MICROCOMPUTER APPLICATION IN MEASUREMENT AND CONTROL OF FERMENTATION PROCESS

BY

ARSHAD AHMAD
JABATAN KEJURUTERAAN KIMIA
UNIVERSITI TEKNOLOGI MALAYSIA
JALAN SEMARAK 54100, KUALA LUMPUR

Dr MEIRION G JONES
CHEMICAL ENGINEERING DEPARTMENT
UNIVERSITY COLLEGE SWANSEA
SWANSEA, SA2 8PP, UK.

Abstract

The application of microcomputer in measurement and control of biotechnological processes is gaining in popularity. In relation to this, an automation system was developed for the operation of a laboratory pilot scale stirred tank fermenter. The package employed a software interrupt function to create background execution for data acquisition and control operations whilst allowing other tasks being carried out in the foreground.

The system was tested by controlling dissolved oxygen concentration employing a three term controller and good control operations were achieved.

Introduction

The role of measurement and control engineering has been emphasized in production along with increasing product quality control demand and more complicated process. Unlike the normal chemical processes, control of fermentation involves more complication because of sterility requirement for the operation. In the past few decades, many developments and improvements have been made in this field to overcome the difficulty.

Measurement techniques can be classified as either on-line versus off-line or direct versus indirect methods. For control purposes, on-line technique is often desired as it provides the controller with real time data, however for fermentation processes, sterility problem may appear. In the other case, direct method is always prefered but the cost and availability factor may limit the application. Hence, indirect measurement is sometimes considered. For example, measurement of biomass concentration can be performed by carrying out species mass balance over the whole system.

Traditionally, sensors and all the necessary instrumentations are coupled with the analog controllers to form the required control system but recently, computer application has come into the scene. Due to the rapid data processing and gathering capabilities, computers can be used to replace the analog controllers to form a direct digital control scheme (DDC) or serve as a supervisor in a supervisory control strategy. The role of computer in process control encompasses many areas; part of it is summarized in figure 1.

There are many advantages offered by the computer control scheme as discussed by Govind and Powers (1982), Hatch (1980) and other workers. These advantages can be conveniently classified into four main areas :

1. Economy
   Computer control scheme reduces the installation, operation and maintenance costs. In relation to this, William (1980) compared this system to the conventional analog one, and for a lifetime of 10 years he concluded that the former possessed an advantage of 10 - 20 % over the later.

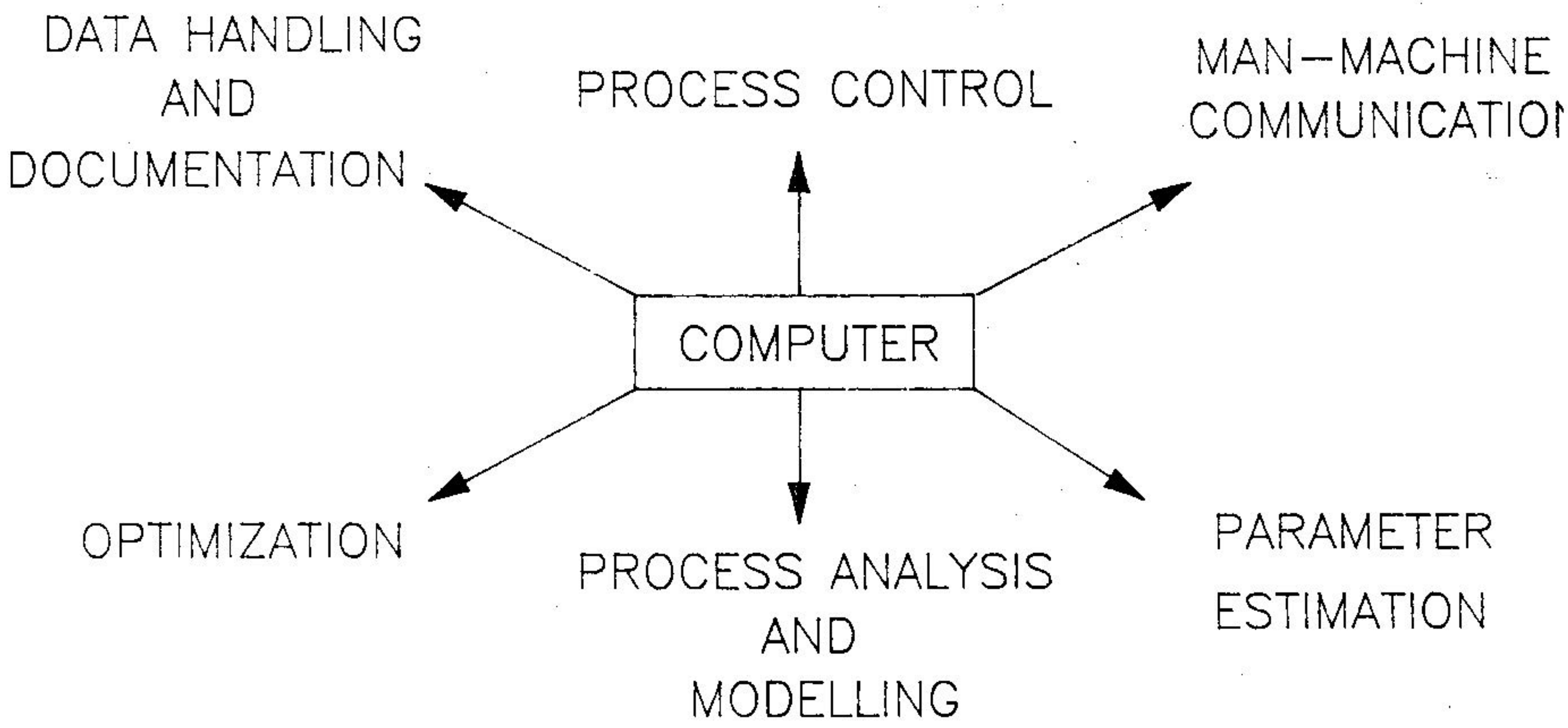


FIGURE 1 : ROLE OF COMPUTER IN PROCESS CONTROL

2. Flexibility of Operation
Being a computer program, the running procedures and conditions of the process can be adjusted without much problems. This is a distinct advantage for a multi-capacity plant, or a plant with variety of feed stock.

3. Data Documentation
Data documentation can be presented in variety of forms - graphical, table and others.

4. Environmental & Quality Control.
Better control of the process leads to better product quality. In addition, adjustment can be made to suit any changes in the process variables to avoid fluctuation in the product quality and environmental pollution.

Development of the System

In any computer-aided system, the tasks to be performed by the computer can ideally be divided into three main parts :

1. Data acquisition from environmental sensors and control action.
2. Data analysis upon the controlled and manipulated variables.
3. Data documentation and man-machine communication.

All these stages are important to observe since failure in one may result in partial or total process failure. Having this in mind, the computer aided system was developed.

This computer - aided package can be conveniently described in terms of the hardware and software system. The hardware system consists of a 70 liter fermenter, IBM personal computer, sensors, and all the necessary interfacing and pheripherals whilst the software system refers to the computer program used to carry out the fermenter operation.

As shown in figure 2, the software which was written in "BASICA" includes various important routines for the automatic operation of the fermenter. The software utilized a time interrupt function to create a continuous background executions. In the foreground, a key interrupt function was used to provide a "touch button" type of operations.

The background task was used for data acquisition and control routines. Within this module, the Savitsky-Golay data filtering algorithm (Savitsky & Golay, 1964) was inserted to overcome signal noises which

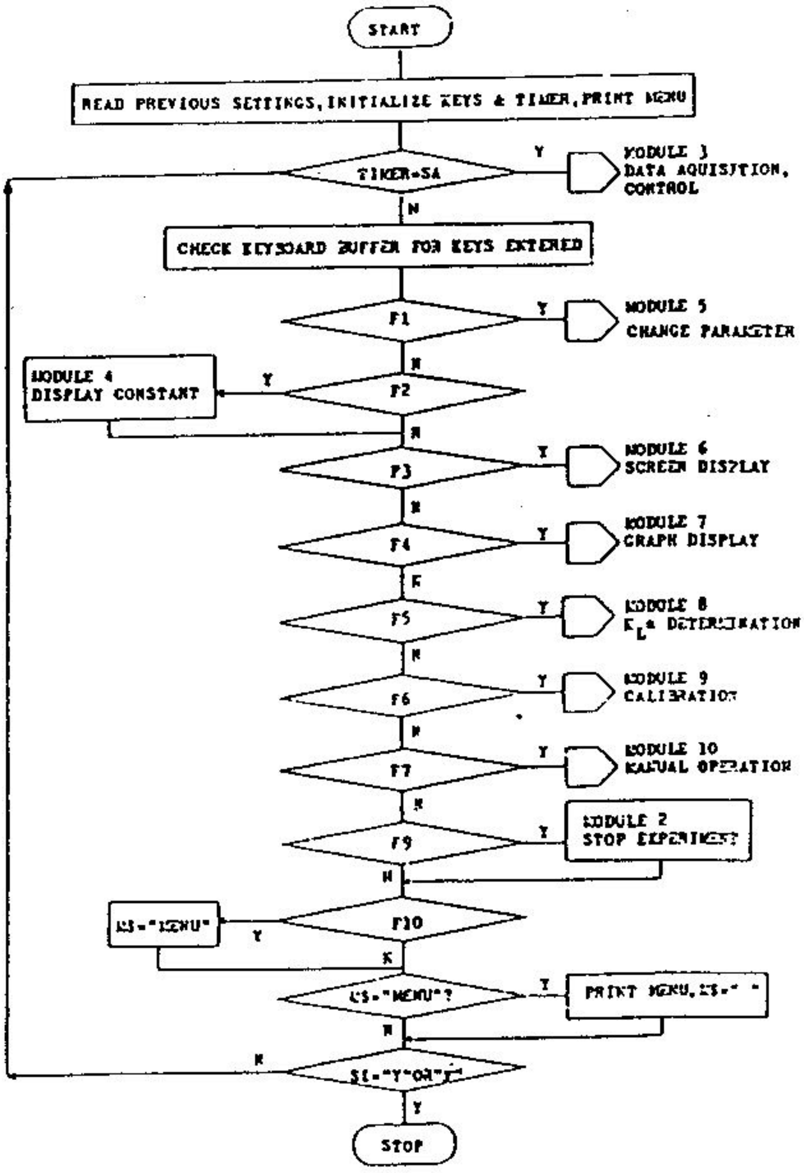


FIGURE 2 : FLOWCHART OF THE MASTER PROGRAM

sometimes appear during the operations. Since the time interrupt function is higher in priority, any execution in the foreground will be suspended if the time for the background operation elapse and resume upon finishing the task. Thus, an uninterrupted data acquisition and control operation was achieved.

In the foreground several important routines were inserted in a modular form. These includes data documentation, calibration and computer-aided start-up and shut-down procedures. In addition, choice of manual operation is available if required. In most operation, confirmation is required to avoid operator mismanipulation.

In addition, protection against power failure was provided by utilizing the auto-execution facility to avoid total lost of the process. In the case of power failure, the fermenter will be automatically operated using the previous set points as soon as the power resume.

Case Study - Control of Dissolved Oxygen Concentration

The reliability of the system developed was tested by controlling dissolved oxygen concentration in the fermenter. In this experiment, a Sodium Sulphite solution was used as the oxygen sink and three control strategies were considered, these were :

1. Control by manipulating the aeration rate
2. Control by manipulating the agitation rate
3. Control by simultaneously varying the aeration and agitation rate.

In all cases, three term control algorithm (PID) was used and good control conditions were achieved. In all the strategies studied, the closed-loop process response were stabilized in less than 5 minutes (see figure 3). Comparing the overall performance of the control strategies, the first two were somewhat competitive. However, control by agitation will not be suitable for system which is not mechanically strong like in the case of filamentous organisms while control by aerations is not suitable for high protein system as excessive foaming may occur. These then limits the applications of the two techniques. The third scheme was the compromise between the first two. In this case both actions act simultaneously thus providing a more sensitive control system.

In addition the effect of various disturbances were also considered and as shown in figure 4, stable conditions were achieved within limited time period.

FIGURE 3

TYPICAL CLOSED-LOOP PROCESS RESPONCES

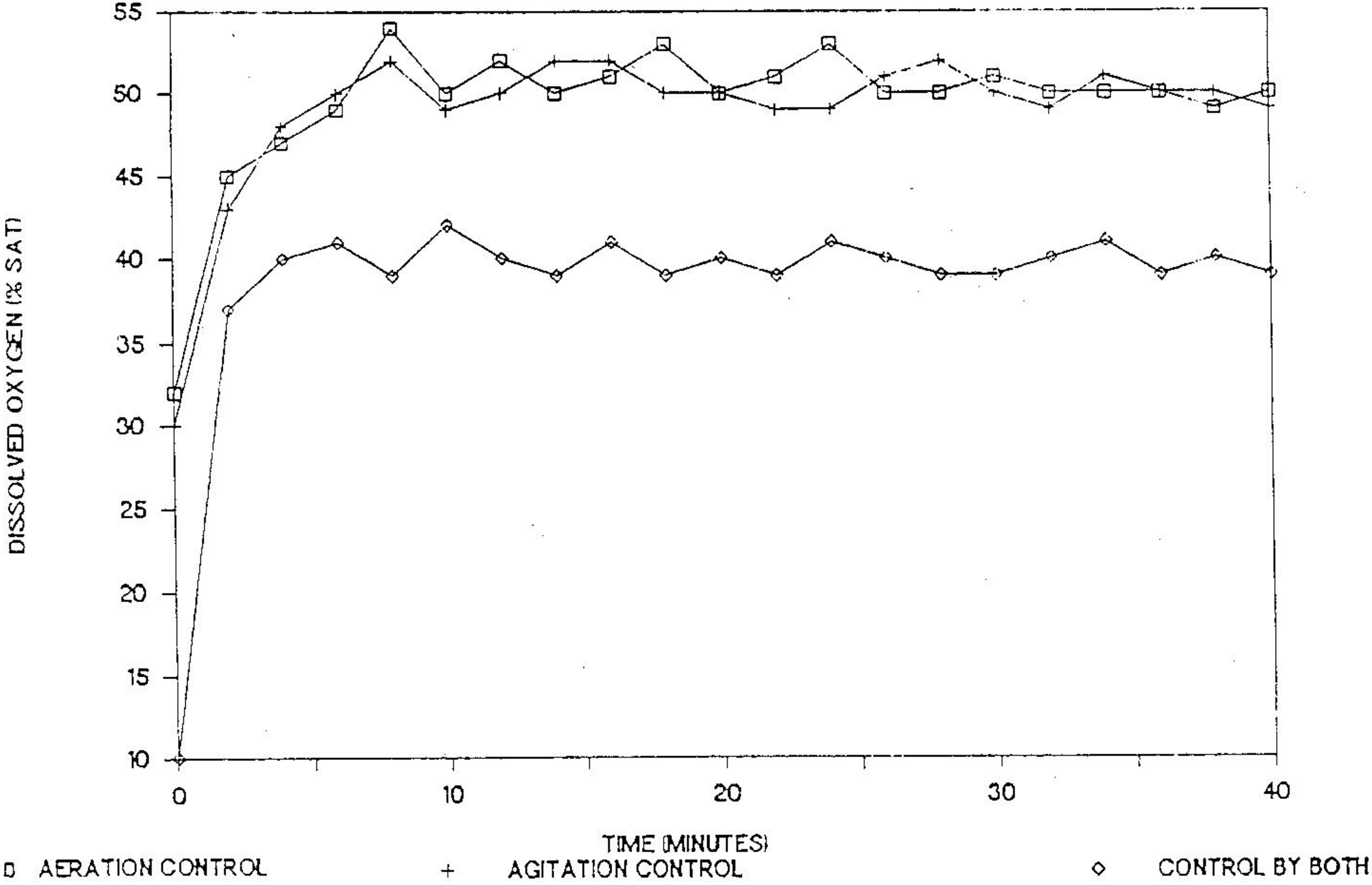
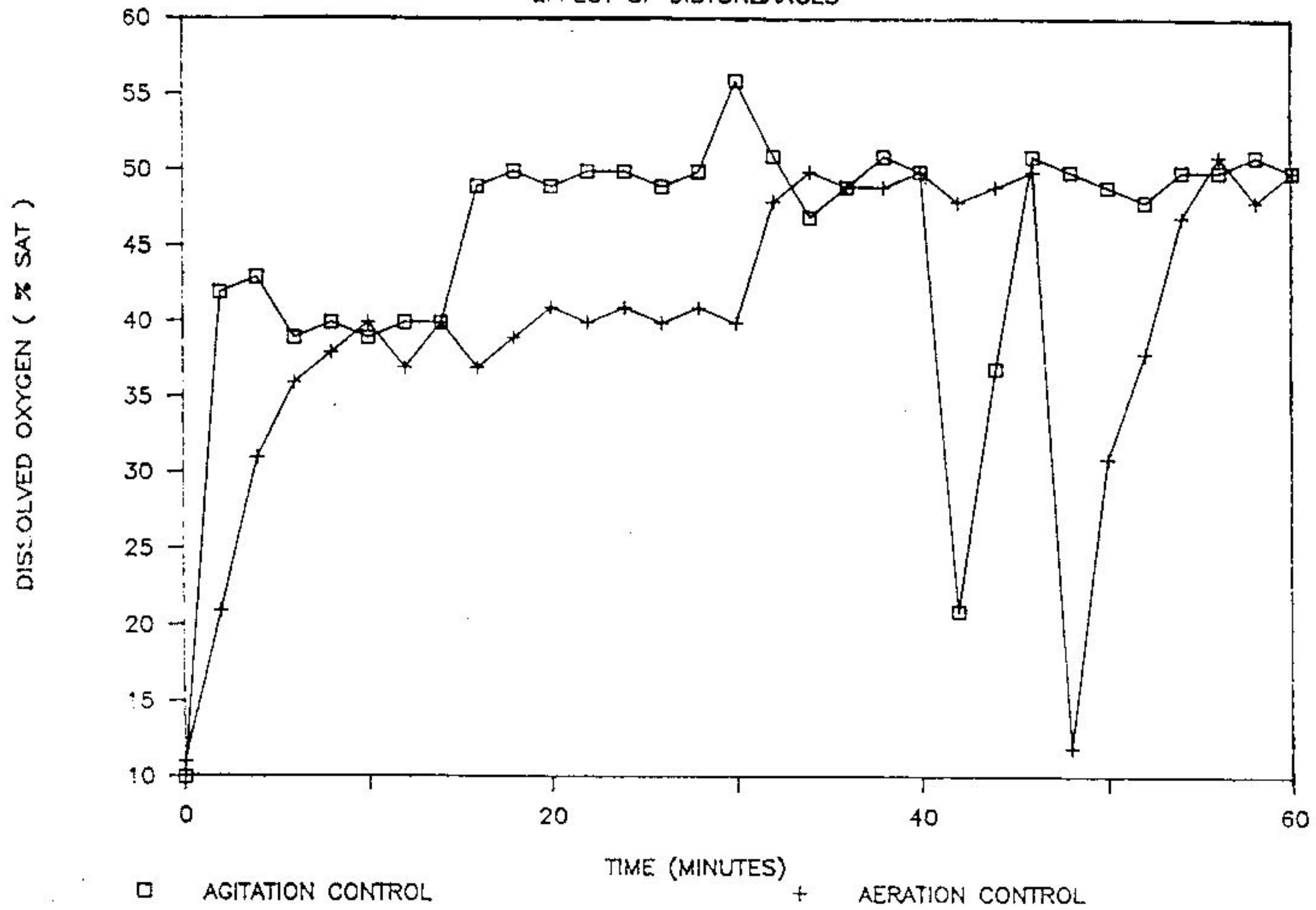


FIGURE 4

EFFECT OF DISTURBANCES



Discussion and Conclusion

The work undertaken here was preliminary to the development of a complete computer-aided fermentation system. At this stage, the operating system for the fermenter has been commisioned with several important functions being installed. These include data acquisition and control modules and other functions as described previously. In the case of the hardwares, the above experiment has prooved their stability and reliability for long operations.

The structure of the software offers a significant advantage to the overall functionality of the package. Being in a modular form, further extension can be easily made by expanding the existing modules or creating new ones.

This simple but robust microcomputer control package has been prooven reliable for operation, however requires further extension such as automatic sequencing of sterilization procedure and additional control loops to be applicable for normal fermentation processes. Other developments like the on-line substrate, product and biomass determination via direct or indirect method, and on-line optimization would be an added advantage to the system. All these operation can be easily and economically achieved by having a microcomputer on line.

Finally, based on this study it can be concluded computer application has simplified and reduced the necessary steps and stages in the operation of a fermenter. In addition, extra capabilities were offered to make feasible application for very complicated processes and therefore showing a bright future.

References

Govind, R. & Powers, G.J.,(1982), "Control system synthesis strategies", AIChE Journal, 28, 60

Hatch, R.T., (1982), "Computer applications in analysis and control of fermentation", Ann. Report on Fermentation Process, G.T. Tsao Ed., London, Academic Press, 5, 291-312

Savitsky, A. and Golay, M.J. (1964), "Smoothing and differentiation of data by simplified least squares procedures", Anal. Chem. 36, 1627-1638

William, D. (1980), "Microprocessors enhance computer control of plants"in Practical Process Instrumentation and Control,368- 372, Mc GrawHill book co. N. York