

Title of Ph.D. thesis:

New Control Algorithm for Universal Multizone Crystallizator

Author:

Alexandr Beljajev

Certificated metallurgical engineer (M.Sc.)

Tutor:

Dr. András Roósz

Professor (D.Sc.)

The conception of implementation of a new crystal growth device -the idea of an facility where the experiments can be carried out with high accuracy- has come up in the eighties, by the experience of the common Soviet and Hungarian space experiment. This project was in critical situation in the beginning of the nineties because of the change of the political and economical circumstances in Central and Eastern European countries and the decreasing cooperation between the former Sovietunion and Hungary.

Due to NASA interests in the already existing prototype, the project was successfully continued and further developments of the facility were carried out. In between 1994 – 1996 tests were made by the instrument -what was called "Universal Multizone Crystallizator" (UMC) already at that time- in Marshal Space Flight Center (MSFC). The test results were promising, so the decision of making a test version of UMC for International Space Station "ALPHA" was carried out.

However higher demands were against the new device both from technological and from process control point of view. By the results of previous test measurements the PID algorithm was not sufficient for the higher expectations, the accuracy of technological parameters could not be sufficiently ensured by PID control system. **The aim of my research activity** was to work out process control algorithm where nearly the best technological parameters accuracy can be achieved, parallel with stabile operation

conditions of the process control system of the device, finally the selection and the design of the most adequate algorithm.

By analyzing the previous operation parameters of the instrument and studying the publications the INA ("Inverse Nyquist Array") multivariable process control algorithm has seemed to be the most adequate solution. For the implementation of algorithm design the appropriate knowledge of the facility operating parameters and thus the work out of the mathematical model for the facility is inevitable. Several test measurements were carried out for ensuring data for the mathematical model.

The aims of these test measurements can be divided into two main groups:

1.) To determine the thermal parameters of the UMC in order to build up a simple, relatively fast and accurate mathematical model for the adequate process control goals. These investigations can be divided into two further additional groups:

- The determination of heating and cooling characteristics (of different zones) of UMC.
  
- The determination of interaction characteristics among the neighboring zones of UMC.

2.) Reference test measurements for ensuring suitability and the goodness criteria of the designed algorithm. During these test measurements Ge-single crystals were grown.

The determination of the mathematical model of transfer function parameters was carried out by the test results of the device operating parameters. The least square (LS) method of MATLAB System Identification Toolbox was used for the evaluation of the measured data. The obtained new model with the help of INA method has ensured opportunity for multivariable process control design. This new process control design has established more accurate

operating conditions than the conventional PID algorithm. For numerical demonstration of PID and INA algorithm the calculation and the determination of the goodness criteria were carried out.

The results of my investigation are as follows:

- I. It has been proofed by experimental measurements that the instrument is not linear by the applied static characteristics, but it can be a linearized system. The linearization of the system ensures possibility of using process control algorithm of linear systems.
- II. The transfer function matrix has been determined by the results of the test measurements; that is valid in a certain determined interval because of the nonlinear property of the system.
- III. Multivariable process control algorithm was designed by INA method using the obtained model. This new model calculates with the interaction of the neighboring zones of the device.
- IV. Comparing the characteristics of the newly designed- and the PID algorithm in case of Ge-single crystal growth, the new process control algorithm ensures more accurate parameters during the most important period of crystal growth, because the interaction among the neighboring zones of the device are taking into account. Thus the distribution of power consumption of the zones will be smother and the control of UMC can be solved with fewer difficulties. The fact that the new process control algorithm can ensure higher accuracy in the operating parameters are justified by the calculated values of the created criteria.

The achieved scientific results can be utilized by the following ways:

- 1.) UMC can be suitable controlled by the newly designed multivariable process control algorithm.
- 2.) They are improving the university curricular knowledge in the fields of crystal growth and the theoretical knowledge of process control methods.
- 3.) The worked out model can be adapted for the implementation of other process control algorithm.
- 4.) The experimental results clearly ensure that the newly designed multivariable process control algorithm of UMC can be applied for other similar type furnace(s)