# Numerical modeling of disintegration process dual control

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Abstract
The instance of ore material disintegration dual control is described in the article.
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In [1] the analysis of the main components of the technological variables base was held for the following model development. As a result, the following components were selected: water flow into the mill, average mill productivity, processed iron ore.

Because of this the decision to use these variables was accepted.

The approaches ([2, 3]) to build the models of disintegration technological process that are used in present are the parametrical ones. That means they involve some process and/or equipment parameters (e.g. time responses, lag factors, some coefficients etc.)

For disintegration process such parameters depend on the ore type, the degree of equipment mantle wear, degree of its filling, volume of feed water and ore material etc.These parameters are usually difficult to estimate because of their frequent parameters changing immediately during technological process.

According to the above-mentioned reasons the building of global (in the sense of time and space of process dynamic parameters varying) model is not conceptually possible. The model parameters and its structure have to be able to vary adapting to the current operating conditions. In other words, on each control interval the model should be able to be corrected (updated). When doing this it is desirable not to maintain any testing effects, which may affect the technological process operation. One of these approaches is to use the dual approach [4,5].

To realize the approach the non-parametric dual model of the process was built [6] for one input and output. This model can be generalized according to arbitrary number of control object inputs and outputs without applying any principal changes.

Let’s briefly explain the main idea of achievement of dual model for two inputs (water, ore material) and one output (operating productivity), basing on the work [1]. Namely these technological parameters were defined as main components that affect the properties of disintegrating process model.

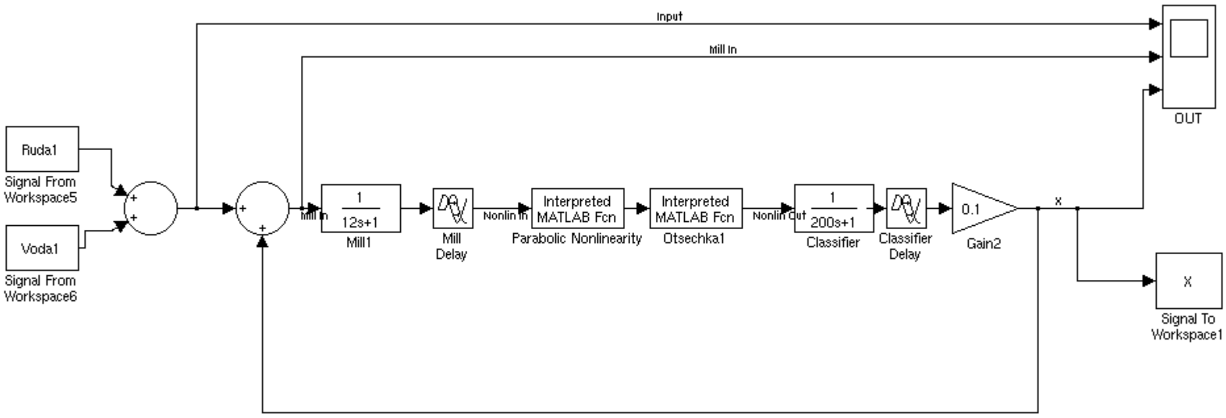


**Figure 1.** Milling process imitation model flowchart

The imitation model of milling process was built (fig. 1).

Blocks used in fig. 1:

- Ruda1, Voda1 – ore and water input signals correspondingly;
- Mill1 – aperiodic link representing the mill itself;
- Mill Delay – block that realizes time lag connected with the time when the material is inside the mill;
- Parabolic Nonlinearity – the block representing the mill static characteristic;
- Otsechka – service block that realizes the output negative values cut-off;
- Classifier – aperiodic link that represents the classifier model;
- Classifier Delay – classifier delay;
- Gain2 – gain constant.

Based on the literature data [4], [5] the main parameters of the model were set. Previously the check of such model functioning logic was held and the adequate behavior was achieved. Next, the technological variables measuring processes without interference into the process itself were simulated. This data was used to build the process extended matrix.

Below the description of applying the dual control approach when derivating the formula for calculating the control action for the simple first-order control object is brought.

$$\begin{matrix} X[i] & X[i-1] & U[i-1] \\ X[i-1] & X[i-2] & U[i-2] \end{matrix} \qquad (1)$$

When multiplying the second row (2) by $\frac{X[i]}{x[i-1]}$ we achieve the following:

$$X[i] \quad X[i-2]\frac{X[i]}{X[i-1]} \quad U[i-2]\frac{X[i]}{X[i-1]} \qquad (1)$$

To equate the first element by 0, we subtract the first row of the base expression from (3). We achieve:

$$0 \quad X[i-2]\frac{X[i]}{X[i-1]} - X[i-1] \quad U[i-2]\frac{X[i]}{X[i-1]} - U[i-1]$$

(4)

Let’s designate the second element of expression (4) as $X'[i-2]$; the third one as $U'[i-2]$

Let’s multiply the first row of the base expression by $\frac{X[i+1]}{x[i]}$. We achieve:

$$X[i]\frac{X[i+1]}{X[i]} \quad X[i-1]\frac{X[i+1]}{X[i]} \quad U[i-1]\frac{X[i-1]}{X[i]} \qquad (5)$$

Thus, the 1st element of achieved expression equals to $X[i+1]$. Next, to get the expression for $U[i]$ from the row being achieved, let's take the second element of this expression (we designate it as $X''[i-1]$) to $X[i]$. For this purpose let's introduce a concept of coefficient $D$, which can be achieved from the expression:

$$X''[i-1]-X'[i-2]*D=X[i]\Rightarrow D=\frac{X''[i-1]-X[i]}{X'[i-2]}$$

Let's multiply (4) by $D$:

$$X[i]\frac{X[i+1]}{X[i]} \quad X[i-1]\frac{X[i+1]}{X[i]} \quad U[i-1]\frac{X[i-1]}{X[i]} \qquad (6)$$

When subtracting (5)-(6) we achieve:

$$X[i+1] \quad X''[i-1]-X'[i-2]*D \quad U''[i-1]-U'[i-2]*D \qquad (7)$$

Let's consider the element 2 of expression (7):

$$X''[i-1]-X'[i-2]\frac{X'[i-1]-X[i]}{X'[i-2]}=X[i]$$

As a result, we obtain the status row on the next interval:

$$X[i+1] \quad X[i] \quad U''[i-1]-U'[i-2]*D$$

The third element of this row equals $U[i]$:

$$U[i]=U''[i-1]-U'[i-2]*D$$

So,

$$U[i]=U''[i-1]-U'[i-2]*D$$

$$U''[i-1]=U[i-1]\frac{X[i-1]}{X[i]};$$

$$U'[i-2]=U[i-2]\frac{X[i]}{X[i-1]}-U[i-1]$$

$$D=\frac{X[i-1]-X[i]}{X'[i-2]}=\frac{X[i-1]\frac{X[i+1]}{X[i]}-X[i]}{X[i-2]\frac{X[i]}{X[i-1]}-X[i-1]}=\frac{X[i-1]X[i+1]-X^2[i]}{X[i-2]X[i]-X^2[i-1]}\frac{X[i-1]}{X[i]}$$

After substitution of corresponding expressions for $U''[i-1];U'[i-2];D$, we achieve:

$$U[i]=U[i-1]\frac{X[i-1]}{X[i]}-\frac{(U[i-2]X[i]-X[i-1]U[i-1])*(X[i-1]X[i+1]-X^2[i])*X[i-1]}{X[i-1]X[i]*(X[i-2]X[i]-X^2[i-1])} \qquad (2)$$

Expression (9) is the required formula of control action. In the expression (9) the variable $X[i+1]$ is the set point $Xzad$. As a result, after making corresponding substitutions, we achieve:

$$U[i]=U[i-1]\frac{X[i-1]}{X[i]}-\frac{(U[i-2]X[i]-X[i-1]U[i-1])*(X[i-1]Xzad-X^2[i])*X[i-1]}{X[i-1]X[i]*(X[i-2]X[i]-X^2[i-1])} \qquad (3)$$

Here it is necessary to mark, that for the task set in this article dual approach calculated for two inputs and one output is used.

The extended matrix (expression (1)) is refreshed on each control interval and doesn't contain neither parameters of any kind nor obvious structure (like differential or difference equations, transfer functions) of control object, like traditional methods do. Per se namely this matrix is the dual non-parametrical model of the process. Originally it doesn't contain information about object non-linearity that changes its characteristics continuously. Namely the refreshing of the model due to the using of dual approach allows to include the current control object behavior, information about which is almost fully contained in the extended matrix as in the data source about the technological process state.

Control object values calculated in this way were input into the imitation model. The corresponding results are shown below.

The productivity set point (*Pin*), the actual mill productivity (*P*), the control signal (*U1*), the mill filling value (*H*) and the optimum mill load indicator (*Optimum*) as well as the graph of increment index ($K_{npup}$) are shown in fig. 2 correspondingly from top to bottom. With the help of arrows 1, 2 i 3 the points where the type of mill static characteristic were changed.

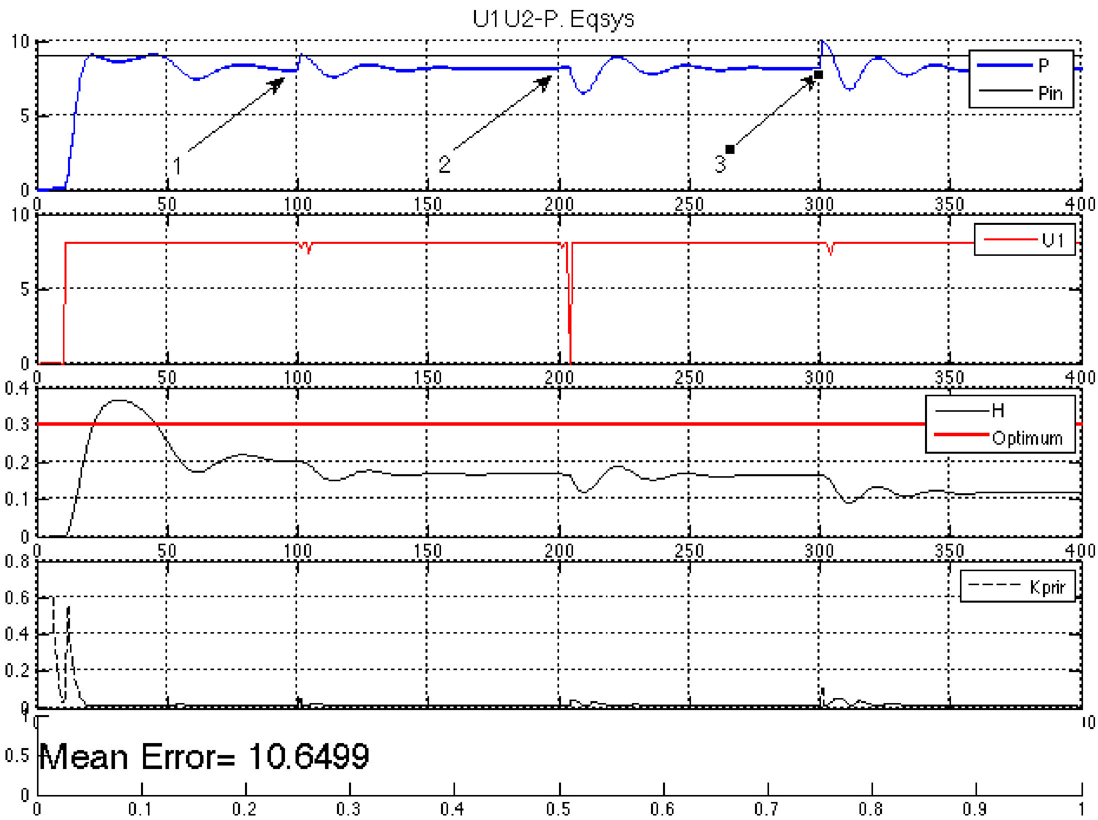


**Figure 2.** Mill productivity graph

According to fig. 2 it is possible to estimate that the dual regulator successfully manages the task of keeping the mill function productivity on the optimal level according to the current character of mill static characteristic, even during mill overfilling and overrunning the value of its productivity behind its static characteristic optimum limits.

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