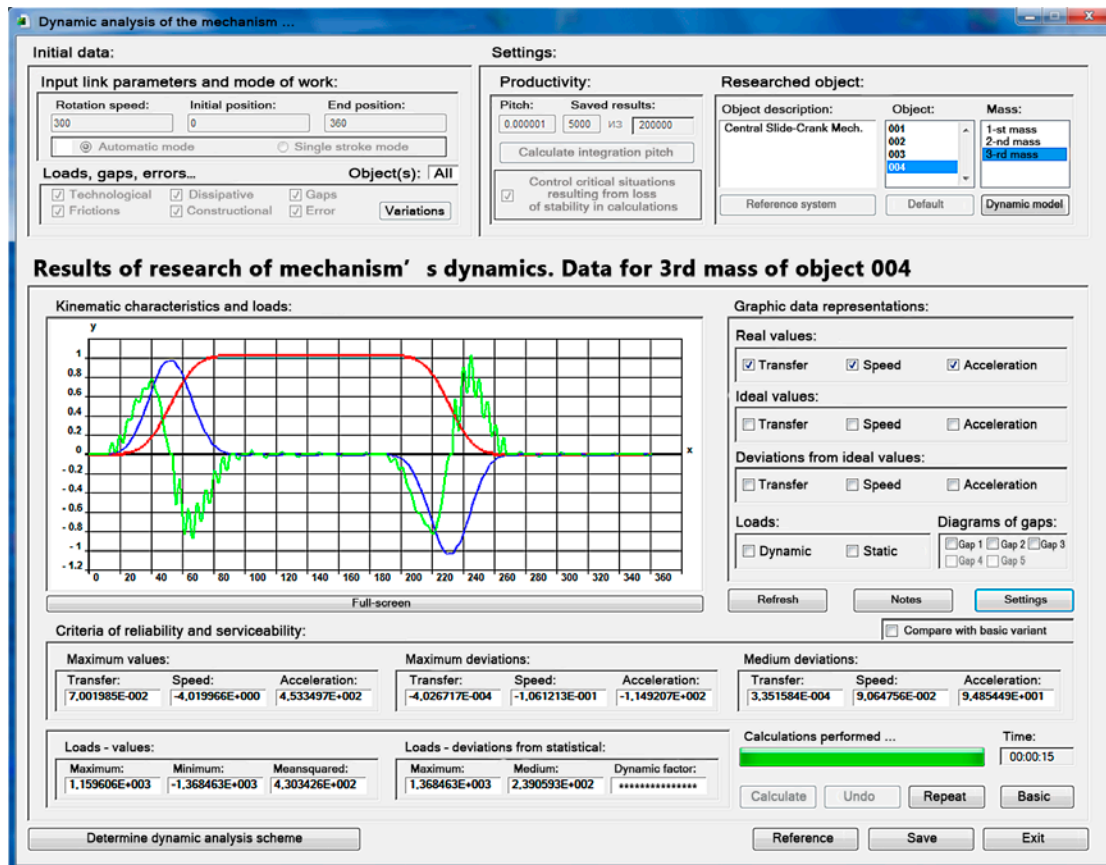


Figure 4. Research of mechanisms' dynamics in the *dam* system

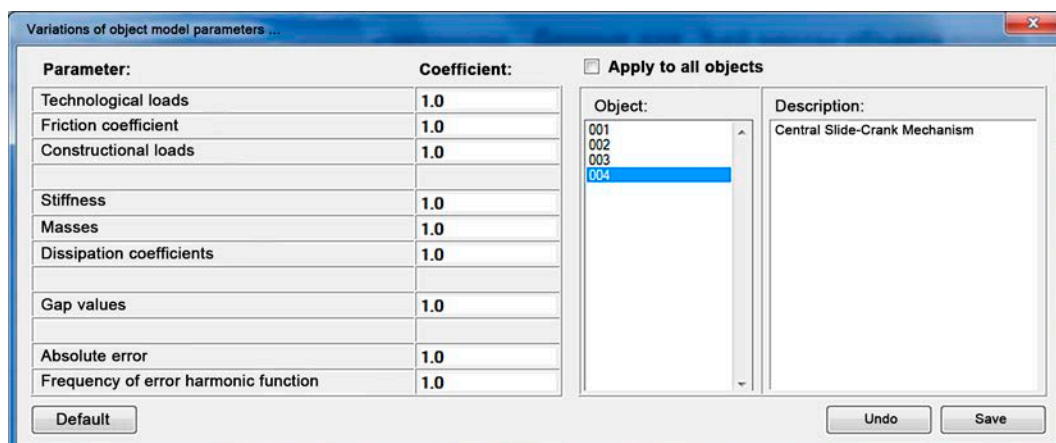


Figure 5. Variation of the object model's parameters

In constructing the strategies of simulation modeling, it is also possible to change the values of most object parameters in the 'Variations of Object Model Parameters' window. Variation possibilities for object model parameters, as is seen from Figure 5, are rather great.

The dynamic analysis of the mechanism is not only the calculation of its kinematic parameters, loads and generalized criteria of quality, but also the tasks connected with forecasting dynamic characteristics depending on the change of external and internal influences and conditions [5]. The realization of similar tasks is possible in the same window ('The dynamic analysis of the mechanism') by means of the button switch 'Determine the dynamic analysis scheme'. The system of the dynamic analysis of the mechanism suggests that the user determine one of 18 types of research each of which is the automation of the dependences construction of the following type: criterion (Y-axis) – changeable parameter (X-axis). After calculations it is possible to determine any of the ten criteria of the quality and to construct corresponding dependences.

References

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