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Mathematical Simulation of Intelligent Control System of Metal Vacuum Sputtering Process on the Basis of Application of Multi-Agent System

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Abstract: A vacuum sputtering process comprises evaporation of the material and subsequent vapor condensation on the substrates. Getting required and repeatable quality of coatings is challenging task. It depends on capabilities of equipment, type of evaporator, interaction evaporator with the evaporating substance and deposition process. Sputtering process parameters are determined by the ability evaporator to maintain a certain temperature evaporated substance for a long time. Controlling operations sequence of pumping and heating depends on achieving optimum vacuum conditions, in spite of used pumping method. The control system must foresee and identify emerging cracks or damage of the system components. This paper focuses on the development of intelligent control system vacuum process on the agent-based approach.

Key words: Vacuum sputtering process · Controlling operations · Intelligent control system

INTRODUCTION

Vacuum equipments are used in the industry from the middle of the last century. Currently, vacuum systems are widely used in such industries as optics, electronics, engineering and aerospace. With the high coating speed, lower energy sputtering in vacuum has received intensive development in recent years. Existing automated system for monitoring vacuum process: UNIP- 900, VACLEADER, Kremen-1, meet modern needs of efficient production. But equipment, operator and information support of process in these systems are not considered as interacting agents of unified system to achieve the required indicators: the decline of reject, the availability of all used information in the process in real time, the optimal planning of production with higher accuracy, the optimization of stocks of raw materials.

To create the intellectual superstructure of the control system device structuring on agent-based modular representation as a set of agents that execute commands and act on inside chamber environment, such as an pumping system, cooling system, etc. and agents that receive data, redistribute, interpret (Figure 1).

Using the following definitions for agents of intelligent process control system sputtering in vacuum:

- Agent data collection - processing data from lower-level components - sensors;
- Agent camera - has information about the processes occurring in the chamber;
- Agent magnetron - has information on the state of the magnetron;
- Agent line - has information about the processes occurring in pumping system tubes;
- Agent pump - has information about the processes occurring in the pump;
- Agent gas cylinder - has information on the state of gas cylinders;
- Cooling agent - has information about the processes occurring in the cooling system;
- Agent-VU (off set), Agent EF (electro flap), Agent cooler - agents of feedback;
- Agent interacting with external sources - displays and requests interesting information for a specific example realized on software package TraceMode;
- Agent Coordinator - implements the function of agent interaction;

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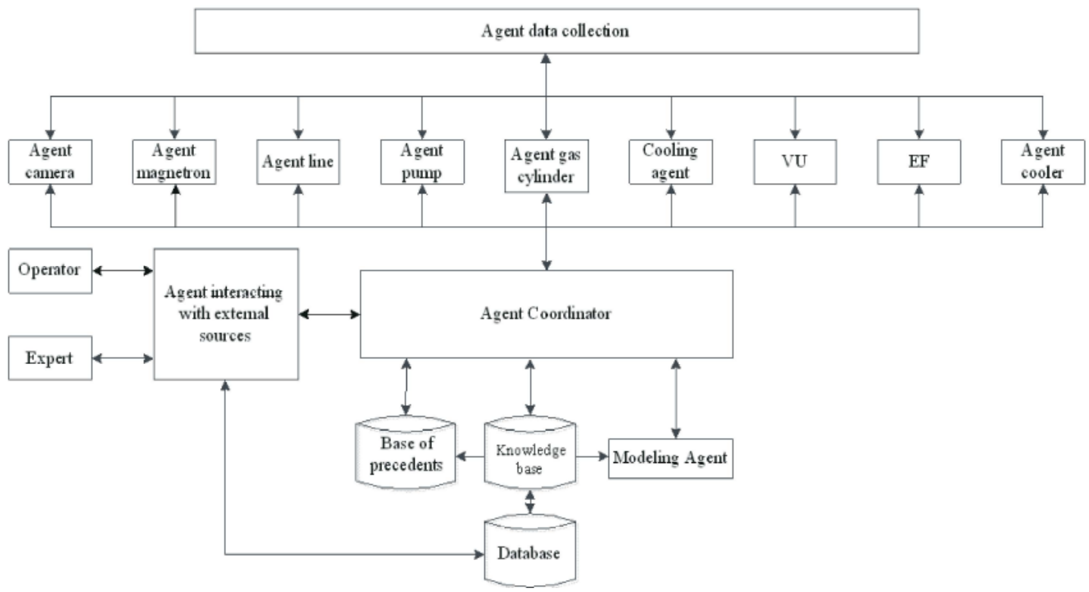

Fig. 1: Control structure based on multi-agent system

Modeling Agent - implements decomposition function and compile agents; In addition system must store data, that provides knowledge base, which consists of a database, database of precedents, working memory. Base precedents - is based on the data processed using methods of multi-agent system. Knowledge base - core of the system, containing complex knowledge simple in understanding to operator and in system language, based on the base of precedent.

The proposed system is distributed. Each agent, manager of one of the parts of the device, has only information about their condition and the options have to make decisions in a lack of information about the behavior of the net options.

MATERIALS AND METHODS

In this system, intelligent agents are able to interact with each other to achieve common goals.

It is offered the knowledge about the structure and state of process to transfer from the agent operator of process at the place of the current process itself, applying the method of Emelyanov V.V. [2]. Organize the interaction place of flow processes and to shift the care of the normal course of the process on their own. So, consider the space of flow of the process in the form of the agent. Developed system has the place the current process (the action) and its virtual counterpart, created as a software agent. The main role played by the current process place agent, which processes data from the lower-level components - sensors.

Agents interaction, belonged to MAS, with the environment provided by the agent data collection, interaction with external sources. Coordinator agent sends messages to other agents on the degree of interconnection of agents and agent that have to get the request is determined. Interconnection of agents determined by knowledge base/.

Interaction - is not just communication link, interdependence between coexisting agents, but also a prerequisite for mutual transformations: modification of both the agents and the relationships between them.

Use the following notation: Agent camera - A1, Agent magnetron - A2, Agent line - A3, Agent pump - A4, agent gas cylinder - A5, Agent cooling - A6, Agent off set –VU, Agent electro flap - EF, Agent cooler -C.

All interactions between agents for the greatest clarity, presented as a graph of A = <B, C>. Tops (B) of the graph correspond to the protection agents and ribs (C) - the transfer of a particular type of messages exchanged between them depending on the situation (Fig. 2).

For example, after transmitting message from the agent coordinator to agent-chamber A1, response message is sent to agent coordinator about of the state agent A1. Further interaction continues, coordinator agent send messages to other agents, in accordance with the degree of intensity of interaction, by scheme is reflected in the knowledge base. Also, knowledge base defines content of the message. If the variable value of the state agent is 1, the coordinator agent is sent a message that everything is normal. In case value is

Table 1:

The order of transmission of messages (number of arcs)	Rib of the arc	The message type	Action agent
1	<AC, A1>	QIP	Query about of agent status
2	<A1, AC>	ANSWER	The transfer agent status value = 1
3	<AC, A2>	QIP	Query about of agent status
4	<A2, AC>	ANSWER	The transfer agent status value = 1
5	<AC, A3>	QIP	Query about of agent status
6	<A3, AC>	ANSWER	The transfer agent status value = 0
7	<AC, A4>	QIP	Query about of agent status
8	<A4, AC>	ANSWER	The transfer agent status value = 1
9	<AC, A5>	QIP	Query about of agent status
10	<A5, AC>	ANSWER	The transfer agent status value = 1
11	<AC, A6>	QIP	Query about of agent status
12	<A6, AC>	ANSWER	The transfer agent status value = 0
13	<AC, C>	RWIP	The requirement for the cooler
14	<C, M>	Message	Message to operator
15	<C, AC>	ANSWER	Report success / failure to start

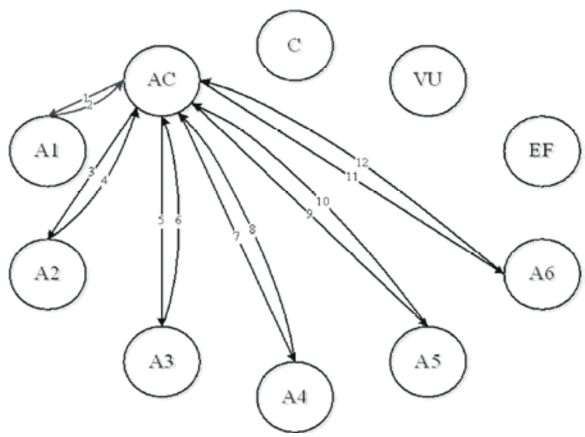

Fig. 2:

0 agent sends message to the coordinator agent, completes a survey of other agents, searching for a rule from knowledge base. If it finds the coordinator agent sends a message from knowledge base to operator with instructions to solve the problem. Agent set off sends information to agent-coordinator of the successful or unsuccessful attempt to disconnect working and a message to the operator.

The initiator of sending messages is always coordinator agent, all messages come through coordinator agent.

In this system, two kinds of cooperative relationships: Request information from the agent (QIP), response (ANSWER) and requirement to agent to perform certain actions under a certain condition (RWIP). Associating only agents, which correspond to each other according to the rules from base of knowledge. The table below shows an example of a situation of interaction of agents (Table 1).

This agents may be bounded in one and independent in another.

Relationship between agents are characterized by intensity. Each agent with varying intensity interacts with several other agents.

For example Agent - cooling (Fig. 3). Its knowledge based on the knowledge of lower Agents: Agent - water temperature at the inlet of cooling system (Agent 1) Agent - water temperature at the outlet of pump (Agent 3) Agent - water temperature at the outlet of the magnetron (Agent 4) (Fig. 4).

This agent may be linked in one respect and are independent to the other.

Relationship and interdependence between agents are characterized by intensity. Each agent with varying intensity interacts with several other agents. Consider the example of the Agent - cooling (Fig. 3). Its knowledge is based on the knowledge of lower Agents (Fig. 4).

Block diagram of an agent - water temperature at inlet of cooling system- A4 includes, for example:

Phase induction motor, electrical processes in the phases of the stator and rotor are described by the equations:

$$U_S = R_S \cdot I_S + L_S \cdot \frac{dI_S}{dt} + \frac{d\Psi_S}{dt}$$

$$U_R = (R_R + R_D) \cdot I_R + L_R \cdot \frac{dI_R}{dt} + \frac{d\Psi_R}{dt}$$

where: U, I, Ø - generalized vectors voltage, current and flux stator (S) and a rotor (R) windings; R, L-resistance and inductance of windings flows dispersion.

It is a standard transfer function [1].

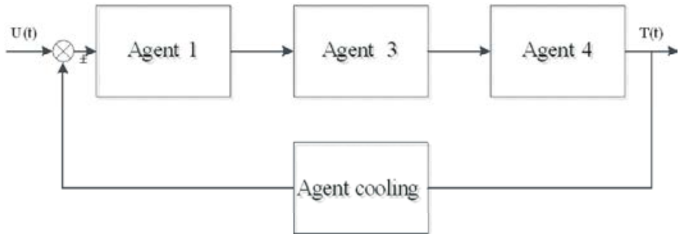

Fig. 3: The block diagram - Agent cooling

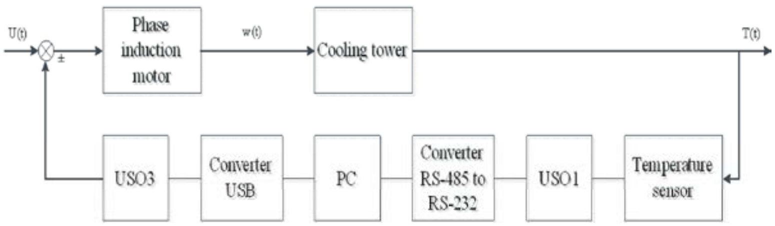

Fig. 4: Block diagram of an agent - water temperature at inlet of cooling system

$$W_e(p) = \frac{1-K_{mech}}{T_{ec}\cdot p+1}\cdot\frac{1-K_{ec}}{T_{ec}\cdot p+1}$$

Cooling tower: between temperature at inlet and outlet of linear dependence.

$$X_3 = K_{tw} = . X_2$$
$$W_{tw}(p) = K_{tw}$$

Temperature sensor: inlet temperature, outlet voltage varies with some lag - aperiodic link.

$$T_{ts}\cdot\frac{dX_4}{dt} + X_4 = K_{ts}\cdot X_3$$
$$W(p) = \frac{K_{ts}}{pT_{ts}+1}$$

USO1 –remote I-O module - The multiplexer

$$X_5 = K_{m1} . X_4$$
$$W_{m1}(p) = K_{m1}$$

Interface converter RS-485 to RS-232 - conversion occurs with some frequency sampling and conversion time of such devices is tens of microseconds. Therefore, this type of elements can be described differential equation as aperiodic link.

$$T_{ic1}\cdot\frac{dX_6}{dt} + X_6 = K_{ic1}\cdot X_5$$
$$W(p) = \frac{K_{ic1}}{pT_{ic1}+1}$$

PC- generates sequence sync and logic signals which determine the sequences switching all of logical devices.

Elements processing speed of device infinitely small in relation to speed of vacuum sputtering processes. So, apparatus processing time constant can be ignored and present it in the form of reinforcement link:

$$X_7 = K_{pc} . X_6$$
$$W(p) = K_{pc}$$

The converter-USB to RS-485 conversion occurs with some frequency sampling and conversion time of such devices in the tens of microseconds. Therefore, this type of elements can be described differential equation as aperiodic link.

$$T_{ic2}\cdot\frac{dX_8}{dt} + X_8 = K_{ic2}\cdot X_7$$
$$W(p) = \frac{K_{ic2}}{pT_{ic2}+1}$$

USO3 - remote I-O module - The multiplexer

$$X_9 = K_{m3} . X_8$$
$$W_m(p) = K_{m3}$$

Same discussed other agents. On the basis of equations of individual units of block diagram obtained a system of equations describing the dynamic processes in the control (Table 2).

Table 2: Equations of the elements

Element	Differential equation
Phase induction motor	$U_S = R_S \cdot I_S + L_S \cdot \frac{dI_S}{dt} + \frac{d\Psi_S}{dt}$ $U_R = (R_R + R_D) \cdot I_R + L_R \cdot \frac{dI_R}{dt} + \frac{d\Psi_R}{dt}$
Cooling tower	$X_3 = K_{tw} \cdot X_2$
Temperature sensor	$T_{ts} \cdot \frac{dX_4}{dt} + X_4 = K_{ts} \cdot X_3$
USO1 – remote I-O module - The multiplexer	$X_5 = K_{m1} \cdot X_4$
Interface converter RS-485 to RS-232	$T_{ic1} \cdot \frac{dX_6}{dt} + X_6 = K_{ic1} \cdot X_5$
PC	$X_7 = K_{pc} \cdot X_6$
Interface converter-USB to RS-485	$T_{ic2} \cdot \frac{dX_8}{dt} + X_8 = K_{ic2} \cdot X_7$
USO3 – remote I-O module - The multiplexer	$X_9 = K_{m3} \cdot X_8$
Tens pump	$X_2 = K_{ten} \cdot X_1$

On the basis of these equations was established mathematical model of the system:

$$W_e(p) = \frac{1 - K_{mech}}{T_{ec} \cdot p + 1} \cdot \frac{1 - K_{ec}}{T_{ec} \cdot p + 1}$$

$$W_{tw}(p) = K_{tw}$$

$$W(p) = \frac{K_{ts}}{pT_{ts} + 1}$$

$$W_{m1}(p) = K_{m1}$$

$$W(p) = \frac{K_{ic1}}{pT_{ic1} + 1}$$

$$W(p) = K_{pc}$$

$$W(p) = \frac{K_{ic2}}{pT_{ic2} + 1}$$

CONCLUSION

To verify the direct characteristics of the developed control system in Simulink environment the use of transfer functions is required. Which have been obtained from the system of differential equations using Laplace transform. Design and implementation of intelligent systems provide access control information used in the entire process in real time, will reduce flaw, allow production schedule with a high accuracy, improves raw material stocks.

REFERENCES

1. Katzman, M.M. and F.M. Yuferov, 1979. Electrical mashinery automation systems, , Yr: Publisher: High School, pp: 261.
2. Tarasov, V.B., 2002. From multi-agent systems to intelligent organizations. M: Editorial URSS, pp: 352.
3. Nikiforov, V.O., 2011. Intelligent control in the face of uncertainty Textbook. St. Petersburg.: ITMO, pp: 226.
4. Kostrzhitsky, A.I., 1991. Reference Operators of coating in a vacuum. M. Mashinostroyeniye, pp: 176.
5. Minaychev, V.E., 1989. Application of the films in the series vacuum "technology semiconductors and microelectronic products.". In 10 books. Textbook for vocational schools. Book 6. M.: Higher School, pp: 96.
6. Petukhov, O.A., A.V. Morozov and E.O. Petukhov. 2008. Simulation: system, simulation, analytical textbook. St. Petersburg.: SZTU Publishing, pp: 288.
7. Kharitonov, J.M. and O.N. Zaitsev, 2007. The theory of automatic control. Continuous linear system. Textbook theory of automatic control. Continuous linear system. / Textbook. allowance. Cheboksary: ChI MGOU, pp: 205.
8. Ohorzin, V.A., 2006. Computer modeling in the Mathcad. Izdat.: Finance and Statistics, pp: 144.
9. Morozov, V.K. and G.N. Rogochev, 2011. Modeling of information and dynamic systems. Izdat.: Academy, pp: 384.
10. Devyatkov, V.V., 2001. Intelligence systems. Studies manual for high schools. Moscow: Publishing House of the MSTU. N.E. Baumana, pp: 352.