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# Generalized net model for foam monitoring control system

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**Abstract**: A generalized net model for foam monitoring control system in cultivation processes is developed and presented in this paper. Generalized nets are preliminary proved to be an appropriate tool for description of the logics of fermentation process modelling, including the opportunity for description of the biochemical variables and the possibility for optimal process carrying out. The proposed GN model presents the monitoring and control of the foam level during the cultivation process.

**Keywords**: Generalized Nets, Modelling, Foam, Monitoring, Control.

## 1. INTRODUCTION

Until now Generalized Nets (GN) [1, 2] have been used as a tool for the modelling of the different operational modes of biotechnological processes, for the different biotechnological processes such as fed-batch fermentations of *E. coli* and *Br. flavul*, as well as for the wastewater treatment processes [11]. On the other hand, generalized nets are used for optimal control of cultivation processes [6] and for control of some physics-chemical parameters of biotechnological processes, such as temperature [8, 10], pH [9] and oxygen [7]. The known advantages of the generalized nets presents them as very appropriate tools for the modelling of complex processes such as biotechnological processes. The facility of obtaining models in this way demonstrates the flexibility and the efficiency of generalized nets as modelling tools. The already developed generalized nets models allow us to simulate the biotechnological processes easily and quickly [11].

This paper will be focused on the application of the apparatus of the generalized nets for the modelling of the foam monitoring control system during a cultivation process. The proposed GN model observes the foam levels and affords an opportunity for automatic foam control by monitoring of the foam level and the dosage of an appropriate antifoam agent (nitrogen neutralization, an organic antifoam, a siliconebased emulsion containing in situ treated silica, a silicone/organic blend silica-free formulation, etc.[4]).

Microbial fermentation requires a high amount of agitation and aeration, which often results in excessive foaming. Antifoam controllers prevent foam levels from getting too high. Excessive foam will exit through ports in the headplate, open the system to contamination, and inhibit proper oxygen transfer [12]. Understanding that foam can cause problems is the first step to knowing what to look for or for finding a solution.

Foaming systems are particularly difficult for accurate liquid-level measurement because foam has a lower density than the foam-free liquid [12]. Many different devices can be used to measure liquid level. However, differential pressure cells, due to their low cost and wide applicability, are the most common [12]. In [4] the authors have described the development of a simple laboratory test for the effective screening of foam control agents on a selected fermentation system. The increase in protein content as a function of growth time was correlated with an increase in foam stability and antifoam consumption. A lot of the investigations show that the control of the foam level is important for optimal run of cultivation process [3, 5, 13-15].

## 2. GENERALIZED NET MODEL

The proposed generalized net model describes a system for monitoring and controlling foam during a fed-batch cultivation process utilizing a foam level sensing device positioned at a downstream location from a defoaming agent delivery arrangement [5]. The foam level sensing device comprises a float having a plurality of foam sensors positioned at various levels above the float and providing signals to a control device regarding the level of foam in the bioreactor. The control device provides instructions to the defoaming agent delivery arrangement so to provide a proper amount of defoaming agent to the culture medium. The defoaming agent delivery arrangement may be operated continuously and includes a backup delivery device for times when the delivery means runs out of defoaming agent or at times when foam is generated at an exceptional rate. Thus, the foam level is controlled to the appropriate value.

The generalized net model, describing the considered control system, is presented in Fig. 2. The model is based on the GN model for fed-batch operational mode [11]. As it has been presented in [11], the GN model developed for fed-batch mode can be easily transformed for batch and continuous mode.

The token $\alpha$ enters GN in place $l_1$ with an initial characteristic "flow rate of the medium feed". The form of the first transition of the GN model is:

$$Z_1 = <\{l_1, l_6\}, \{l_5, l_6\}, \begin{array}{c|cc} & l_5 & l_6 \\ \hline l_1 & false & true \\ l_6 & W_{6,5} & true \end{array}, \vee (l_1, l_6)>,$$

where $W_{6,5}$ is "need of new concentration of substrate, depending on the value in place $l_{10}$". The token $\alpha$ obtains the characteristics "concentration of the substrate added to the bioreactor" in place $l_5$, "amount of medium feed in storage" in place $l_6$.

The token $\beta$ enters GN in places $l_2$ with a characteristic "initial concentration of process variables". As process variables could be considered substrate(s), biomass, product(s), gasses, bioreactor volume etc. In place $l_3$ the token $\gamma$ enters the GN model with a characteristic "the current value of the foam level" measured by foam level sensing device. The control of foam level is realized by adding defoaming agent (transitions $Z_2$ and $Z_3$) in dependence on signal from foam level sensing device.

The token $\delta$ enters GN in places $l_4$ with a characteristic “defoaming agent”. The form of the second transition of the GN model is:

$$Z_2 = <\{l_4, l_8\}, \{l_7, l_8\}, \begin{array}{c|cc} & l_7 & l_8 \\ \hline l_4 & false & true \\ l_8 & W_{8,7} & true \end{array}, \vee(l_4, l_8)>,$$

where $W_{8,7}$ is “existence of token in place $l_{11}$”. The token $\delta$ obtains the characteristics “amount of defoaming agent added to the bioreactor” in place $l_7$, “amount of defoaming agent in storage” in place $l_8$.

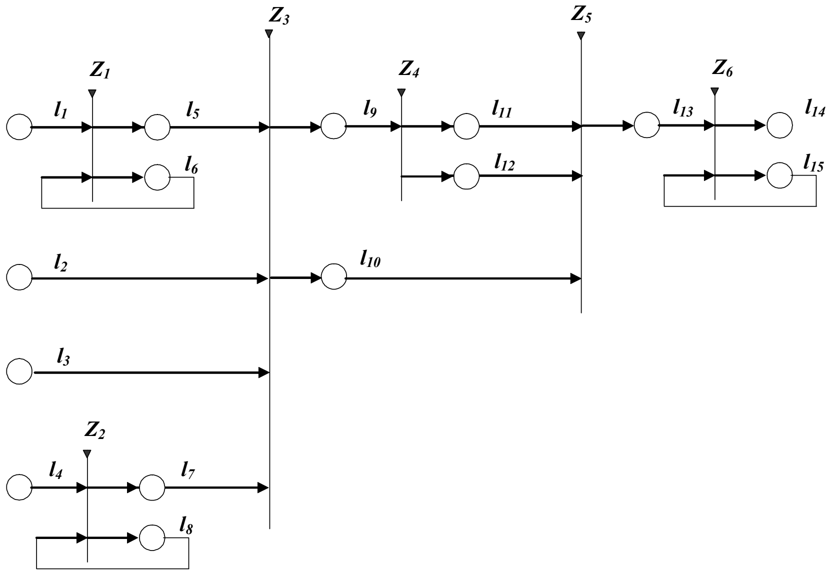


Fig. 2. GN model of foam monitoring control system

The form of the third transition of the GN model is:

$$Z_3 = <\{l_2, l_3, l_5, l_7\}, \{l_9, l_{10}\}, \begin{array}{c|cc} & l_9 & l_{10} \\ \hline l_2 & false & true \\ l_3 & true & false \\ l_5 & false & true \\ l_7 & false & true \end{array}, \wedge(l_2, l_3, l_5, l_7)>,$$

In position $l_9$ the current foam level is compared to the assigned foam critical level. If the foam level is above the critical level then a proper amount of defoaming agent is provided to the bioreactor. If the foam level is below the critical level defoaming agent is not provided to the bioreactor.

In position $l_{10}$ information of the tokens $\alpha$ (place $l_5$), $\gamma$ (place $l_3$) and $\delta$ (place $l_7$) are combined a new token $\rho$ that keeping the information about the concentration of the process variables, foam level, added amount of defoaming agent, i.e. has a characteristic “process information”.

The form of the fourth transition of the GN model is:

$$Z_4 = <\{l_9\},\ \{l_{11}, l_{12}\},\ \begin{array}{c|cc} & l_{11} & l_{12} \\ \hline l_9 & W_{9,11} & W_{9,12} \end{array},\ \vee (l_9)>,$$

where $W_{9,11}$ is "the foam level is above foam critical level" and $W_{9,12}$ - "the foam level is below foam critical level". The token $\gamma$ obtains the characteristics: "need of foam control" in place $l_{11}$ and "no need of foam control" in place $l_{12}$.

The form of the fifth transition of the GN model is:

$$Z_5 = <\{l_{10}, l_{11}, l_{12}\},\ \{l_{13}\},\ \begin{array}{c|c} & l_{13} \\ \hline l_{10} & true \\ l_{11} & true \\ l_{12} & true \end{array},\ \vee (\vee (l_{10}), \wedge (l_{11}, l_{12}))>,$$

In place $l_{13}$ the token $\rho$ keeps your previous characteristic – "process information".

The form of the sixth transition of the GN model is:

$$Z_6 = <\{l_{13}, l_{15}\}, \{l_{14}, l_{15}\},\ \begin{array}{c|cc} & l_{14} & l_{15} \\ \hline l_{13} & false & true \\ l_{15} & W_{15,14} & W_{15,15} \end{array},\ \vee (l_{13}, l_{15})>,$$

where $W_{15,14}$ is "end of the fed-batch cultivation process" and $W_{15,15} = \neg\ W_{15,14}$. The token $\rho$ obtains the characteristics "process information in the end of the process" in place $l_{14}$ and "process information during the process" in place $l_{15}$.

## 3. CONCLUSION

A generalized net model of the foam monitoring control system during a cultivation process is developed. The proposed GN model permits to control the foam level in an appropriate value. The GN model, taking into account the foam level in the bioreactor and decides if a proper amount of defoaming agent to be added to the culture medium or not.

The apparatus of generalized nets allows easily and simple in logics description of the foam monitoring control system. However, even our best control systems depend upon the information that comes to them. Control systems are decision systems. Control systems '*decide*' to change some process conditions to maintain others at desired targets. Like every decision system, poor information leads to poor decisions. A fuzzification of the foam levels based on intuitionistic fuzzy logic will be allowed to reflect the degree of uncertainty when the foam level is measured. The previous results show that the application of intuitionistic fuzzy logic to the developed GN control model [10] leads to a significant decrease of the measurement error influence. Therefore, further researches will be focused in developing of a GN model with a fuzzification of the foam levels aiming an improvement of the foam monitoring control system.

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