A WORKSTATION FOR VISUALIZATION OF FLUID AND PARTICLE MOTION IN AN ENZYMATIC FLUIDIZED BED REACTOR FOR BLOOD DEHEPARINIZATION

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ABSTRACT

An integrated workstation for the study of fluid and particle motion in a fluidized bed reactor, which will permit effective and safe drug removal within an extracorporeal system, was constructed. Our main objective was to identify and investigate those flow conditions which will yield high efficiencies of heparin removal and low levels of blood damage. This workstation, which can be used as a general purpose fluid and particle motion analyzer, enabled the investigation of the complex dependence of the overall reactor performance on flow conditions at a micro-level. The workstation's main features include real-time capture and analysis of video-information, a user-friendly interface, graphics displaying various time-dependent flow parameters, and image processing features for selecting the area and image contrast for visualization.

INTRODUCTION

This workstation enables the visualization and analysis of particle motion, at a micro-level. The input to the system is video information. In our research, the video information was obtained from laboratory experiments in a small (5cm. by 5cm.) fluidized bed reactor utilizing using 0.1mm transparent blood substitutes and cross-linked agarose particles as microcarriers for immobilized heparinase and a continuous flow of transparent. Also human blood and the same agarose particles with immobilized heparinase were used in ***in vitro*** experiments. Large polymer microspheres (144 um) and 1g/L blue dextran solution were also applied as the tracers in studying the liquid and particle flow patterns. The reactor itself was positioned on a shaker which moved the reactor in an oscillatory manner. The shaker speed as well as the rate of fluid flow into the reactor could be controlled.

In testing the workstation and its image processing and graphics features, our goal was to put the system to test in allowing the system to graphically display particle motion changes given changes in various paramters. For example, the workstation should be powerful enough to respond to sudden changes in reactor speed and to display the subsequent particle motion kinematics.

METHODS

The processing of the video information proceeds along these steps: 1) The user specifies a region of interest (ROI) in the image, 2) an image is grabbed and stored on a frame buffer, 3) the time of image capture is recorded, 4) within the ROI, pixel after pixel is processed through a filtering algorthim, 5) valid pixels' locations are stored, 6) after the entire image has been processed, an averaging algorithim is performed, 7) the locations and times are stored in a file on disk, and 8) steps 2 through 7 are repeated for as many images as specified.

In our research, the immobilized agarose particles are white and fairly transparent in a strong back-light. Therefore, it was easy to distinguish their locations. The viewed portion of the reactor was roughly 5cm. by 5cm. and the image frame buffer's dimensions were 512 by 512 pixels. Each pixel therfore mapped to a particle of size 0.1mm. This mapping proved to be quite convenient since the size of a particle could be given in terms of whole pixels.

The workstation also enables the user to specify the characteristics of the particles to be tracked or processed. These characteristics include the size of the particle and the color range in which the particle appears. One can get an idea of the color range of the particle by using the workstation's sampling feature which gives a histogram of the percent of particles within different color ranges. Therefore, image "noise" can be easily distinguished.

IEEE ENGINEERING IN MEDICINE & BIOLOGY SOCIETY 10TH ANNUAL INTERNATIONAL CONFERENCE--1451
CH2566-8/88/0000--1451 $1.00

CONCLUSIONS

As an example of the use of the workstation, we consider the data from a video in which the reactor speed is suddenly increased, midway, during a thirty second period. Specifically, the speed is increased from 100 rmp to 200 rmp. The flow rate into the reactor was kept constant at 100 cc/min.

In Fig. 1, the average locations of the particles is illustrated. In Fig. 2, the average horizontal location of the particles with repsect to time is shown. In Fig. 3, the average vertical location of the particles with respect to time is shown. Fig. 4 shows the average displacement of the particles with respect to time. Finally, Fig. 5 shows the average velocity the with respect to time.

The reactor, as mentioned before, oscillates in the horizontal direction. Fig. 2 reveals this fact. Fig. 3 shows that the particles also move in a vertical fashion. This result is verified in viewing the original video tape. Figs. 4 and 5, in particular, reveal the sudden change in reactor speed at approximately the 15 second mark.

In this example, we have taken velocity and displacement measurements; however, other quanitites such as shear velocity can also be computed and easily visualized.

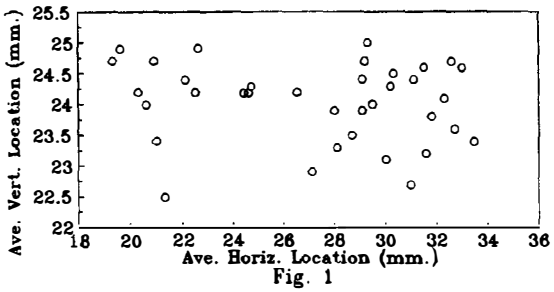

Fig. 1

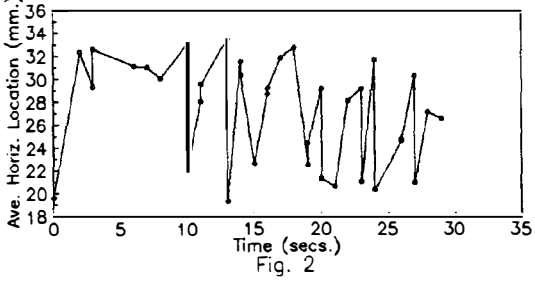

Fig. 2

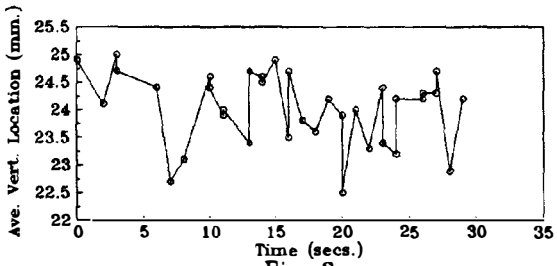

Fig. 3

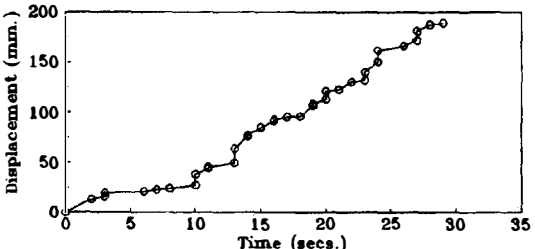

Fig. 4

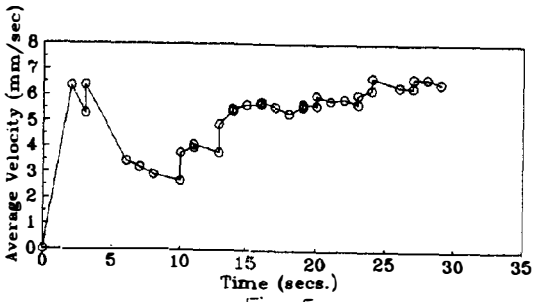

Fig. 5

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