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FROM MONITORED VALUES TO THE MODEL CREATION OF THE DYNAMIC SYSTEM

OD MONITOROVANÝCH HODNOT K TVORBĚ MODELŮ DYNAMICKÉHO SYSTÉMU

Abstract

Current information technology allow sensing and processes data recording under severe conditions of operation with new technical means in real time, storing the measurement data, its processing and evaluation in situ or in the laboratory [1]. An example would be the monitoring system boring machine-rock used in tunneling Branisko. The monitored variables of the boring process were downforce of disconnecting head of boring machine, torque, speed of disconnecting head, the power consumption of the aggregate and the extended position of disconnecting head depending on the drilled length. These measured values allowed the creation of models, which help to modeling various properties of boring process within the meaning of Eykhoff definition: "A model is an expression of the essential characteristics of an existing object, which describes the knowledge of this object in a usable form" [2, 3].

Abstrakt

Současné informační technologie umožňují snímání, záznam a zpracování dat v náročných podmínkách provozu s novými technickými prostředky v reálném čase, ukládání, zpracování naměřených dat a jejich vyhodnocení v místě jejich sběru nebo v laboratoři [1]. Příkladem by mohl být monitorovací systém, který byl použitý při strojovém ražení průzkumné štoly tunelu Branisko. Monitorované veličiny procesu ražení byly přítlak rozpojovací hlavy razícího stroje, kroutící moment, otáčky rozpojovací hlavy, příkon agregátu a poloha vysunutí rozpojovací hlavy v závislosti na odvrtané délce. Tyto naměřené hodnoty umožnily tvorbu modelů, pomocí kterých můžeme modelovat různé vlastnosti procesu ražení ve smyslu Eykhoff definice: "Model je vyjádřením podstatných vlastností existujícího objektu, který popisuje znalosti o tomto objektu v použitelné formě "[2, 3].

Keywords

Model, modeling, planned experiment, optimization of the process.

1 INTRODUCTION

Boring of the Exploration gallery Branisko from the east took place with the help of full-profile tunneling machinery Wirth TB-II-330H/M. During tunneling the boring machine went through

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various geological formations. Tunnel tube was excavated simultaneously from both portals by New Austrian Tunnelling Method Technology (NATM).

2 MONITORED VARIABLES OF TUNNEL BORING MACHINE WIRTH TB-II-330H/M

Installation of a monitoring system for tunnel boring machine allowed its use as a research facility. Restrictions were the only Technical parameters and operating conditions. The examples of monitored variables courses depending on drilled length in the same section of boring are in Figures 1 to 4.

The each course shows that in general this are the random variables, depending on drilled length and with the known sampling rate fvz=2,03 s have different values.

In Figure 1 we can notice the course of the downforce of the boring machine head, which acts on the rock. In that section of monitored signal we can notice that the values oscillate in much of the range of values from 500 to 600 kN. The drilled length of rock at a distance of 144.68 m shows a rapid increase in the observed values of around 40 kN, representing start-up and downforce on the boring machine head. Its course in the part of the signal looks like a unit step.

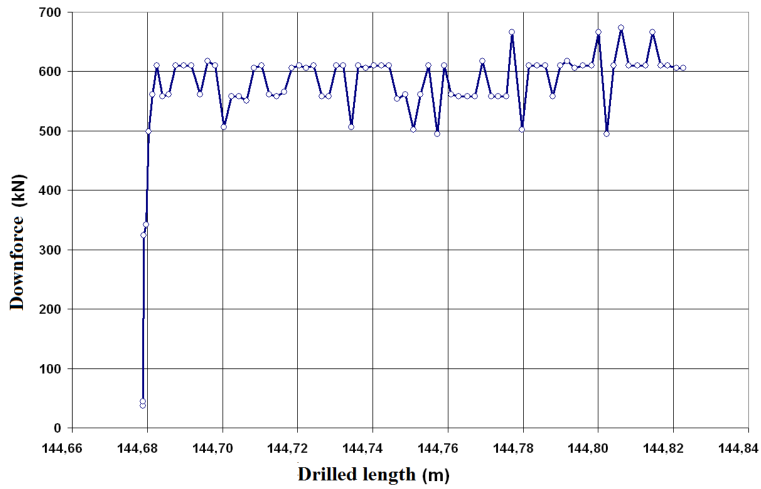

Fig. 1 The course of the part of monitored signal – downforce

In Figure 2 is the part of the signal of torque, which acts on the boring machine head. Its course oscillates in much of the observed signal in the range from 80 to 100 kNm in the amount of 144.68 m drilled length off watching the fall and subsequent rise in the signal value of 80 kNm.

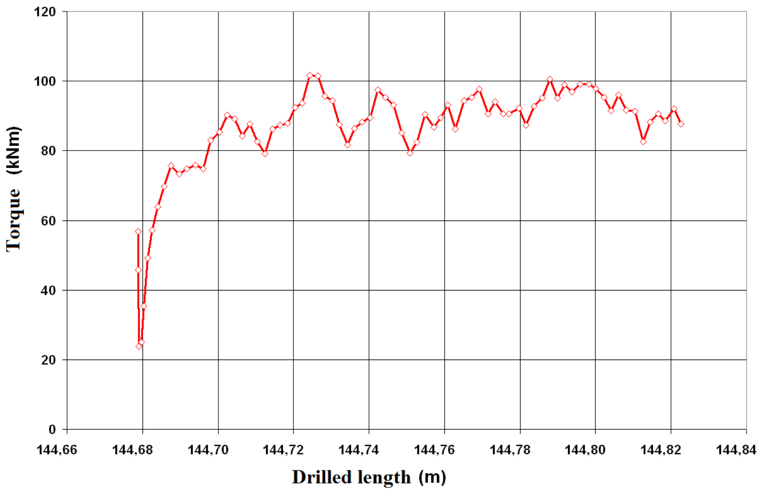

Fig. 2 The course of the part of monitored signal – torque

In Figure 3 we can see the course signal speed, which in large part oscillates around the value 0.00225 s-1 in the range of 0.0022 to 0.0023 s-1. Rapid onset and subsequent decline observed variable is explained by changing the applied downforce the boring machine head to the disintegration massif.

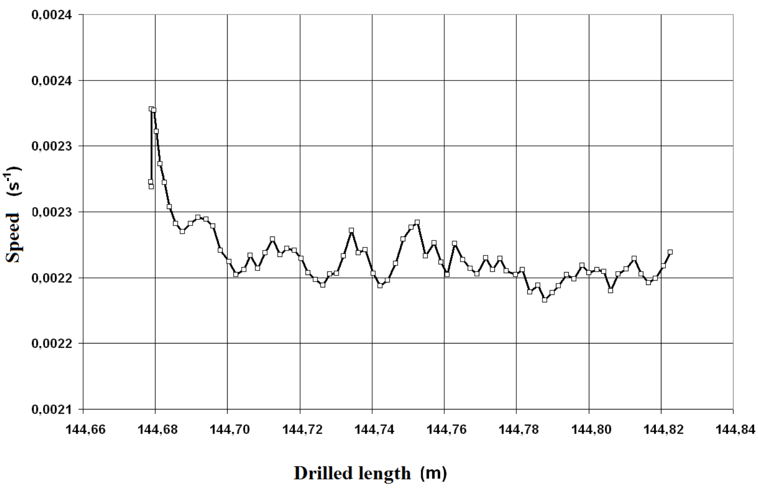

Fig. 3 The course of the part of monitored signal – speed

In Figure 4 is part of the signal, which represents a value of the force needed for rock massif disconnecting in each time period, respectively in the case of its integration mentioned course represents a work done at disconnection this outturn of rock, which is given by average of the boring machine head and a drilled length. The signal value is in the range of drilled length of 144,70 m to 144,82 m and oscilates around the value 9000 kW, merely around a drilled length of 144,68 m is possible monitor the sharp increase and decrease.

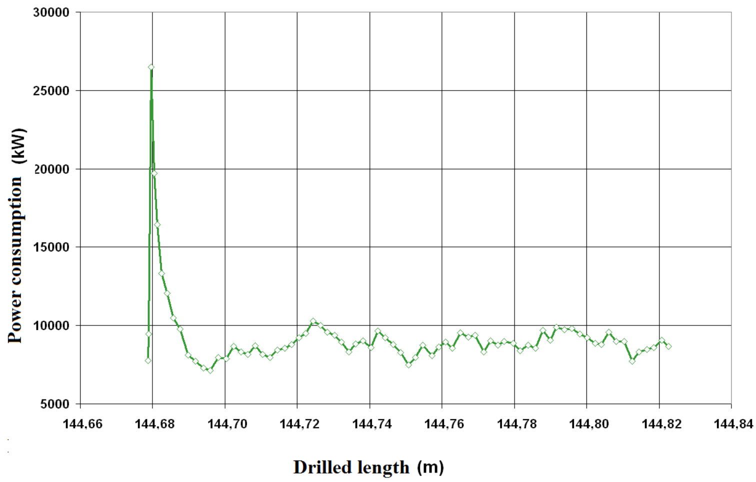

Fig. 4 The course of the part of monitored signal – power consumption

3 MATHEMATICAL MODELS OF SYSTEM BORING MACHINE - ROCK

In general, this system has q inputs and v outputs that can be described in the operating point and its vicinity by equations:

$$\mathbf{x}^{(1)}(t) = \mathbf{A}\mathbf{x}(t) + \mathbf{B}\mathbf{u}(t), \tag{1}$$

$$\mathbf{y}(t) = \mathbf{C}\mathbf{x}(t), \tag{2}$$

where: $\mathbf{x}(t), \mathbf{u}(t), \mathbf{y}(t)$ - mean state variables, input and output,

A, **B**, **C** - mean matrices with the appropriate dimensions.

The starting point for the system identification are measured values, it means inputs and outputs.

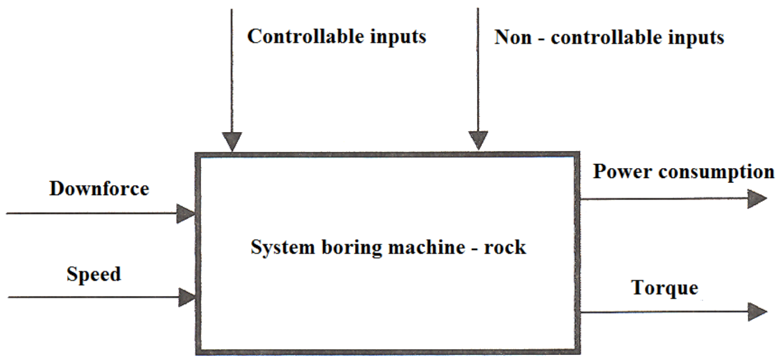

Fig. 5 System boring machine – rock inputs/outputs

In Figure 5 is displayed simply dynamic system boring machine - rock. As input variables we consider downforce and speed and output variables torque of the boring machine head and the power consumption depending on drilled length, respectively on time. Sampling frequency of signals is fvz = 2,03 s.

Dynamic model creating is based on the characteristics of the input signal downforce F, part of which can be considered as unit step. On the output side we monitor the course of the signal torque Mk, which contains information about the dynamic properties of the system as a result of changes in downforce on the input side of the model. (To simplify the model we neglect the input signal speed, respectively the output signal power consumption Figure 5).

Converted time course of output value Mk to a unit change in the input variable F is transient response. Given the complexity of the system it is impossible to make conclusions from a single pair of these realizations. For the examination of this system we use the medium probability course. Its principles is based on using of more realizations (repeated measures) for the resulting course specifying.

$$f_i = \frac{\sum_{k=1}^{N} sign(\Delta u_k) y_{ik}}{\sum_{k=1}^{N} |\Delta u_k|} , \qquad (3)$$

where fi - means ordinate the resulting transient response in the time t = iΔt and Δt is a period of sampling,

y_{ik} - means input, resp. output realizations,

k - means the value of the output variable response system in the *i* - th sampling interval at the *k*-th measurement a number of repeated measurements of transient response in general unequally large step input variable object,

Δu_k - means step change of the input variable by the k - measurement of transient response,

i - means an order of sampling points of transient response, i = 0, 1 ...m [4].

By the model creation according to equation (3) is important to elect appropriate number of repeated measurements. Its final number is given by statistical and physical regularities of investigated system. The examples of these courses we can monitor in Figure 6.

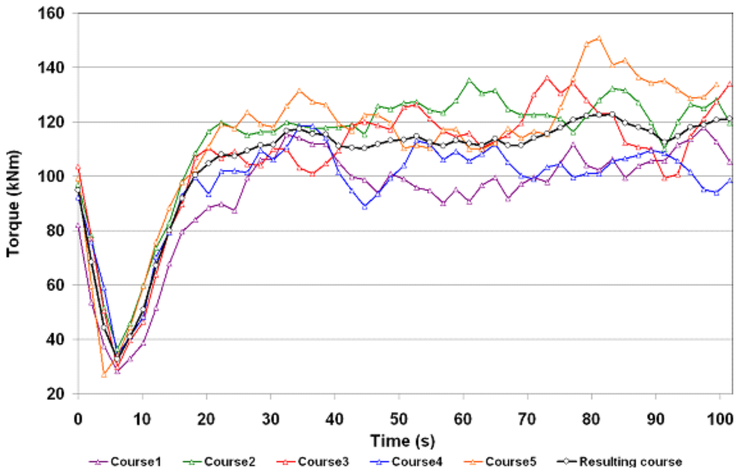

Fig. 6 The courses of transient responses of the repeated measurements and resulting statistical model

Listed resulting statistical model is possible to substitute by approximation - the simplest differential equation of first order without, respectively time-delay. An example of this approximation we can monitor in Figure 7.

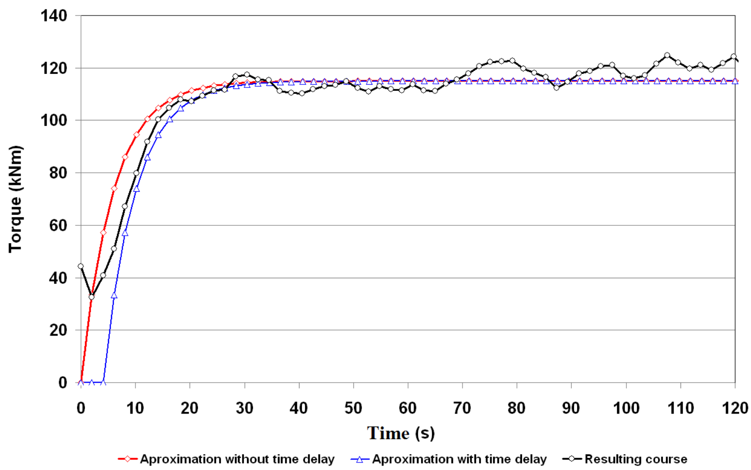

Fig. 7 The model without time delay and the model with time delay

Monitored variables allowed application of Box evolution method of planning by monitoring of two input variables (factors), which were kept approximately on the constant level to the system: downforce and speed. The Figure 8 shows two-dimensional cut of the surface, where output variable (monitored indicator) has another method of measurement and physical interpretation. According to used graphical interface, the isolines are substitued by square (quadratic) grid structure, which division is given by process values. The arrow indicates the direction of progress towards optimum in this case the minimum energy consumed in the process of disintegration.

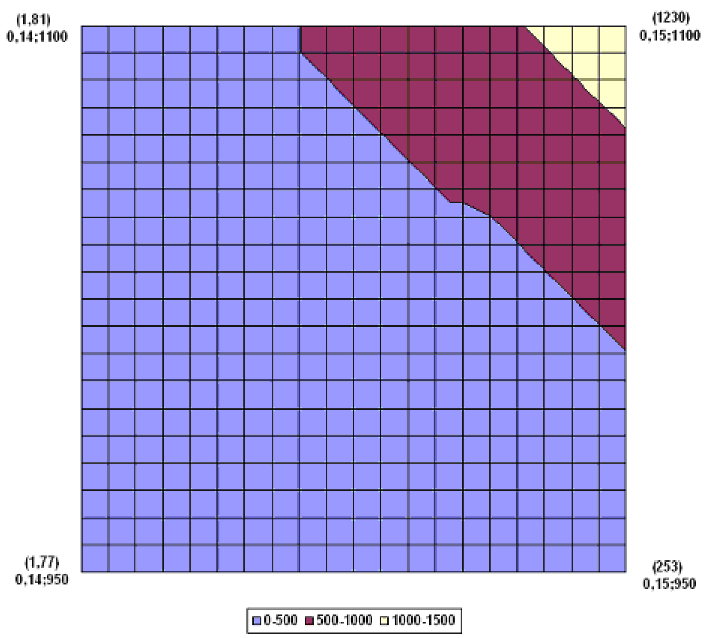

Fig. 8 An application of Box method in the process of tunnel boring machine - rock

4 CONCLUSIONS

1. For editorial limitation article only briefly describes some graphical and mathematical models of system boring machine - rock. It is largely the models, that serves for the investigation of the dynamic properties of the system.

2. By model creating an important role has their accuracy, which is determined by the purpose (aim) for which they were created. An example of such a model is the median probability course according to equation (3), which forms the basis for all other additional models.

3. For quantitative evaluation of the quality of the model, we can use a criterion that describes monitored part of the model in an appropriate way. For the models mentioned in the article are used the integral criteria that takes appropriate account of the whole monitored course.

4. The models based on Box method describe the synergetic effect of two input variables on output variable and allow monitoring visual approach towards the optimum.

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