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Optimizsation of the lacquering process

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ABSTRACT

Purpose: The topic of this research is estimation of coat parameters generate by paint robots. The purpose of this article is to present results of optimization of the varnishing process.

Design/methodology/approach: After theoretical analysis of the methods of the optimization, in examinations was used multicriterial with method of the optimization. This method allows for diagnosing the problem of the lacquering process.

Findings: Optimization of the process with multicriterial method let for selecting right parameters of the process of painting. The possibility of the optimum technological process choice was proposed. The optimization methods should have more and more meaning in the materials engineering. It is because of many possible technical problems to solutions.

Research limitations/implications: The method of optimization such as multicriterial depend on degree of complexity of physical and technical relations of the analysed lacquering processes.

Practical implications: The work is an example of analysis of chosen technological process in aspect of its efficiency. It could be helpful to improve a level of total productivity of technological processes by using multicriterial method.

Originality/value: This paper is obtained original model for experimental domain of forming parameters and identification of parameters influence in that model.

Keywords: Optimisation; Multiobjective optimisation; Industrial management; Industrial application of optimization methods; Industrial robot

MATERIALS MANUFACTURING AND PROCESSING

1. Introduction

In the contemporary world, in all parts of life there appears to be the necessity of search for better solution – best to achieve success in given conditions and for accepted criteria. The effect of such the best (the optimum Latin – the best) solutions search, especially in the production sphere, is searching of better solutions than till well-know now [1]. These days, to function and develop enterprises have to do: products optimize and their way of production optimize [2]. This operation can be made on many different ways. In the last years can be observe increase of interest with the technological process optimization methods, especially in materials engineering.

We can optimize the whole technological process, but received during the optimization optimality criterion function has to be equal for all subsystems [2, 3]. The optimization usually encloses the most essential technological operations which in the direct way influence on the course of the technological process [4].

2. Methods of the optimization

The theory of optimization deals with investigation of methods of optimization [5, 7, 12]. The theory of optimization founds the widest use. It is the most useful in field of making decisions. The process of making optimum decisions consists in searching of admissible solutions, for which definite parameters achieve maximum values [5].The process of making decisions contains the following stages [11] (Fig. 1).

The process of making decisions should be the most profitable on each stage of manufacturing and technological process [7].

The optimization of most tasks is realized by using the model of considered problem. Because all occurrences an quantities are related and depended on random disturbances, their model states always simplification of reality. The general division of decision models with regard on basic criterions are presented in Table 1.

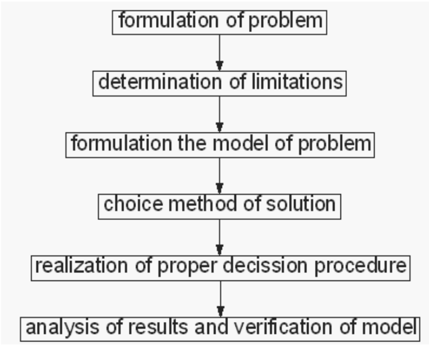

Fig. 1. Scheme of making decisions [2]

Table 1.
The classification of decision models used in the optimization theory [11]

No.	Assesment criteria of models	Kind of model	
1	Form of an objective function	Linear	Nonlinear
2	Kind of variables	Continuous	Discrete
3	Description	Deterministic	Random
4	Amount of states of model	Static	Dynamic

Presented models of optimization theory were prepared by many scientists as well as mathematicians, engineers, economists, statisticians [5]. The are many varied problems, which could be formulated as optimization models.

Generally, optimization can be divided on [6, 7, 8]:

- single - criterial,
- multicriterial,

Single - criterial optimization, when the optimum state achievement is required in view of one criterion of this state estimation. In the single – criterial optimization, whole necessary information to solutions should be gathered before beginning calculation.

Multicriterial when the optimum state achievement is required in view of many criteria of this state estimation.

The methods of optimization such as [5, 9, 10]:

- linear programming,
- non-linear programming,
- dynamic programming,
- theory of games,
- forwarding questions,
- genetic algorithms,

are using in distribution of supplies, planning, steering, approximation and estimation.

Optimization as scientific discipline is based on methods and techniques of operations research. It seems to be one of the most developing direction of science, which is using the possibility of information technology. Procedures and methods of optimization are often using in designing the manufacturing processes, but they could be applied in different fields of life, not only engineering tasks [5, 14, 15].

3. Experimental setup

Paints are industrial products mainly used for the protection of objects from destructive external attacks and for decoration. In recent years the automotive industry has invested heavily in new paint shop facilities, paint process and application equipment, in order to meet ever stricter requirements to cost, quality, flexibility and emission reduction. Many of these investments have gone to install paint robots for either external or interior painting, in a multitude of different applications and configurations. Behind this increased use of robotics is the fact that the automation industry now offers a technology with a level of robustness, where the advantages with flexible automation, such as paint robots, can really be utilized. Reasons to select robots for automotive painting are [13, 16]:

- repeatability and accuracy of applicator motion path is unrivalled,
- new body styles require enhanced profiling performance from paint automation,
- the ability to maintain a constant tool centre point orientation and painting distance improves transfer efficiency,
- the flexibility/agility of robot automation for rapid model changes,
- process control improvements integrating process and motion in the robot controller,
- painting equipment is now dynamic, accurate, repeatable, small, and light enough to be used by robots,
- robotic solutions often represent lower investment and/or operating costs than hard automation.

It's important to understand the advantages of robotic paint application and how to apply paint using the capabilities of a robot. The gun combined with the robot's motion, fluid delivery, and control functions, provides an optimum paint application. With the control of the paint parameters(i.e., atomization, and paint flow) robots can therefore, deliver a consistent and uniform film build. The robot and its control software ensure that the same amount of linear travel at a constant relative speed is used to traverse the object. With robots, speed, gun (head painting), distance from the part, and the approach vector to the sprayed object remain constant and the same amount of paint is used every time. This consistency of paint usage is critical component to achieving quality finishes while minimizing paint waste.

An aim of examination was solving the problem of diversifying thickness coating varnish on details of car bodyworks. Preliminary parameters of painting process are selected at special robot position. Trial painting are generate at sheet stainless steel. Next step is making a measure by especially magnetic meter Elemtron MG-401. The theoretical part contains description of many methods of optimization. In examinations was used multicriterial with method of the optimization. This method allows for diagnosing the problem of the lacquering process.

Influence an quality of coat have got three factors: atomized pressure p1, formed pressure p2, outflow of paint w (Table 2).

In the time of research realized, makes seventeen samples (for stainless plate), and then establish scale of the problem.

In the next step it accept aprocsymetly function and then indicate factors functions, correlations by them and characteristic of secondary function. Appoint ideal characteristic, it is possible found influence each parameter for coat. Design of experiment is powerful tool for modelling and analysing the influence of process parameters.

Table 2.
The parameters of varnishing

Nº trial	Value of parameters		
	Atomization pressure	Form pressure	Outflow of paint
	p1 [bar]	p2 [bar]	w[cm^3/min]
1	3	3	250
2	3	4.5	400
3	4.5	3	400
4	4.5	4.5	250
5	3.75	3.75	325
6	3	3	400
7	3	4.5	250
8	4.5	3	250
9	4.5	4.5	400
10	3.75	3.75	325
11	2.5	3.75	325
12	5	3.75	325
13	3.75	2.5	325
14	3.75	5	325
15	3.75	3.75	200
16	3.75	3.75	450
17	3.75	3.75	325

On the basic of performed experiment can be represented the functional relationship between response of varnishing process, in this case the thickness of the coating and the investigated independent parameters by the following form of mathematical model:

$$Y(x) := \frac{A}{\left[1 + A1\cdot\left(\frac{1}{20}\cdot x - 1\right)^2 + A3\cdot\left(\frac{1}{20}\cdot x - 1\right)^6\right]} \quad (1)$$

or in coding form where all the constants including interactions can be estimated (Table 3).

The secondary figure of the approximating polynomial is the following:

$$Z = A + A_1x_1 + A_2x_2 + A_3x_3 + A_1(x_1)^2 + A_2(x_2)^2 + A_3(x_3)^2 + A_1(x_1x_2x_3) \quad (2)$$

Where factors functions A, A_1, A_2, A_3 are value received after the approximation of points with primitive function, x_1, x_2, x_3 value received after transforming leveling the secondary function into the arrangement of three equations; $x_1 = p1$, $x_2 = p2$, $x_3 = w$.

$$Z := \begin{pmatrix} 1 & 18.80628 & 6.29739 & 53.237 \\ p1 & 7.17301 & 4.79892 & 104.004 \\ p1\cdot p1 & -.12622 & 1.05434 & 64.672 \\ p2 & -6.70096 & -6.42155 & -99.154 \\ p2\cdot p2 & -.30479 & -.65816 & 50.669 \\ w & .02745 & -7.15116 & -113.356 \\ w\cdot w & -.30479 & 5.39899 & 82.435 \\ p1\cdot p2 & -1.91250 & -1.77875 & 81.400 \\ p1\cdot w & .08750 & 3.56125 & 73.437 \\ p2\cdot w & .08750 & 4.70125 & -58.865 \end{pmatrix}$$

$$A := \overrightarrow{\left(Z^{\langle 0\rangle}\right)\cdot Z^{\langle 1\rangle}} \quad A1 := \overrightarrow{\left(Z^{\langle 0\rangle}\right)\cdot Z^{\langle 2\rangle}} \quad A3 := \overrightarrow{\left(Z^{\langle 0\rangle}\right)\cdot Z^{\langle 3\rangle}}$$

Table 3.
Coding form of parameters of the function

Parameters of the function							
Coding			A	A1	A2	A3	R
-1.000	-1.000	-1.000	14.000	26.790	0.00	578.180	0.99
-1.000	1.000	1.000	5.000	.270	0.00	1.520	0.51
1.000	-1.000	1.000	30.000	21.360	0.00	532.660	0.99
1.000	1.000	-1.000	14.000	0.000	0.00	529.030	0.73
0.000	0.000	0.000	18.000	5.250	0.00	51.610	0.98
-1.000	-1.000	1.000	13.000	0.000	0.00	45.500	0.96
-1.000	1.000	-1.000	5.000	0.000	0.00	10.020	0.95
1.000	-1.000	-1.000	30.000	57.742	0.00	11.950	0.95
1.000	1.000	1.000	13.700	6.260	0.00	54.640	0.99
0.000	0.000	0.000	21.000	5.410	0.00	23.820	0.97
-1.673	0.000	0.000	8.000	.510	0.00	2.680	0.84
1.673	0.000	0.000	36.000	23.850	0,00	553.320	0.99
0.000	-1.673	0.000	34.000	13.380	0.00	470.490	0.99
0.000	1.673	0.000	9.000	1.390	0.00	7.090	0.91
0.000	0.000	-1.673	21.000	46.070	0.00	640.520	0.99
0.000	0.000	1.673	22.000	2.620	0.00	14.950	0.51
0.000	0.000	0.000	16.000	7.060	0.00	66.810	0.99

Figure 2 is demonstrating the received perfect curve, however Figure 3 is demonstrating function about the highest rate of R correlation in to perfect curve.

4. Conclusions

Robotic painting has achieved increased popularity in recent years, due to the flexibility and enhanced performance with such systems. There is a clear trend among major automobile makers to change from hard to flexible automation, and, in that respect, paint robotics is becoming increasingly more important for future paint shop design.

New programming tools offer operators and paint engineers better possibility to program and maintain robot systems.

Classical experimental design methods are too complex and not easy to use. a large number of experiments have to be carried out especially when the number of process parameters increases.

Advantage of classical experimental design methods are possible to obtain mathematical model which is powerful tool to predict response for any input parameters value within the experiment range and optimal values can to be any of parameters point.

The proposed methodology has pointed out the potential of the optimization methods in the optimization of the process parameters of lacquering. With regard to still increasing quantity of possible technical solutions, the optimization methods should have more and more meaning in materials engineering.

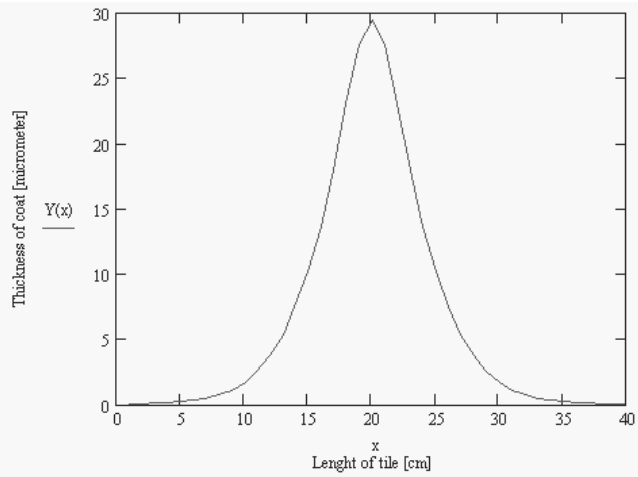

Fig. 2. The graph of the perfect curve

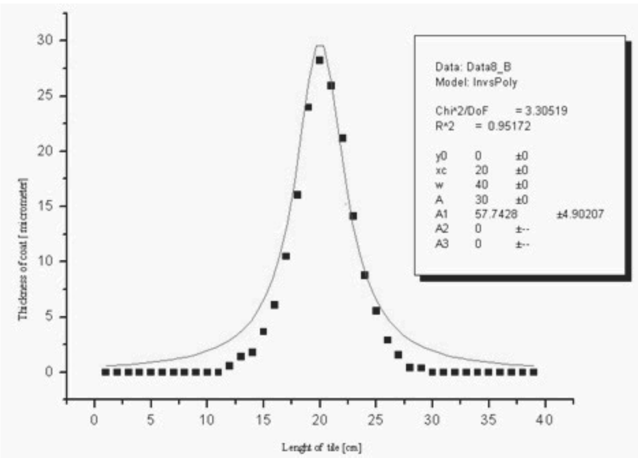

Fig. 3. The graph of a function about the highest rate of R correlation

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