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Hybrid Control Method for Glazing Ceramic Surfaces

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Abstract

The paper presents a hybrid control method for solving the problem of the uniform glazing of ceramic parts. The proposed solution avoids the waste of the raw material and ensures a corresponding quality of the finite product. A discrete event representation of the plant is used to develop the control strategy. A Petri Nets based model describes the behaviour of the discrete event subsystems.

Key words: hybrid system, Petri nets, hierarchical control architecture, simulation

1. Introduction

In order to control complex industrial plants, good modelling techniques are required. Experience has shown that the use of good modelling techniques can considerably reduce the complexity of the models, and thus increases the confidence in their correctness. In some cases, parts of the plant are best modelled by means of discrete-event concepts, while the others are best modelled using continuous time concepts. The combination of this two models leads to a hybrid model.

Another important way in which hybrid systems arise is from the hierarchical organisation of complex control systems. In these systems, the hierarchical organisation helps manage the system complexity. Higher levels in the hierarchy require less detailed models of the functioning of the lower levels, sometimes necessitating the interaction of discrete time, discrete events and continuous components. Supervisory systems are often used to control hybrid plants.

In some cases the glazing of the ceramic parts is considered as a continuous process [2]. The performances obtained in this case are not always satisfactory.

In the proposed control strategy, the glazing process with discrete event detection may be regarded as a special class of hybrid systems. When the ceramic surface has a regular shape the points where the glaze is applied (the work points) can be situated at equal distances and the commands actions are given at constant intervals of time. In this case, the controller can be considered as a discrete- time controller. If the ceramic surface has an irregular form, the work points where the glaze is applied are not equidistant. In this case, the supervisor transmits the commands signals at different intervals depending on the irregular degree of the surface and on the time needed to give to the spray gun a perpendicular orientation towards the surface. The arrival of the device at the calculated point is an event detected by a sensor and transmitted to the supervisor. The end of the glazing operation in a work point is another event. Others possible events, such as the appearance of defects, are considered. The discrete event representation of the plant is non-deterministic (from a given discrete state, transitions to more than one new discrete state are possible) and described by a Petri nets based model.

2. The treatment and glazing process

The obtaining of the glazed ceramic surface is the result of the treatment and glazing subprocesses, which are sequentially executed. The schematic representation is given in figure 1.

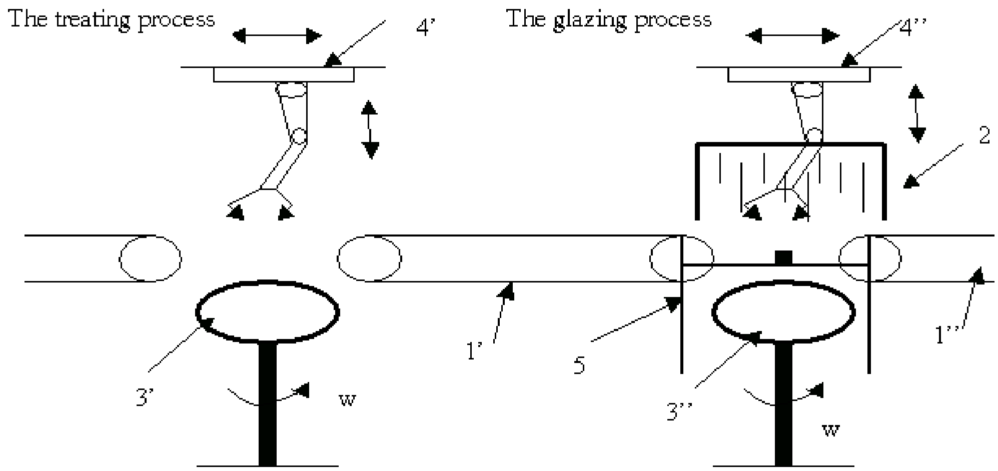

Figure 1 Schematic representation of the process

Where:
1, 1' and 1'' – conveyers;
2 – water cooling;
3' – support with one degree of freedom (it can execute a rotation around the Oz axis);
3'' – support with one degree of freedom (rotation around the Oz axis);
4 - Robot arm for the manipulating of the treated ceramic part;
4'' - robot arm for the manipulating of the part before and after the glazing process;
5 – robot (metallic frame), which executes the glazing operation;
Details about the metallic frame are given in figure 2.
The frame can have a forward motion and a backward running along the whole support. The assembly composed by the parts denoted by 3 and 4 can move on left or on right along the axis denoted by 2. The spray gun used for glazing and its support can move up and down and can rotate around the Oz axis.

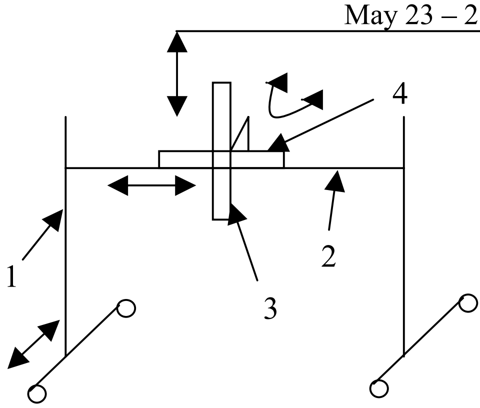

Figure 2 Schematic representation of the metallic frame

During the glazing process a uniform coat of material has to be applied overall surface of the ceramic part. The uniformity of the glaze coat depends not only on the considered distances between the work points but also on the orientation of the spray gun. In order to ensure the required performances, a perpendicular orientation of the device towards the ceramic surface as well as a suitable ratio between the quantity of the glazing material and the air volume are necessary.
The robot first glides along the Ox axis between two specified limits. Successively the robot applies the glazing material at the points of whose coordination are determined by the supervisor. At the end of this trajectory, it moves up at an established distance (on the Oz axis) and accomplishes the same operation moving along the Ox axis in the reverse direction. When one face is finished, the part is rotated with a specified angle and the operation is repeated. When it is necessary, the outside glazing is followed by the inside glazing.

3. The control architecture

The control architecture, presented in figure 3, is structured on two layers.

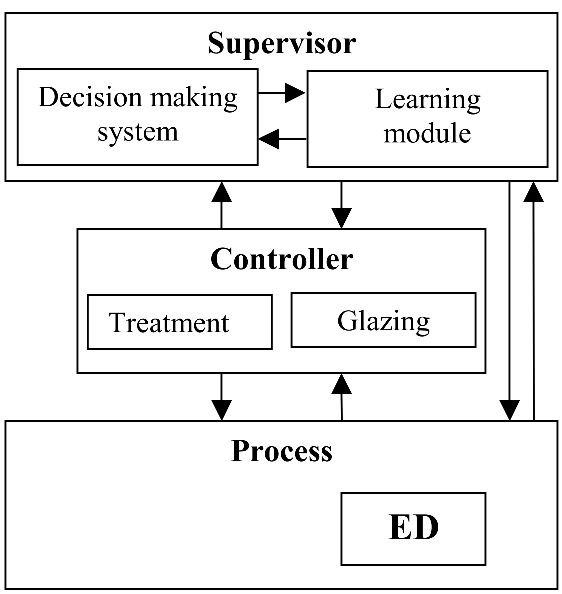

Figure 3 Control architecture

When an operation ends or another event occurs, the corresponding event detector sends a signal to the control system [5]. Following the state of the system, the decision-making system elaborates command which correspond to an adequate, predetermined strategy. The supervisor acts directly on the process when the system fails, or when a subprocess is finished. In the case of the normal operating conditions, the most important role of the supervisor is to send to the controller the coordination of a new point of work (when the previous operation is finished). In the case of an irregular surface, the values of the sent coordination implicitly influence the moment when the next operation begins. In this case, the control system is a discrete event system. When the surface of the part has a regular shape, the commands are given at constant time intervals and the control system can be considered as a discrete-time system.

3.1 The learning process

The ceramic product is explored from left to right following successive vertical parallel plans. This operation is necessary to establish the coordinates of the work points and the orientation of the spray gun (the possibility to glaze the internal surfaces is also taken into account).

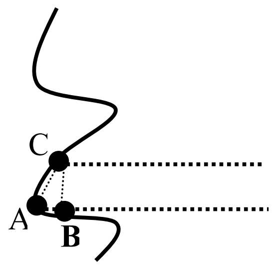

Figure 4 Learning process

The orientation of the spray gun is determined using two sensors [1]. Measuring the distances from the sensors to the part and knowing the vertical distance between the two sensors the angle formed by the horizontal line with the surface of the part (figure 4) is calculated.

The values of these angles together with other determined parameters serve also to establish the irregularity degree of the surface. Based on this data the supervisor establishes the coordination of the work points and storage them in the memory.

3.2 The controller

The controller executes the commands sent by the supervisor [3]. Two Petri nets model the glazing and the treatment subprocesses and allow the pursuit of their evolution. The two subprocesses have many similar characteristics. For this reason only the Petri net based model of the glazing process (figure 5) is represented. The inside and the outside

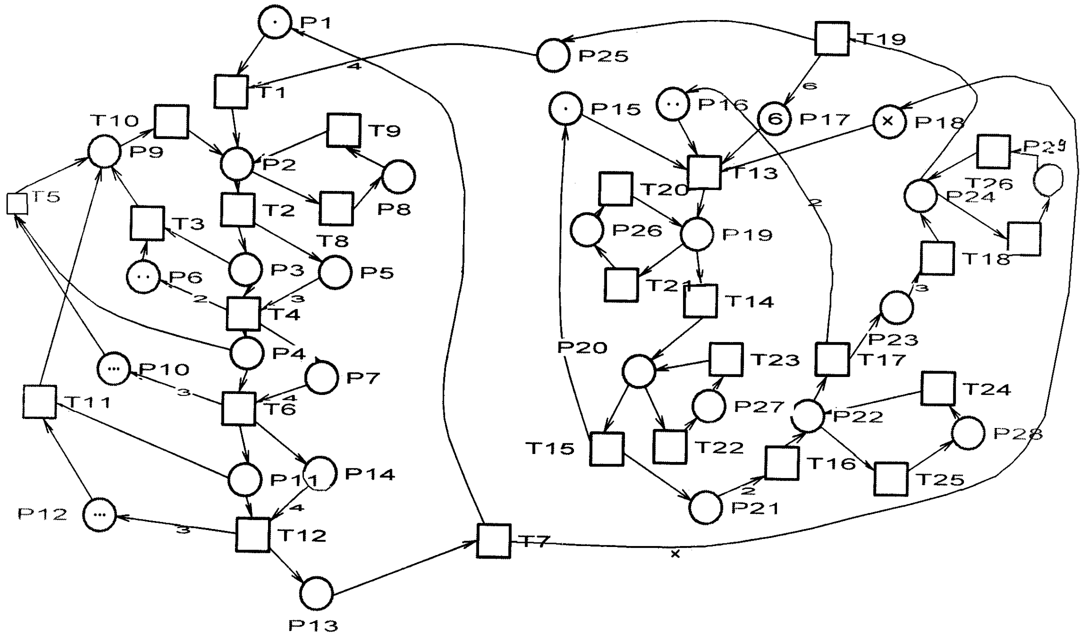

Figure 5 The Petri net base model of the glazing process

glazing processes can be followed on the left side, respectively on the right side of the model.

The significance of the places and transitions is:

P_1 - the spray gun is ready for the inside glazing (initial state); P_2 - the glaze is applied at the first point; P_3 - the robot glides on Ox axis; P_4 - the robot glides on Oy axis; P_5 – the number of glazed points on Ox axis is countered; P_6 – initial condition for the displacements on Ox axis; P_7 – the number of glazed points on Oy axis is countered; P_8 – the breakdown is repaired; P_9 – the spray gun is positioned; P_{10} – initial condition for the displacement on Oy axis; P_{11} – the robot moves around the Oz axis; P_{12} – initial condition for the displacement around the Oz axis; P_{13} – the robot is positioned for the outside glazing; P_{14} – the number of glazed points on Oz axis is countered; P_{15} – initial condition for the movement of the robot along the Ox axis; P_{16} – initial condition for the glazing of a part side; P_{17} - initial condition to perform a complete rotation of the part; P_{18} – initial condition for the outside glazing; P_{19} – the glaze is applied at the work point; P_{20} – the robot glides on Ox axis; P_{21} – the number of glazed points on Ox axis is countered; P_{22} – the robot glides on Oz axis; P_{23} - the number of glazed points on the Oz axis is countered; P_{24} – the part is rotated; P_{25} – the number of glazed sides is countered; P_{26}, P_{27}, P_{28}, P_{29} – the breakdown is repaired; T_1 – the inside glazing starts; T_2 – the glazing in the work point is finished; T_3 – the displacement on the Ox axis is finished;T_4 – starts the displacement on Oy axis ; T_5 - the displacement of the robot on the Oy axis is finished; T_6 – the movement of the robot around the Oz axis starts;T_7 – the cycle is complete; T_8 – a breakdown occurs; T9 – the breakdown is repaired; T_{10} – the glazing is restarted; T_{11} - the movement of the robot around the Oz axis is finished; T_{12} – the robots starts the displacement for the outside glazing;T_{13} - the glazing of the first outside point starts; T_{14} - the glazing of the first outside point is finished; T_{15} - the gliding of the robot on the Ox axis is finished; T_{16} – the robot starts the gliding on the Oz axis; T_{17} – the robot finishes the gliding on the Oz axis; T_{18} – the rotation of the part starts; T_{19} – the rotation of the part is finished; T_{18},T_{21}, T_{22} and T_{25} – a breakdown occurs; T_{20}, T_{23}, T_{24} and T_{26} – the breakdown is repaired.

The variable time interval, sent by the supervisor, is not given explicitly in the presented model. To mention this values, a timed Petri net (possible with timed-places) could be used. The main difficulty is connected with the variable time intervals calculated in the case of an irregular surface.

4. Simulation results

The simulation results were obtained taking into account surfaces that have a great variety of shapes. To verify the accuracy of the proposed learning method, the coordination of each point were first given and stored. Based on the storage data, the calculated value corresponding to the orientation of the spray gun was verified. The obtained results prove also that the repartition and the number of the resulting work points are strongly influenced by the irregularities of the surfaces. The connection between the learning process and the control actions was studied using the Petri net based model. In order to avoid the deadlocks, the properties of the proposed Petri net based model were studied.

This process was simulate with a program write using Java language.
The figure 6 represent the UML class diagram.

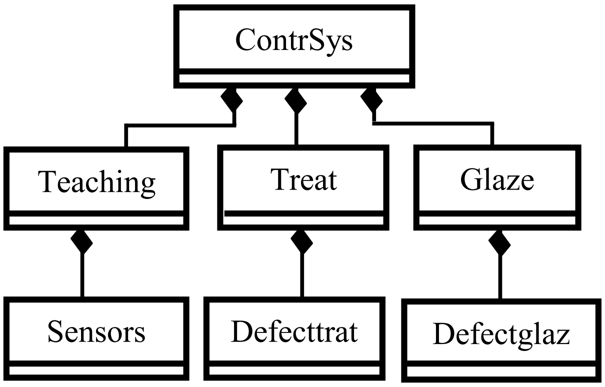

Figure 6 Class diagram

Sensors - Sensors placed on field give information about objects.
Defecttrat - All defects who could appear during treating process are solved using Defecttrat class.
Defectglaz - The defect appears on Glazing process are solved using Defectglaz.
Glaze - Using information about object receive from Teaching class, Glaze class make changes on object state. The Glaze structure will be an instance of type Defectglaz.
Teaching - Information from sensors will be collect and save by the Teaching class. The Teaching class could give information from sensors.
Treat - Using information about object, Treat class make changes on object state. The Treat structure will be an instance of type Defecttrat.
Controller - The controller commands the process Glaze, Treat and Teaching.

5. Conclusions

The presented control method proposes a new approach which can improve the specified characteristics of the ceramic glazed surfaces, especially the equal covering of the part. In the case of irregular surfaces there is a strong connection between the positioning and the number of the points at which the glaze is applied and the degree of the equal covering. The proposed determination of the work points can also save an important quantity of the raw material.

The method can be improved by the introducing of a supplementary calculus coefficient in order to take into account the viscosity of the raw material[4]. Better results can also be obtained, when the appropriate ratio quantity of glazing material/air volume is used.

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