

EXPERIMENTAL MODELING OF PRODUCTIVITY WHEN PROCESSING WITH ABRASIVE MAGNETO-RHEOLOGICAL MEDIUMS

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Abstract: One of the forms accomplished and developed by the rheological abrasive mediums are the magneto-rheological abrasive mediums. These mediums are based on the capacity of the magnetic field to act upon some abrasive grains with a force greater enough to compact them and create abrasive actions. There is used a chemical solution - a mixture of magnetic field, magnetic fluid and non-magnetic abrasive materials, which, according to the principle of magnetic levitation induce ascending forces which can be use as splintering forces. The action of the magnetic field on the abrasive grains consists mainly in the concentration and leading of the abrasive grains on the manufactured area. The energy of the magnetic field and the relative movements in the process determine a mechanical splintering. The authors propose in this paper is to develop an experimental model for determining machining productivity.

Keywords: modeling, levitation, rheological abrasive medium, experimental modeling.

1. INTRODUCTION

The usefulness of analytical models elaborated on various technological processes is mainly gnosiological because their appliance in solving a practical problem is laborious and difficult.

This difficulty is created both by the amount of influent factors **IF**, which describe complex interactions and the hypothesis adopted which sometimes, due to their simplicity are getting far from real facts involved in the current analyzed system. Thus, it was considered that the most reasonable way to follow is to elaborate analytical models that are relatively simple, but able to provide reasonable fidelity of achieved data for using it on experimental modeling.

2. PROBLEM FORMULATION

The use of the factorial experiment on technological processes modeling represents one of the most efficient methods of experimental modeling.

The main objectives of experimental modeling of productivity when processing with abrasive magneto-rheological mediums (**AMRM**) are:

- achieving experimental models providing such highly fidelity that the

estimations made using them can be used in technological purpose;

- achieving some experimental values for the purposed analyzed functions, that can allow comparisons with the estimated values from the analytical values presented in the previous chapter, to verify the their adequacy.

Fulfillment of these objectives is sustained by a specific reasonable programming of experiments, which for processing with cu **AMRM** is the following:

- preliminary experimenting to determine significant **IF** for analyzed technological processes, and their required technological values;

- for maximum importance **IF** obtained, experimental determining of regression equations for analyzed objective functions (**OF**);

- based on the elaborated experimental models, choosing **IF** domains or values that ensures the optimization **OF** when an optimizing criteria is specified.

3. EXPERIMENTAL DESIGN AND CONSTRUCTION

Experimental modeling requires to follow the stages below [1], [2], [3]:

a) establish the experimental range, which consists of establish the base level (the experimental central point) and establish the variation range of each **IF**;

b) building the program - matrix of experiments and run the experiments;

c) determining the mathematical model of objective function inquired, which consists of choosing the type of the mathematical model (usually polynomial), calculation of regression coefficients with explicit quantitative mathematical model adopted and statistic analyze of the obtained model, which consists of experimental errors estimation, verifying statistical significance of regression coefficients and verifying adequacy of **OF** values calculated with the empirical model, with the **OF** real (measured) values.

The calculations are much facilitated by the existence of high-performance software. One of them is the software *STATGRAPHICS* [2] which was used for experimental data processing.

After the preliminary experiments and the ones referring to the abrasive capacity of

AMRM the following significant **FI** have been set for these measures:

- $X_{F1} \Leftrightarrow n$ [rot/min] - **PO** (processing object) revolution;
- $X_{F2} \Leftrightarrow g_a$ [μm] - abrasive's granulation;
- $X_{F3} \Leftrightarrow R_{ai}$ [μm] - initial roughness of the processed surface;
- $X_{F4} \Leftrightarrow C$ [%] - **AMRM** concentration.

As **OF** for processing with **AMRM** it was set the function $Y_{S1} \Leftrightarrow Q_p$ [g/min] - processing productivity, which identifies the material quantity sampled per time unit;

Table 1 shows the coordinates of the central point of experimentation, upper and lower level values, and also the variation range of **IF**, X_{F1} , X_{F2} , X_{F3} , X_{F4} .

The specific program – matrix of composed factorial experiment and centered second order Box-Wilson with four **IF** and also the measured values of **OF** $Y_{S1} \Leftrightarrow Q_p$ are shown in table 2.

Table 1. IF shape values and productivity levels.

Parameter	Code	Physical values			
		$X_{F1} \Leftrightarrow n$ [rot/min]	$X_{F2} \Leftrightarrow g_a$ [μm]	$X_{F3} \Leftrightarrow R_{ai}$ [μm]	$X_{F4} \Leftrightarrow C$ [%]
Higer level	+1	900	100	12,5	35
Lower level	-1	355	20	1,6	6
Central point	0	627,5	60	7,05	20,5
Positive jib	$+\alpha$	1172	140	17,95	49.5
Negative jib	$-\alpha$	82.5	12	0,51	3,1

Processing results was made using *STATGRAPHICS* software based on the methodology from the speciality bibliography [1], [2]. For **OF** $Y_{S1} \Leftrightarrow Q_p$ and $Y_{S2} \Leftrightarrow R_a$ the following were determined:

- **FI**'s influence and significant second order interactions;

- searched experimental model coefficients, determined for coded values of the **IF** for the two **OF**'s (table 3); experimental model is a second order polynomial usually having the following form:

$$Y_{F1} = b_0 + \sum_{j=1}^4 b_j \cdot x_j + \sum_{\substack{u,j=1 \\ u \neq j}}^4 b_{uj} \cdot x_u \cdot x_j + \sum_{j=1}^4 b_{jj} \cdot x_j^2$$

- histograms of effects, which reveal the variation amplitude values of **OF** made when **IF** is going between lower level and higher level;

- comparing measured values with those estimated using polynomial model found (fig.1) estimated to an accuracy of 93,5 %.

For all possible combinations of **IF** grouped by twos, response **OF**'s surfaces were drawn

4. CONCLUSIONS

Analyzing all the results obtained from processing experimental data, the following conclusions can be drawn on processing productivity with **AMRM**:

- second order polynomial models obtained after completion of second order factorial experiments are adequate to estimate response surfaces corresponding to the experimentally investigated, so they can get a good estimate of productivity in the manufacturing process;

- for the prime importance there are: quadratic terms of initial roughness and the grain, the second-order interaction between roughness and initial concentration, granulation and revolution, are

inversely proportional to **OF** $Y_{S1} \Leftrightarrow Q_p$ and initial roughness with linear term, which is directly proportional to **OF** $Y_{S1} \Leftrightarrow Q_p$;

Table 2. Matrix-modeling program productivity

Nr. crt.	IF values coded (physical)				OF Values $Y_{S1} \Leftrightarrow Q_p$ [g/min · 10 ⁻³]
	X_{F1}	X_{F2}	X_{F3}	X_{F4}	
1	-1 (355)	-1 (20)	-1 (1,6)	-1 (6)	16,52
2	+1 (900)	-1 (20)	-1 (1,6)	-1 (6)	18,42
3	-1 (355)	+1 (100)	-1 (1,6)	-1 (6)	19,36
4	+1 (900)	+1 (100)	-1 (1,6)	-1 (6)	20,14
5	-1 (355)	-1 (20)	+1 (12,5)	-1 (6)	22,67
6	+1 (900)	-1 (20)	+1 (12,5)	-1 (6)	24,36
7	-1 (355)	+1 (100)	+1 (12,5)	-1 (6)	27,53
8	+1 (900)	+1 (100)	+1 (12,5)	-1 (6)	29,62
9	-1 (355)	-1 (20)	-1 (1,6)	+1 (35)	19,36
10	+1 (900)	-1 (20)	-1 (1,6)	+1 (35)	20,86
11	-1 (355)	+1 (100)	-1 (1,6)	+1 (35)	21,54
12	+1 (900)	+1 (100)	-1 (1,6)	+1 (35)	22,48
13	-1 (355)	-1 (20)	+1 (12,5)	+1 (35)	24,34
14	+1 (900)	-1 (20)	+1 (12,5)	+1 (35)	26,46
15	-1 (355)	+1 (100)	+1 (12,5)	+1 (35)	24,60
16	+1 (900)	+1 (100)	+1 (12,5)	+1 (35)	26,56
17	-2 (82,5)	0 (60)	0 (7,05)	0 (20,5)	24,52
18	+2 (1172,5)	0 (60)	0 (7,05)	0 (20,5)	25,18
19	0 (627,5)	-1,2 (12)	0 (7,05)	0 (20,5)	22,47
20	0 (627,5)	+2 (140)	0 (7,05)	0 (20,5)	24,36
21	0 (627,5)	0 (60)	-1,2 (0,4)	0 (20,5)	20,23
22	0 (627,5)	0 (60)	+2 (18)	0 (20,5)	24,64
23	0 (627,5)	0 (60)	0 (7,05)	-1,2 (3,1)	24,16
24	0 (627,5)	0 (60)	0 (7,05)	+2 (49,5)	29,43
25	0 (627,5)	0 (60)	0 (7,05)	0 (20,5)	26,62
26	0 (627,5)	0 (60)	0 (7,05)	0 (20,5)	26,65

Table 3. Experimental model coefficients for OF

Coefficient	Value	Coefficient	Value	Coefficient	Value
b_0	26,1511	b_{12}	-0,090	b_{34}	-0,7512
b_1	0,5958	b_{13}	0,1712	b_{11}	-0,3712
b_2	1,2724	b_{14}	$3,75 \cdot 10^{-3}$	b_{22}	-1,2127
b_3	2,9647	b_{23}	0,1325	b_{33}	-1,9164
b_4	0,6996	b_{24}	-0,6575	b_{44}	-0,2427

- having no significant statistical significance in the area investigated, there are the other second order interactions between **IF** and also the linear term concentration for **OF** $Y_{S1} \Leftrightarrow Q_p$;

- the good correspondence between estimated and measured values of the two

OF (93,5 %) enables the experimental model found to allow to formulate necessary and sufficient conditions that must be met by **IF** to achieve the objectives of maximizing **OF** $Y_{S1} \Leftrightarrow Q_p$.

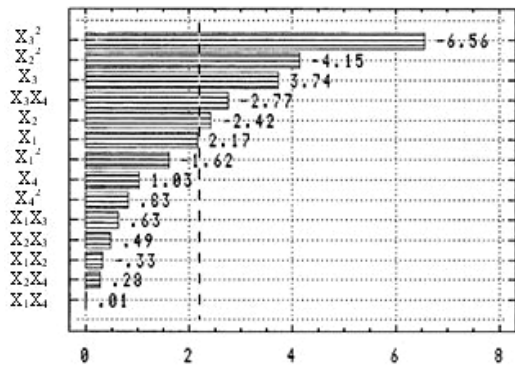


Fig.1. Standard effect on productivity caused

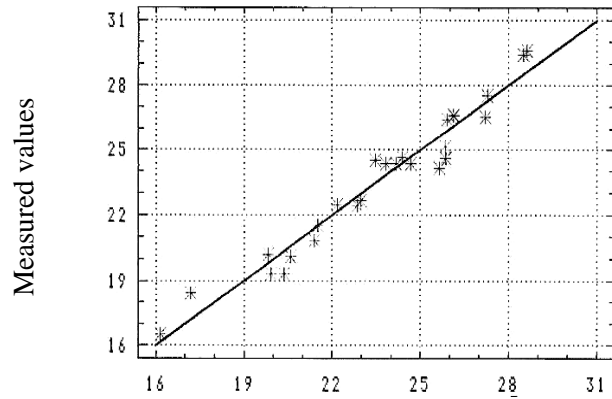


Fig.2. Measured and estimated values

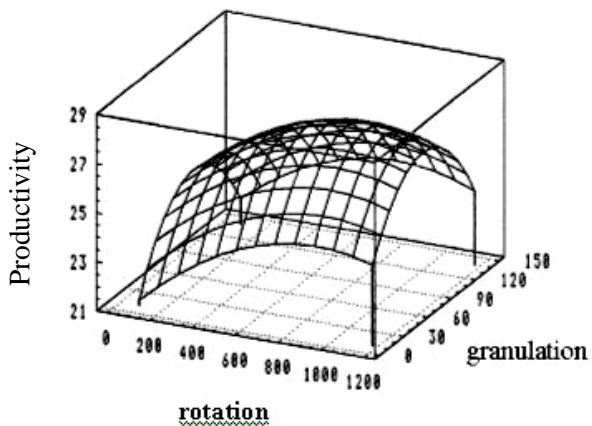


Fig.3. Response surface with respect to rotation and concentration

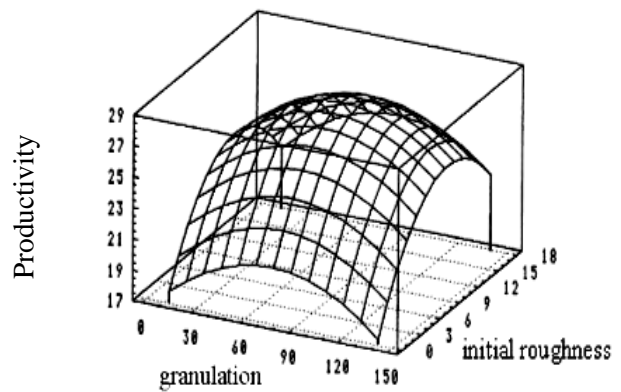


Fig.4. Response surface with respect to rotation and concentration

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