1. Jozef STEINHAUSER, 2. Milan NAĎ

PRINCIPLES OF MODELLING OF MACHINE AGGREGATES

1-2. Slovak University of Technology, Faculty of Materials Science and Technology in Trnava, Department of Applied Mechanics, SLOVAKIA

Abstract: Modelling of machine aggregates requires systematic approach. There is no general agreement about the definition, structure and classification of subsystems of machine aggregates. In the present paper general principles of modelling of machine aggregates are outlined. Machine aggregate is treated as complete integration of electronic control subsystem, electric driving subsystem and mechanical working subsystem.
Keywords: machine aggregates, modelling, integration

INTRODUCTION

The machine aggregate in Fig. 1 represents dynamic system to drive a plant and to control the technological process and displays schematics of a modern controlled system. There are three subsystems:

Ξ the (electric) drive, i.e. the (electro)motor and the gear,

Ξ the driven mechanical equipment that represents equipment for electromechanical energy conversion, the actual technological process and the product of the process ,

Ξ the control system performing an optimal control of the machine aggregate.
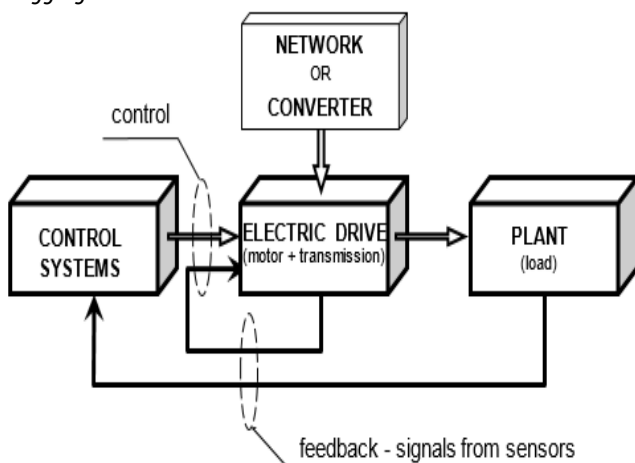

Figure 1. Block diagram of the machine aggregate.

By the quality of the machine aggregates, i.e. by the static or dynamic characteristics of the subsystems are assigned the productivity of the process, the quality (operational stability, accuracy, speed) of the process and the product as well as the static/dynamic loading of the aggregate mechanical, electrotechnical and electronical units. Also the level and type of mechanical load, accuracy of gears, characteristics of drive and control, overall quality etc. obviously influence the motor and control performance conditions [1], [2].

MACHINE AGGREGATE – STATE OF THE ART

A machine aggregate and its intended control functions respecting the mutual energetic interaction of subsystems consisting of:

Ξ supply and power converter of some kind,

Ξ electric AC or DC drive with proper kind of electromotor,

Ξ a plant subsystem,

Ξ control electronics (analog or digital, if digital than programmable microcontroller system).

All but the last subsystems are power subsystems. The control subsystem is an information subsystem. Hence, from another point of view, a machine aggregate is an integration of following subsystems:

Ξ power electromechanic system of machine aggregate and plant generating the torques and forces needed by the process, under prescribed speed, position etc.

Ξ energy supplying power electronic system modifying the electrical energy constant parameters of the primary sources to values of the converter postulated by the process,

Ξ information control electronics.

The power electromechanic system together with the energy supplying power electronic system performs an electro-mechanical energy conversion. The goal is an optimal control with respect to the technological process or the dynamics of the aggregate as a whole.

Machine aggregates with controlled drives often need a multi-level hierarchical control. In the basic level of, say a speed system, the angular speed of the motor/drive is controlled by a speed controller, perhaps with the aid of a subsidiary current controller [3].

The control of both current and speed loop controllers can be designed starting with the current controller at the most internal loop in a number of ways. To design the position control systems, the speed control system with speed feedback loop designed above becomes subsidiary to a position control loop. Cascade, parallel and feedback groupings of

controllers are available, just to refer to some of the design procedures. In the higher control levels of technology control, operational quantities/parameters are managed, with the goal to keep the conditions of the process optimal. The system approach finds machine aggregate to be merely a subsystem, which is internally controlled part of the whole system, see Fig. 2.
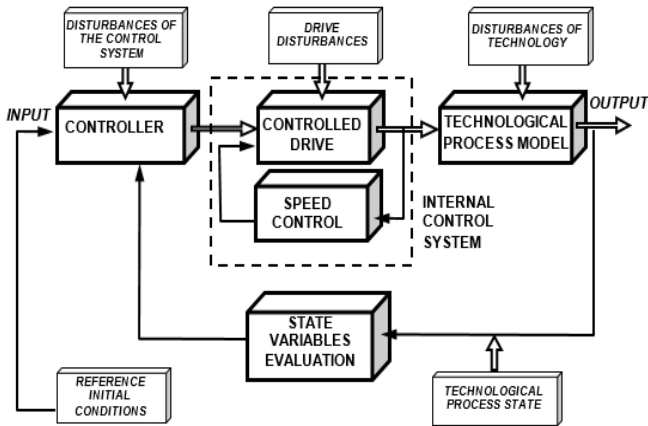

Figure 2: Detialed block scheme of machine aggregate.

Then the machine aggregate MA is an integrated system consisting of three subsystems: electronic control subsystem ECS, electric driving subsystem EDS and mechanical working subsystem MWS. The integration covers design, construction, operation and maintenance with respect to optimal static as well as dynamic attributes of the MA:

Ξ ECS performs the optimal control of the MA heading the MA objectives: product or/and process,

Ξ EDS is an energy electric-to-mechanic converter,

Ξ MWS executes the final production or process, following the MA objectives.

MODELLING THE MACHINE AGGREGATE

Transition from a real machine aggregate to its model is only possible if ideas on the goal of the system, on the states of the system, on the foregoing analysis, on specification of characteristic features for the designed functions of the system are taken into the consideration. There are lot of cases, when the model and simulation are the only way to get some knowledge. Two main aspects of the approach to the task are:

Ξ creating a proper model (Modelling)

Ξ working properly with the model (Simulation).

Writing the mathematical model in a mathematical form is the first step and is deduced from the proper theory of the investigated subject, namely from known physical laws from all the relevant branches.

The next step is writing the model code as a package of main program and supporting subprograms, using the results of the first step. After the verification of the main program and the whole program package, simulation experiments follow as the step three. The fourth step is verification of the results of the previous steps, probably using some kind of experimentation with physical models, or experimentation with the real object or process modelled.

Synthesis of computational and experimental methods is the basis for modern experimental work and is the most effective method for analysis and synthesis of machine aggregates.

The whole sequence to create a machine aggregate mathematical model as described above has three parts:

1. Modelling of energetic interactions among the subsystems

Ξ Formulate in natural language and describe mathematically all the individual construction parts of the machine aggregate and interactions among them (Fig. 1).

Ξ Create the main program based on the previous point and the subprograms for the main program.

Ξ Perform identification measurements on the model, i.e. perform the simulation experiments and postprocess them. Make statement, how truly the model substitutes the real object/process. Understand the numbers, tables, graphs etc. generated, describe the results in the natural language.

Ξ Make an expert opinion on the model. The goal is to get the best possible working and simple model of the reality. The quality of the model depends on the quality definition, as an example the quality might be a compromise between the best possible stability of the model, its minimal computational time and accuracy of results.

2. Reducing the model to formulate the control laws

Ξ Create a linearized model of control, say, for the machine aggregate with working point shifted within a small displacement zone.

Ξ Create a linearized model in the working part of the torque-speed characteristics.

Ξ Create a nonlinear model by the constants assigning method for the nonlinear model using the regression principle.

3. Creating the control law

Verification within the validity area of the reduced model is based on simulation experiments. Numerical or analytical simulation is optional, depends on the CAMS program (program system, package) in use. The MATLAB can work analytically but perhaps its main domain is the discrete simulation. The MATHEMATICA works analytically. As for the dynamic modelling and simulation, the key view is whether the integration of differential equations describing the machine aggregate is performed by symbolic or numerical integration.

The recent works in the machine dynamics deal mainly with discrete parameters, lumped mechanical system models and also with FEM models. Let us have a look into the recent decades to display what is to be done in next ones. The recent works of experts in drive systems treated in-depth the phenomenon of their own, while the mechanics of the plant was treated with a reasonable overlap of both branches. The same is valid for the experts in mechanics. As for experts in control, this branch is rich in experts and literature, both in analogue and digital types of control. Even in well done works from electrical (controlled) drives the mechanical subsystem has been assessed and modelled with reduction to single or two rotating bodies, using an ordinary differential equation of the 1st or 2nd order [4].

Some very specific problems emerge due to the above conventional approach to predominantly machine aggregates. One of them is the time constant: The shortest time constants of a common control subsystem

may be in units of 10^{-3} sec. The shortest time constant of a electrical part of the drives is within orders 10^{-2} - 10^{-1} sec, while for usual mechanical subsystem may be within orders 10^0 - 10^1 sec. This difference is the source of compatibility problems even for machine aggregate with the most trivial control subsystems. Future research and models have to develop means to cover the mismatch at time constants of physically different subsystems.

CONCLUSION

The structure and principles of modelling of the machine aggregate was analyzed, respecting the interdisciplinary nature of individual steps leading to final global model of machine aggregate as well as respecting the interactions between mechanical and control parts of the drive and the parameters of the plant.

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