11th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2007, Hammamet, Tunisia, 05-09 September, 2007.

CONTROL OF BIOPROCESSES IN LABORATORY FERMENTER

Radek Sedlačík, Marie Dvořáčková, Jiří Šrámek
Thomas Bata University
Faculty of Technology
Department of Environmental Protection Engineering
Nam. TGM 275, Zlin 76001
Czech Republic

ABSTRACT
This work is focused on processing and studying of biochemical processes in laboratory fermenter. This technological equipment is connected to the Internet and makes it possible a remote control and monitoring. There is studied an influence of a solutions additions, aeration and warming or cooling. The dosed solutions were: acid and alkali solution, sugar solution and phosphoric buffer. There was utilized suspension of aerobic activated sludge which had a distinctive feedback on the changes of setting parameters and batching of solutions. There was arisen a problem with main server which caused a collapse of aerobic activated sludge. This incident provided some interesting data from anaerobic zone. This paper describes the results of the carried out experiments.
Keywords: measurement, biochemical processes feedback, fermenter, liquid phase.

1. INTRODUCTION
Recently, there has been growing interest in biological treatment of solid and water waste. Biological treatment is based on the bioprocesses proceeding in or out the microbes´ or plants´ cells. Biotechnologies make bioprocesses more intensive, reduce a quantity of biodegradable waste and give some interesting products, for example biogas.
The most common equipment applied to carry out bioprocesses is a fermenter (bioreactor). The development of the fermenter construction has moved from a universal fermentation unit to specially designed bioreactors [1]. On the other hand, most of researchers work with ordinary bioreactors and focus on the modification of the process conditions. For instance, Soni [2] has shifted to modelling and modifying the bioprocesses. Other research papers have described the influence of pressure [3], mixing [4] or control sensitivity [5].
This paper reports on the results obtained from experiments with activated sludge in a laboratory fermenter. The laboratory fermenter is a part of the system „Integrated Automation Laboratory-LABI", which is built at Tomas Bata University in Zlin. This fermenter has not been tested with real biochemical process yet.

2. EXPERIMENTAL
The fermenter was filled with 10 litres of mixture of the return aerobic activated sludge (wastewater-treatment plant Malenovice, Czech Republic) and a bio-medium. The ingredients of bio-medium are described in Table 1. The starting dry mass of this suspension was 0.889 $g.l^{-1}$. Phosphoric buffer solution, which was omitted in bio-medium, was batched manually. Conversely, acid (0.1M HCl) and alkali (0.1M NaOH) solutions were dosed via peristaltic pumps automatically according to the requested pH value. Dosing of sugar solution (20 $g.l^{-1}$; 40 $g.l^{-1}$) was remote-controlled by the operating staff. Six water quality parameters (concentration of dissolved oxygen, oxidation-reduction potential (ORP), turbidity (TRB), conductivity (G), temperature (T) and pH) were measured by new sensors and recorded on a main server of LABI project.

Table 1. The composition of 1 litre bio-medium.

Ingredient (solution)	Volume [ml]	Concentration [$g.l^{-1}$]
$MgSO_4 . 7H_2O$	1	22.5
$CaCl_2$	1	27.5
$FeCl_3 . 6H_2O$	1	0.25
$(NH_4)_2SO_4$	5	10 (c_N = 2.1)
Phosphoric buffer - KH_2PO_4 - K_2HPO_4 - $NaHPO_4 . 12H_2O$	20	(c_P = 9.7) 8.5 21.75 44.7
„trace elements“ - H_3BO_3 - $FeSO_4 . 7H_2O$ - $ZnSO_4 . 7H_2O$ - $MnSO_4 . 4H_2O$ - $CuSO_4 . 5H_2O$ - $CoSO_4 . 7H_2O$ - $(NH_4)_6Mo_7O_{24} . 4H_2O$	1	--- 0.75 3 0.1 0.5 0.05 0.1813 0.05

3. RESULTS AND DISCUSION

The main experiment was divided by server problems into the three shorter experiments. First experiment was ended by a software mistake, which disable the remote control via the Internet. The bioreactor was controlled from local industrial PC integrated in the fermenter. Second experiment was discontinued by a blackout. After this blackout, fermenter rebooted and the experiment did not continued. Discovered imperfect was corrected. Now, the system detects automatically the uncorrected experiment termination (blackout, server breakdown) and continues with set-point adjustment.

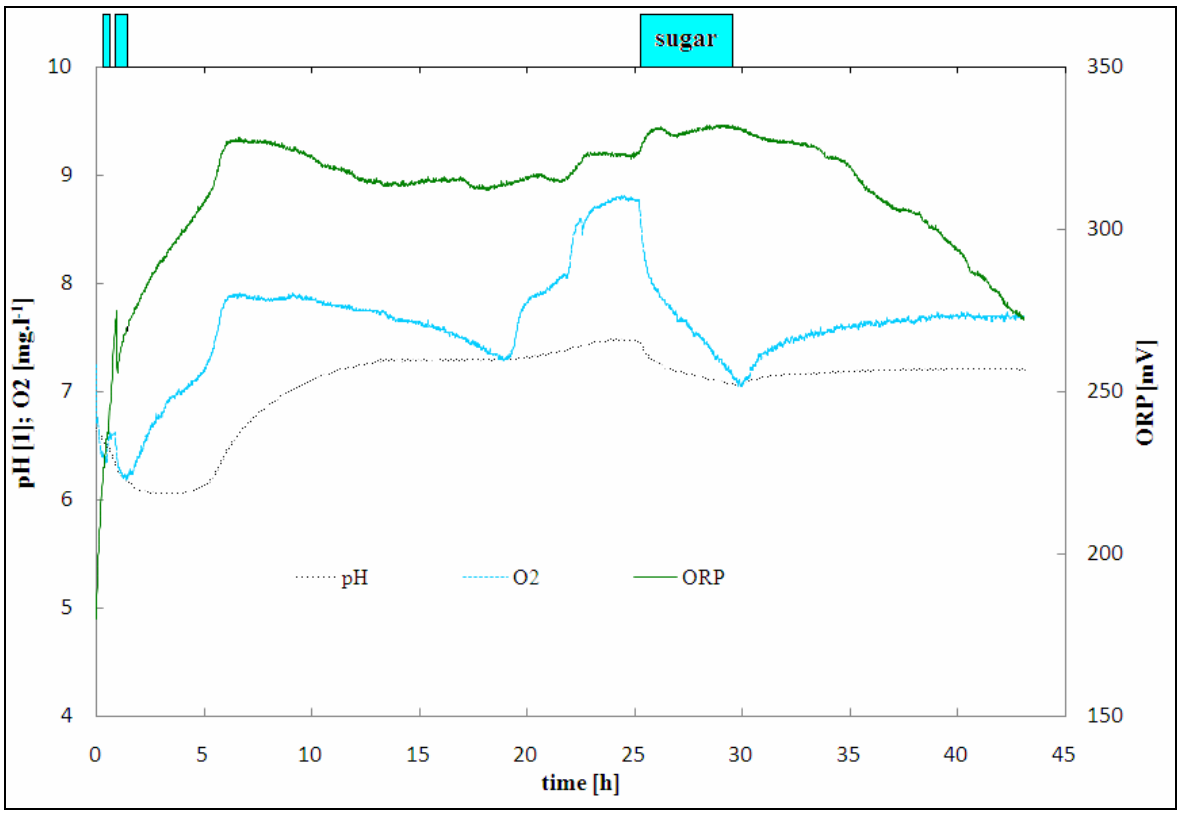

Figure 1. Dependence of pH, O2 and ORP on dosing sugar solution in the 1st experiment.

Figure 1 shows pH, concentration of dissolved oxygen (O2) and oxidation-reduction potential (ORP) during the first experiment. As can be seen, the ORP is depended on the dissolved oxygen. The fermenter was continuously aerated and as a result, concentration of O2 and ORP level grew up. Conversely, microbes dissipated oxygen by the respiration. When was dosed a sugar solution, microbes accelerated their metabolism, hence, the concentration of dissolved oxygen fell off.
Activated sludge is a complex system, which have a natural tendency to establish more or less stable equilibrium. For example, microbes´ activity is close-connected to their enzymes, which have an optimal pH level. If the pH level is going to change, the sludge sustains it on the same (optimal) value by its buffer capacity. As shown in the Figure 1, the required pH value was 7.5. Therefore, the control system dosed an alkali solution. The sludge buffer capacity neutralized a lot of added alkali. Finally, the pH level was changed after five hours. The microbes in activated sludge were adapting to new conditions for several hours. Then, the activated sludge kept a new pH value, approximately pH 7.

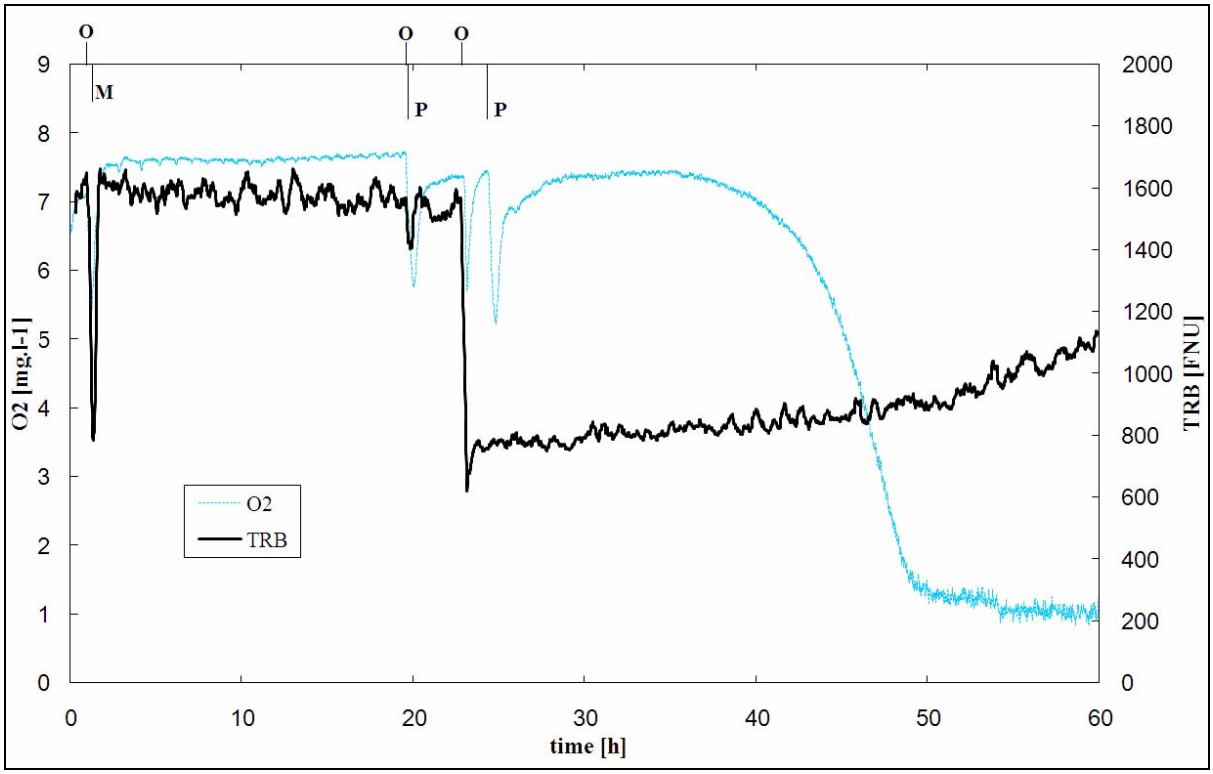

Figure 2. Relationships between O2 (aeration), turbidity (TRB) and dosing of phosphoric buffer.

Figure 2 illustrates the development of turbidity and dissolved oxygen in connection with batching the phosphoric buffer and the discontinuing of aeration. The turbidity is linked to a quantity of biomass in fermenter and indicated a growth of microbes. However, the space in the fermenter tank is narrow and the bubbles originated by aeration influence the measurement of turbidity. Therefore, we stopped aeration (O) for ten minutes, and the "bubble effect" was negated. Furthermore, the mixing of suspension was turned off (M) in the second hour to estimate a sedimentation velocity. The dramatically decline in the 23rd hour was caused by modification of output range of conversion device between TRB sensor and fermenter computer.
As revealed by Figure 2, the batching of phosphoric buffer (P) decrease a level of dissolved oxygen for a short time. Due to the fact, that the phosphoric buffer was omitted in bio-medium, microbes missed phosphorus. After dosing this macronutrient and sugar solution, microbes rapidly increased their activity between 40th and 50th hour. Unfortunately, the experiment was ended by a blackout.
Figure 3 presents data from the third experiment. This experiment was started over twelve hours after the blackout (blackout appeared at 2 a.m.). The sludge was not aerated or mixed, accordingly, aerobic conditions inverted to anaerobic. In anaerobic sludge, is mainly optimal an acid pH. We dosed alkali to level up pH. Then, the level of pH return to acid pH = 4.0.

The temperature was set on 30°C ±1°C to bring down level of dissolved oxygen. The anaerobic conditions (ORP-) were interesting, because the fermenter had operated only in aerobic (ORP+) area yet. Some small errors in measurement occurred under anaerobic conditions were fixed.

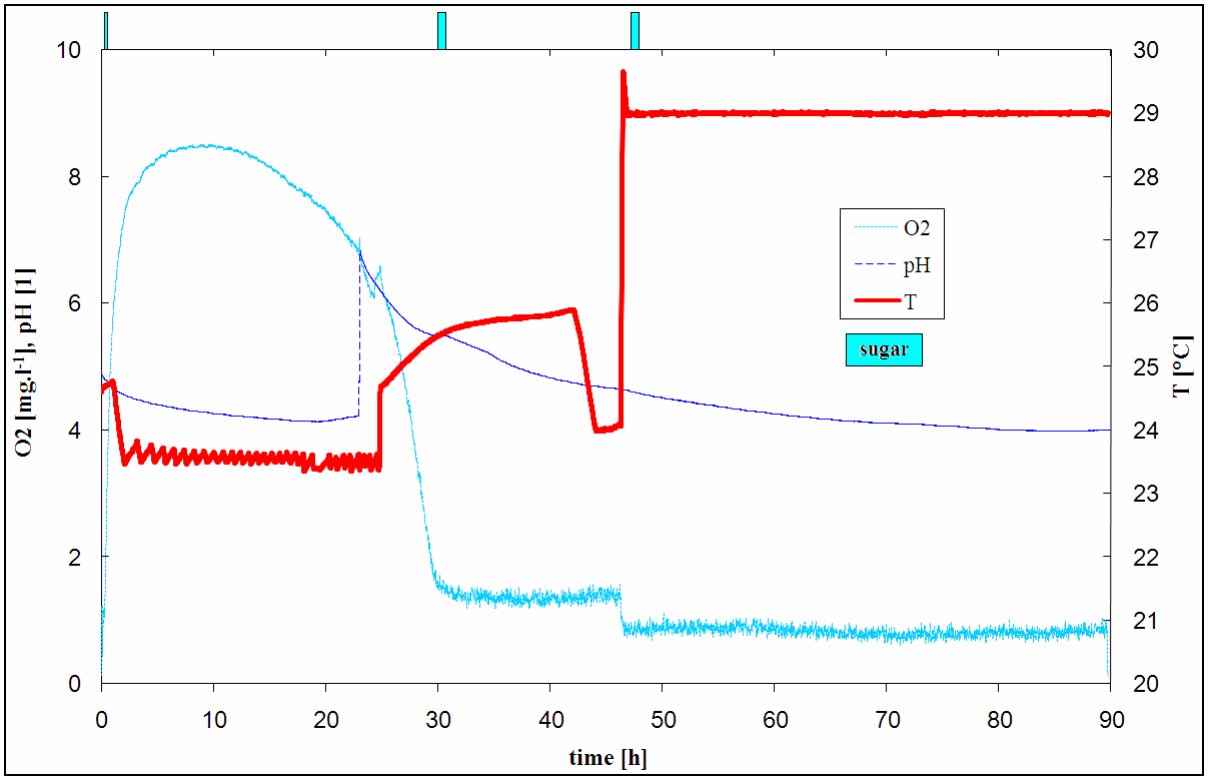

Figure 3. Variations in pH and dissolved oxygen (O2) depended on temperature (T) in the third experiment.

4. CONCLUSION

An activated sludge is a living biochemical system reacting to external interventions. Although, its feedback can be quick (dosing sugar solution) or slow (pH variations), there are limits that should not be crossed (long-time without aeration). This study has concentrated on an aerobic activated sludge, which is more resistant than a microbes´ culture with one or two microbial species.

5. ACKNOWLEDGEMENT

This work was supported in part by the Ministry of Education, Youth and Sports of the Czech Republic under grant FRVS, No. MSM 7088352101.

6. REFERENCES

[1] Tanaka, H.: Development and Practical Application of Bioreactors. Seibutsu-Kogaku Kaishi. 2006, vol. 84, no. 1, p. 2-15. ISSN 0919-3758

[2] Soni, A.S.; Parker, R.S.: Closed-loop Control of Fed-batch Bioreactors: A Shrinking-horizon Approach. Industrial & Engineering Chemistry Research. 2004, vol. 43, no. 13, p. 3381-3393. ISSN 0888-5885

[3] Knoll, A.; Maier, B.; et al.: The Oxygen Mass Transfer, Carbon Dioxide Inhibition, Heat Removal, and the Energy and Cost Efficiencies of High Pressure Fermentation. Technology Transfer in Biotechnology: From Lab to Industry to Production Advances in Biochemical Engineering/Biotechnology. 2005, vol. 9, no. 2, p. 77-99. ISSN 0724-6145

[4] Oktay, S.; Cokgor, E.U. et al.: Effect of Mixing on Primary Sludge Fermentation Products. Fresenius Environmental Bulletin. 2004, vol. 13, no. 10, p. 1024-1027. ISSN 1018-4619

[5] Stigter, J.D.; Keesman, K.J.: Optimal Parametric Sensitivity Control of a Fed-batch Reactor. Automatica. 2004, vol. 40, no. 8, p. 1459-1464. ISSN 0005-1098