CHAPTER 8

DYNAMIC MATRIX CONTROL OF THE ACETYLENE HYDROGENATION PROCESS

8.1 Introduction

This chapter presents the dynamic matrix control application and the results. The last application that discussed, is the study of the effect of reconciled data on the control performance.

8.2 Dynamic matrix control simulation of an acetylene hydrogenation process

The objective of an acetylene hydrogenation process is to remove acetylene from ethylene product. The set point is to maintain the level of acetylene in ethylene product at 0.1 ppm. The acetylene concentration can be controlled by the inlet temperature but the temperature is more effectively to the reaction. Thus, the change of temperature value should be slowly and little. The pre-heated system is added in the process for this reason. The pre-heated system comprises of one control valve and one heat exchanger. The inlet temperature is controlled by the by-pass flow between the valve and the heat exchanger. On the other hand, the acetylene concentration is controlled by the by-pass flow.

8.2.1 The controller design

Like the dynamic matrix control theory that presented in chapter 3, the controller design is made from the convolution model between the control variable and manipulate variable. Thus, first, the convolution model between an outlet acetylene fraction and a valve position of an acetylene hydrogenation process model must be found out through the open loop relationship between both of variables as shown in the Figure 8.1

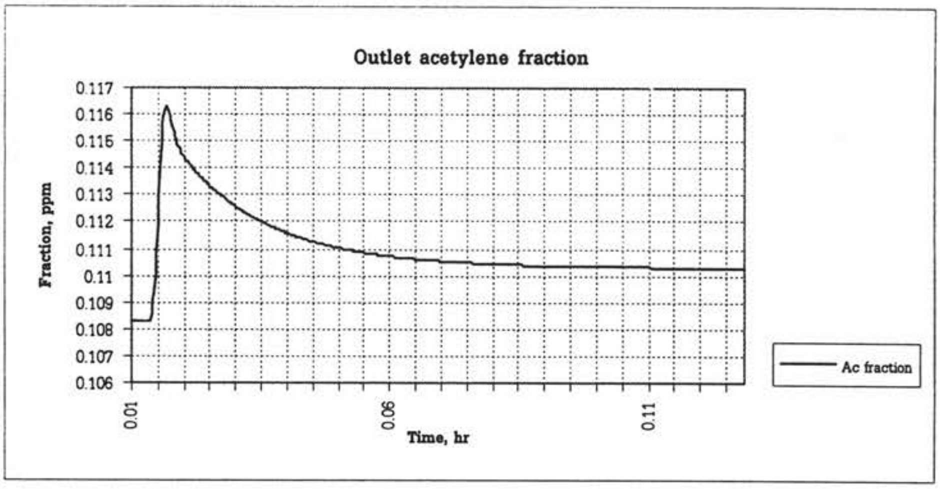

Figure 8.1 The convolution model of outlet Ac fraction by increasing valve position 1%

The matrix of the convolution model (***A***) can be found out through the Figure 8.1. The elements of the matrix ***A*** are the value of acetylene fraction at each time step. The tuning parameters of DMC (U, V, and Δt) are varied to achieve the best controller design for an acetylene hydrogenation process as

- V = 3, U = 2, a = 40, Δt = 21 seconds f1 = 1000, and f2 = 0
- V = 3, U = 3, a = 40, Δt = 21 seconds f1 = 1, and f2 = 0
- V = 4, U = 2, a = 40, Δt = 21 seconds f1 = 1000, and f2 = 0
- V = 3, U = 2, a = 120, Δt = 7 seconds f1 = 100, and f2 = 0
- V = 3, U = 3, a = 120, Δt = 7 seconds f1 = 1, and f2 = 0
- V = 4, U = 2, a = 120, Δt = 7 seconds f1 = 1000, and f2 = 0

The comparison of the control performance of DMC for each the set of tuning parameters and the control performance of PID are shown in Figure 8.2, 8.3, 8.4 and the error accumulations for each control response are shown in Table 8.1. Figure 8.2 shows the performance of controllers in the outlet acetylene fraction(the control variable) sense to the step change in total mass flow. Figure 8.3 shows the performance of controllers in the valve position sense and Figure 8.4 shows the performance of controllers in the inlet temperature sense.

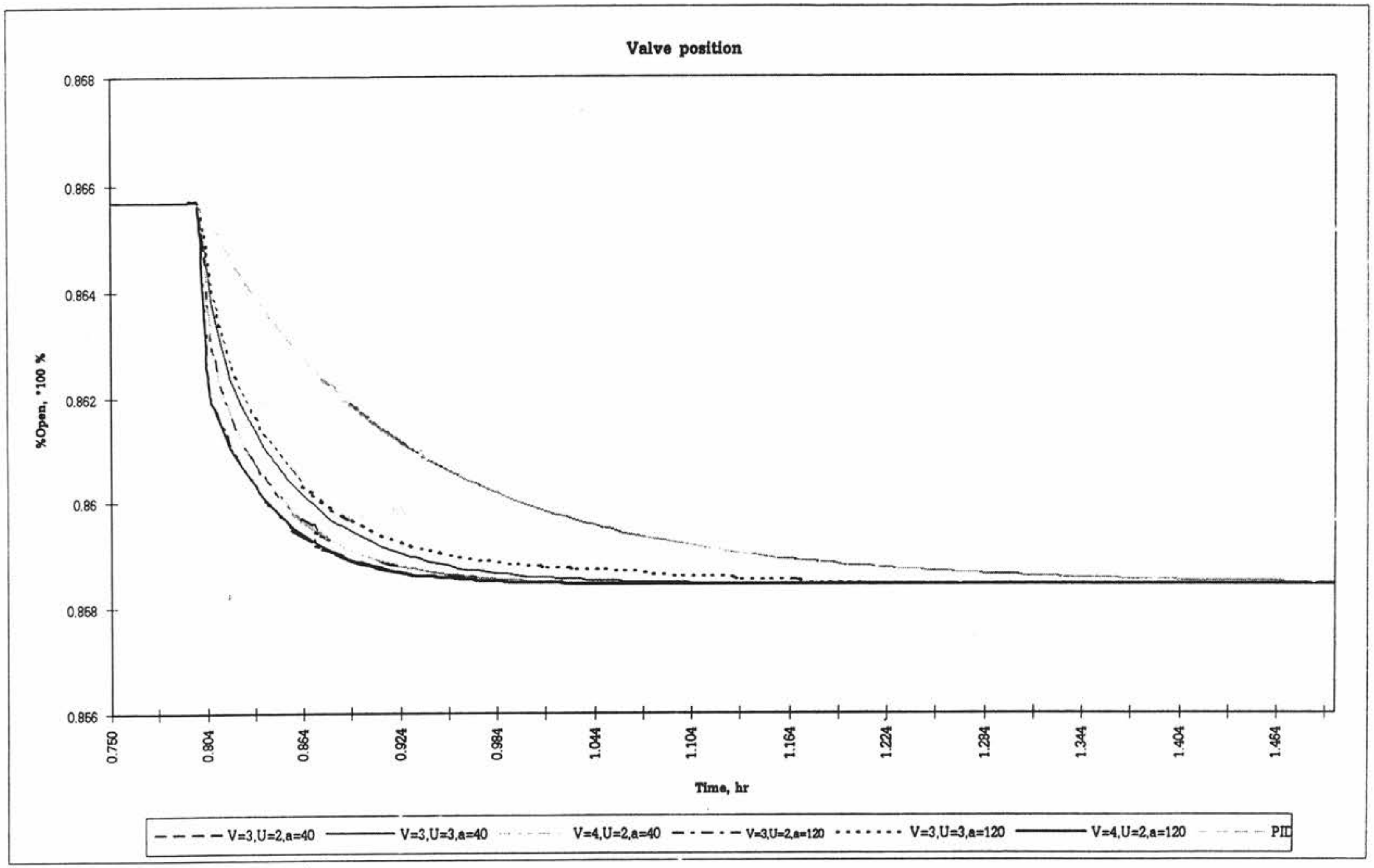

Figure 8.2 Valve position change to step change in total mole flow (increasing 1%)

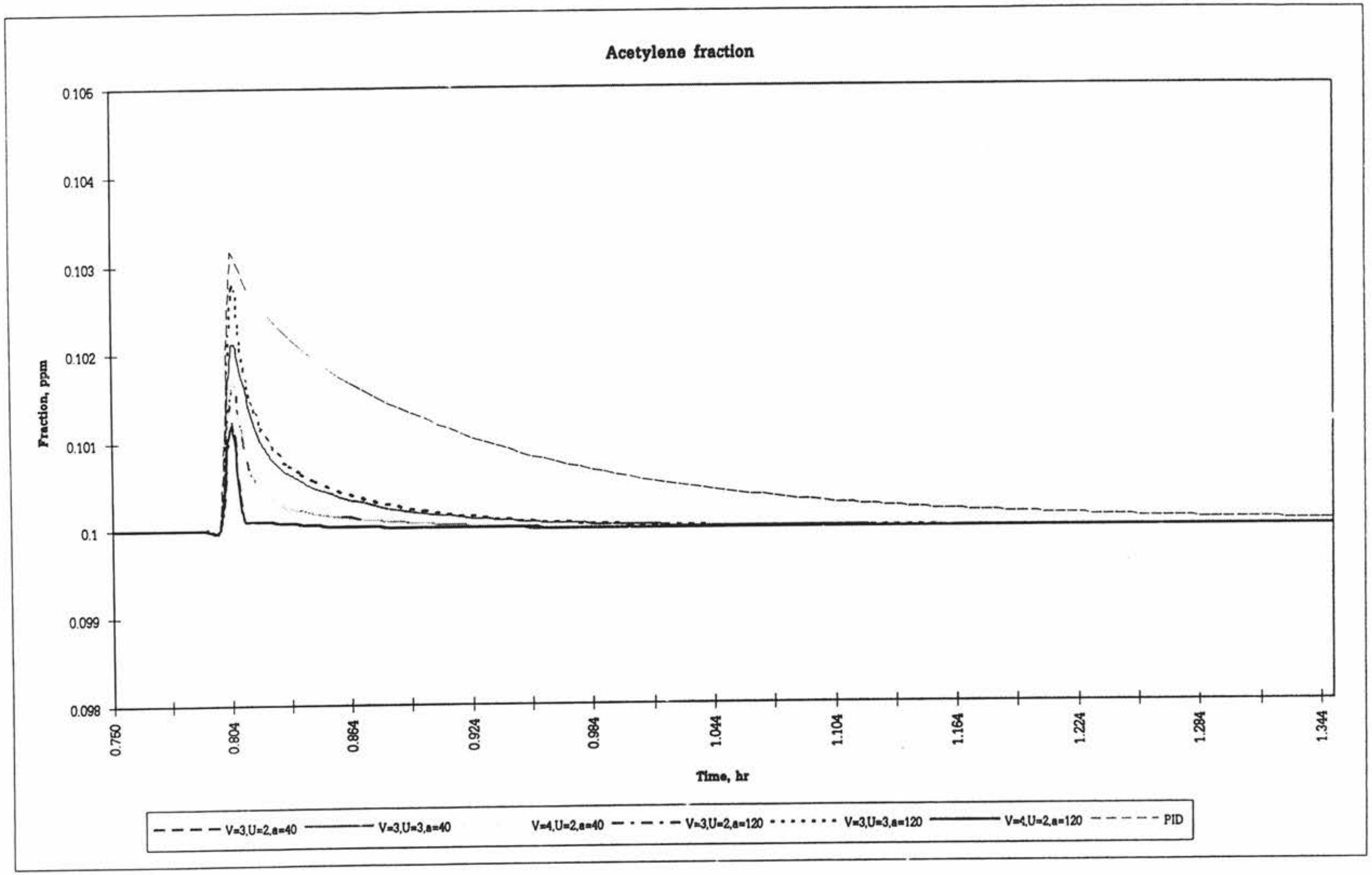

Figure 8.3 Outlet Acetylene response to step change in total mole flow (increasing 1%)

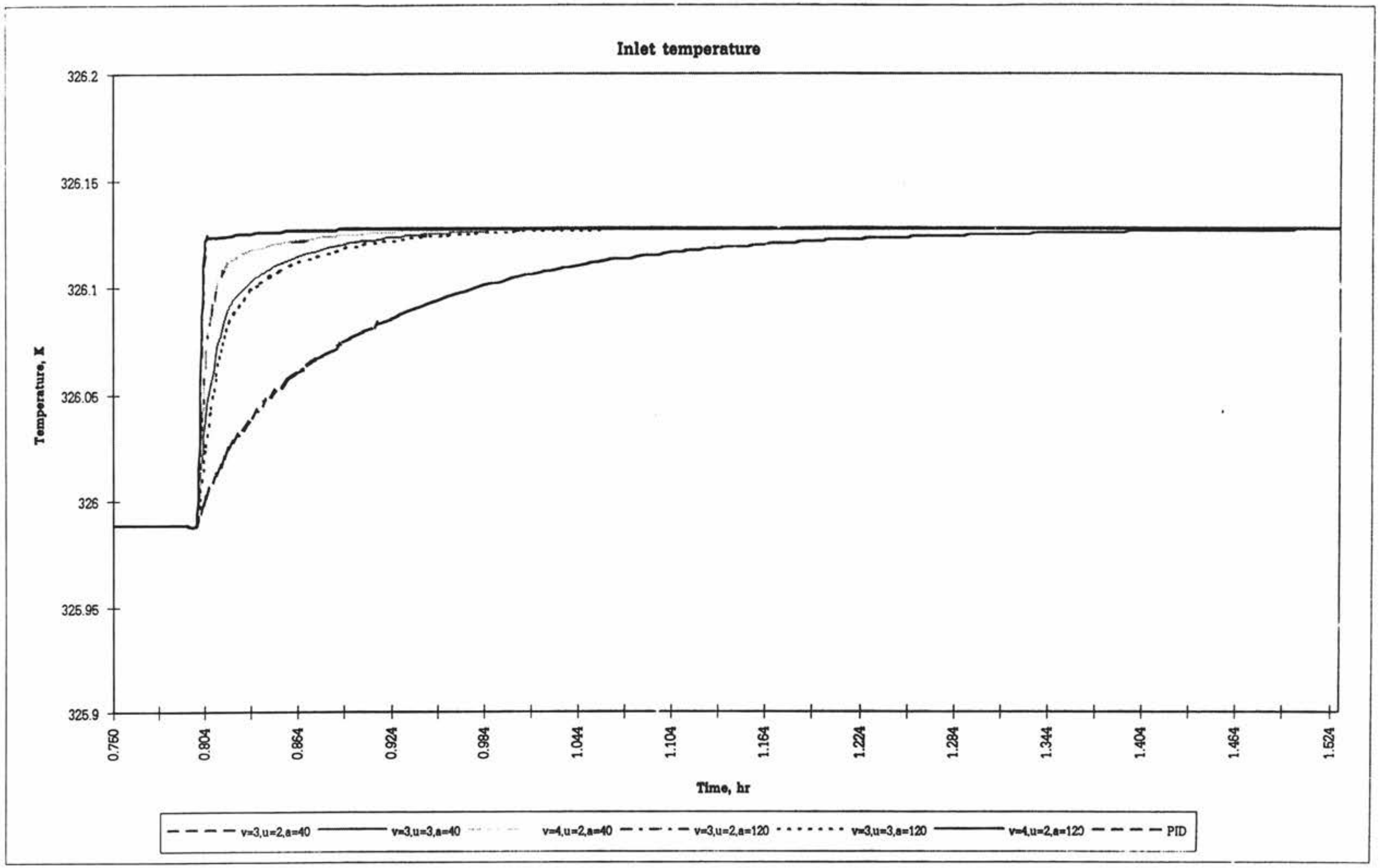

Figure 8.4 Inlet temperature response to step change in total mole flow (increasing 1%)

Table 8.1 Control performance for each controler

Control design					Sum of error
V	U	a	f1	f2	(IAE)
3	2	40	1000	0	0.006076
3	3	40	1	0	0.012301
4	2	40	1000	0	0.00606
3	2	120	1000	0	0.002082
3	3	120	1	0	0.014856
4	2	120	1000	0	0.002102
PID					0.060036

From Table 8.1, the IAE value of the DMC with V=3, U=2, a=120 and the DMC with V=4, U=2, a=120 are nearly and are smaller than the others. Similar to the IAE value, the overshoot and the setting time of the both controller are nearly and are smaller than the others

From Figures 8.2 - 8.4, the control performance of the DMC with V=3, U=2, a=120 and the DMC with V=4, U=2, a=120 are the best result. They can control the acetylene fraction to achieve the set point before the other controller, but the DMC with V=4, U=2, a=120 need the larger data based. Thus, the suitable controller design is the DMC with V=3, U=2, a=120. The DMC controller with V=3, U=2, a=120 gives

- The setting time = 21.6 seconds that is about 18.4% over the value of PID controller
- The overshoot = 0.0013 ppm that is about 39.4% over the value of PID controller
- The amount of acetylene that passed out with the product is reduce by 96% over by using PID controller

8.2.2 The control capability of the DMC with V=3, U=2, a=120.

The control capability is tested with the difference feed conditions and the step change in the set point. All control results are compared with the results from PID control and shown in Figure 8.5-8.22. All Figures show the performance of the controller in terms of outlet acetylene concentration, the valve position action, and the inlet temperature.

Figure 8.5 shows the response obtained using the selected DMC controller to set point change. The set point is changed from 0.1 ppm to 0.15 ppm of outlet acetylene concentration. The outlet acetylene concentration has little oscillation and overshoot, and takes a shorter time to reach the set point than those of using the PID controller. The performance of the PID controller to the same condition is shown in Figure 8.6.

Figure 8.7 shows the response obtained using the selected DMC controller to set point change. The set point is changed from 0.1 ppm to 0.07 ppm of outlet acetylene concentration. The outlet acetylene concentration has little oscillation and overshoot as same as the response to the positive set point change, and also takes a shorter time to reach the set point than those of using the PID controller. The performance of the PID controller to the same condition is shown in Figure 8.8.

Figure 8.9 shows the response obtained using the selected DMC controller to step change in feed temperature. The feed temperature is changed from 320K to 325 K. The outlet acetylene concentration has more oscillation and bigger overshoot than the response to the set point change, and maintains a shorter time to reach the set point than those of using the PID controller. The performance of the PID controller to the same condition is shown in Figure 8.10.

Figure 8.11 shows the response obtained using the selected DMC controller to step change in feed temperature. The feed temperature is changed from 320K to 315 K. The outlet acetylene concentration has more oscillation and bigger overshoot than the response to the set point change but if compared with the the response to positive step change in feed temperature, it has the smaller oscillation and overshoot. Similar to the other cases, it maintains a shorter time to reach the set point than those of using the PID controller. The performance of the PID controller to the same condition is shown in Figure 8.12.

Figure 8.13 shows the response obtained using the selected DMC controller to step change in feed flow rate. The flow rate is increased 2%. The outlet acetylene

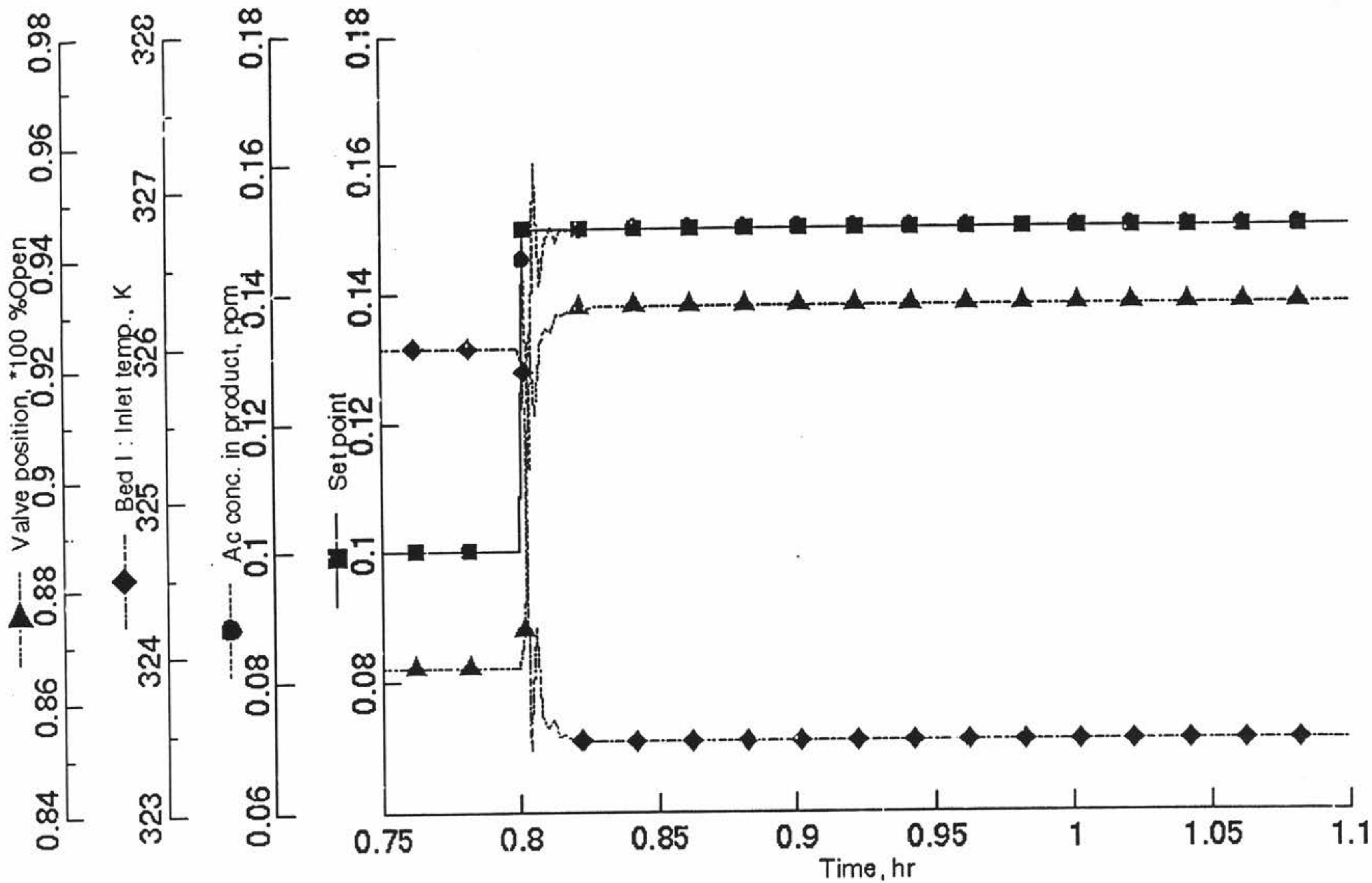

Figure 8.5 The control performance of the selected DMC to step change in set point (from 0.1 to 0.15)

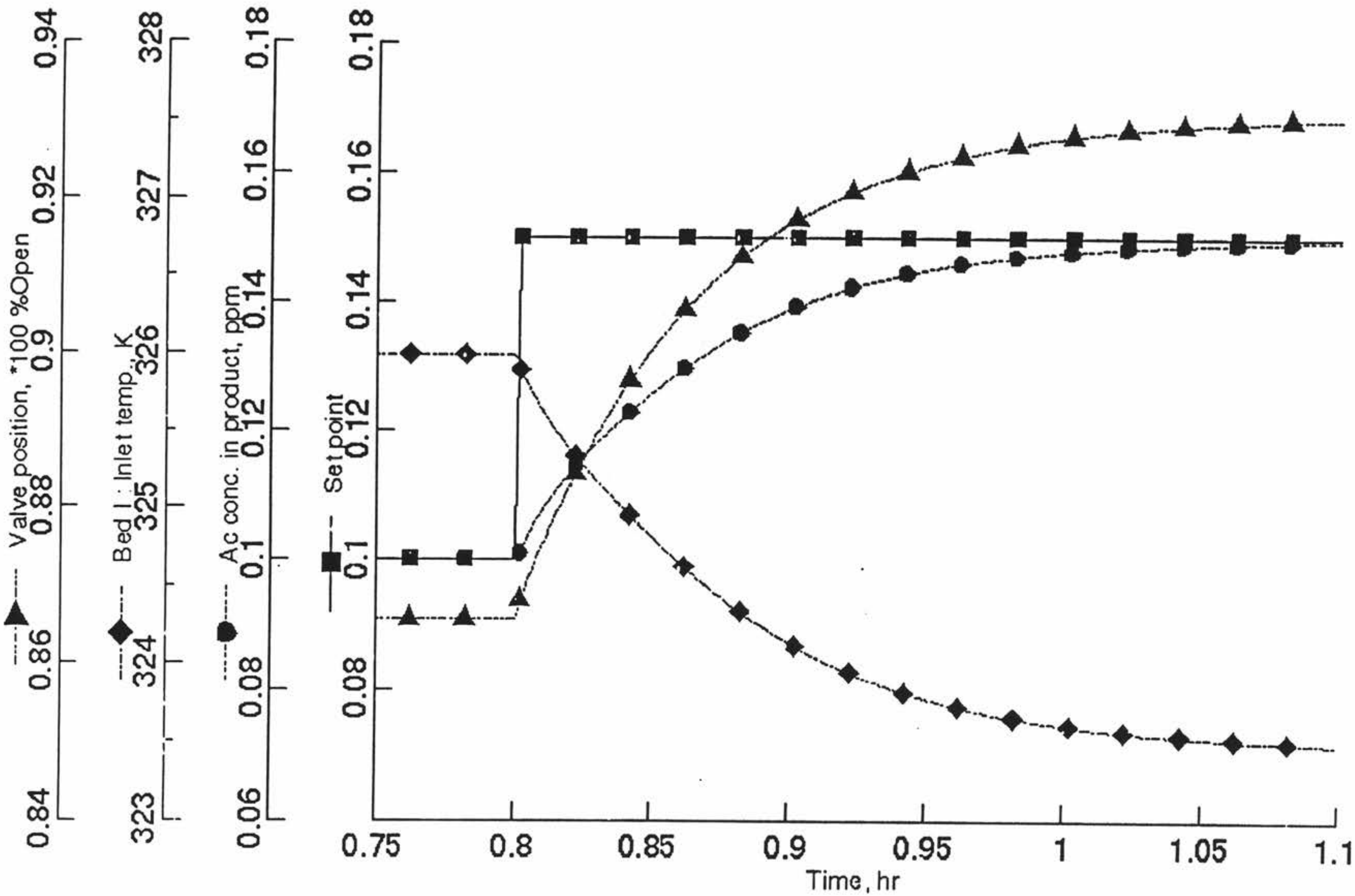

Figure 8.6 The control performance of the PID to step change in set point (from 0.1 to 0.15)

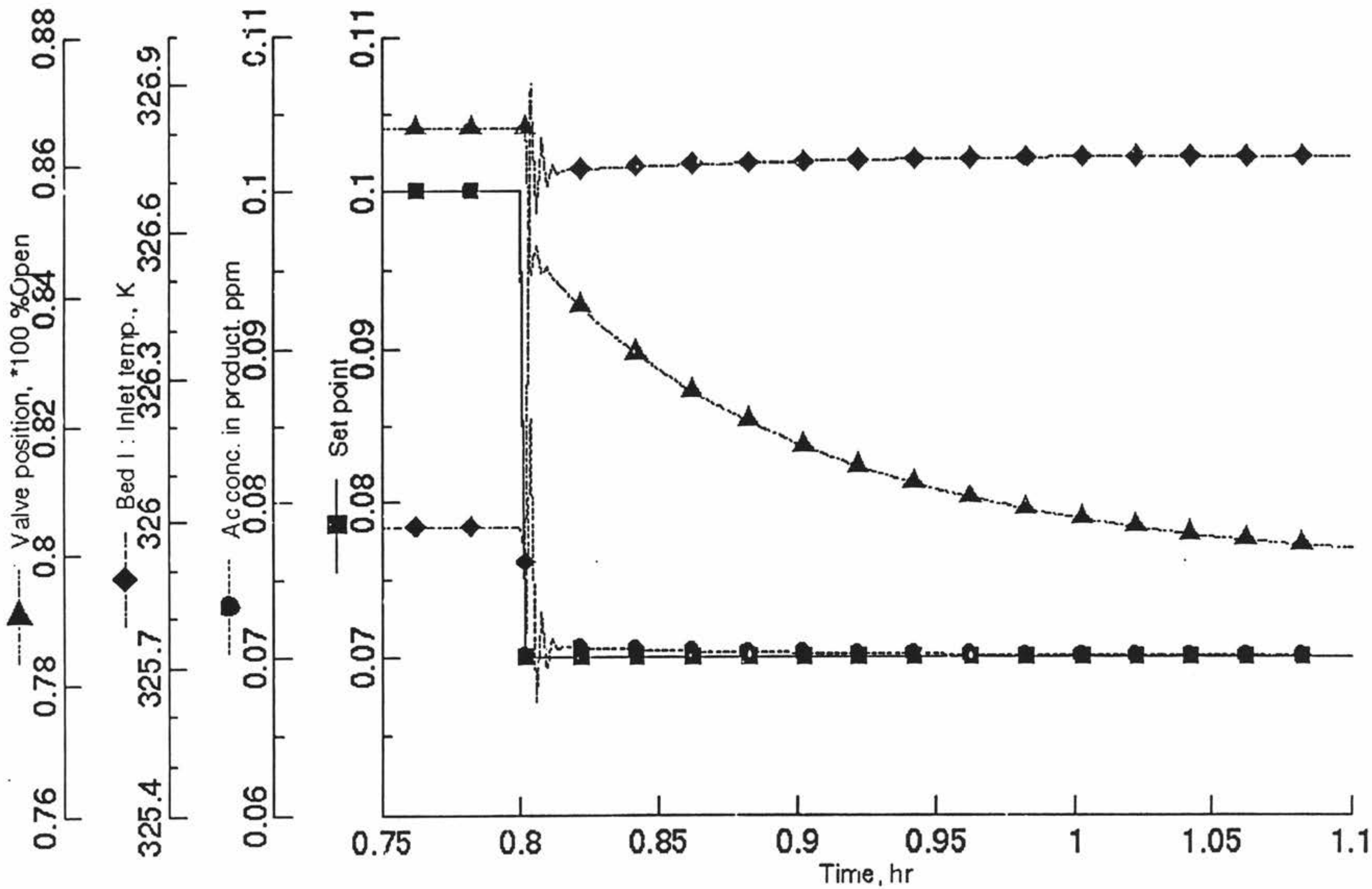

Figure 8.7 The control performance of the selected DMC to step change in set point (from 0.1 to 0.07)

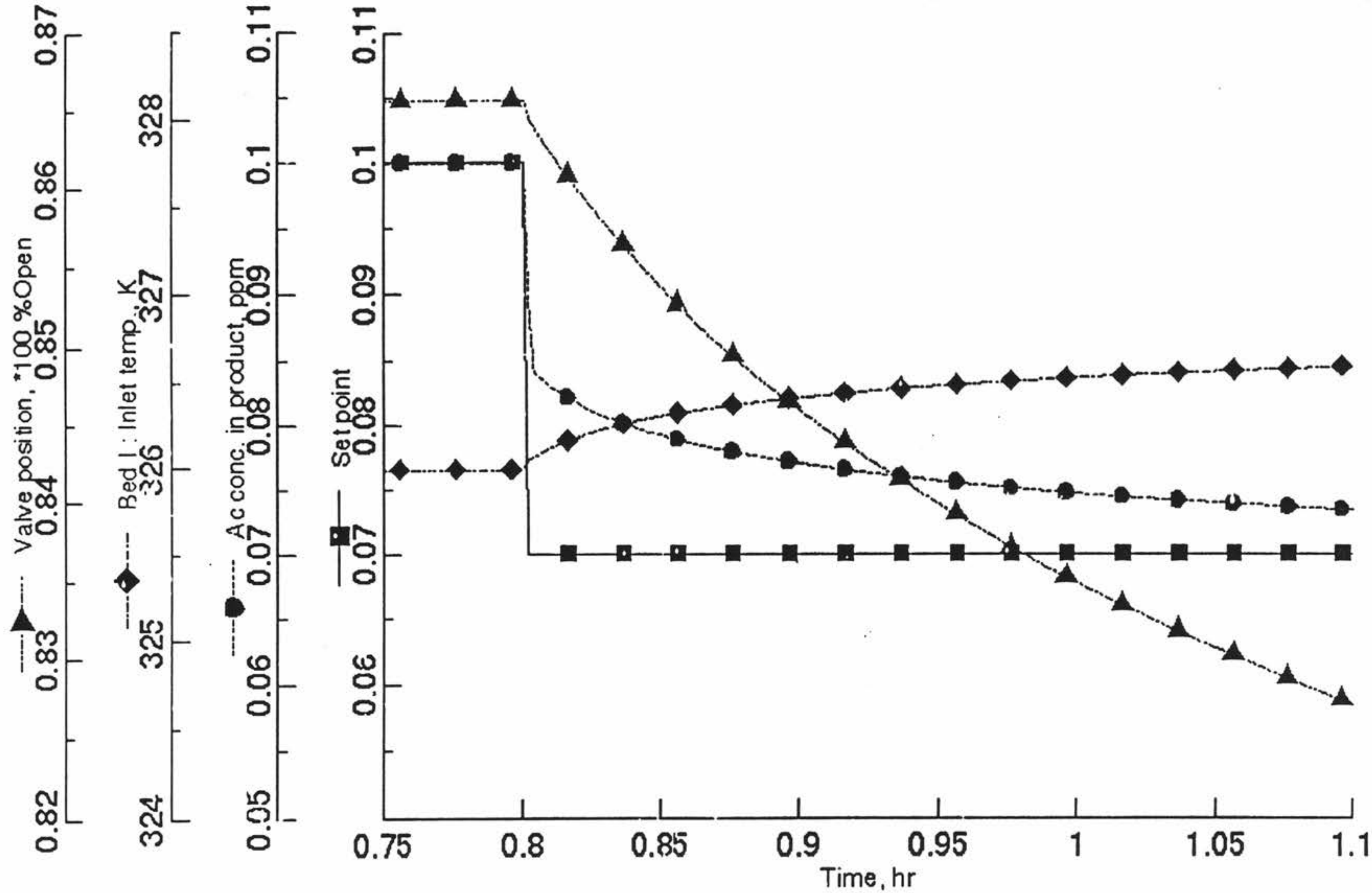

Figure 8.8 The control performance of the PID to step change in set point (from 0.1 to 0.07)

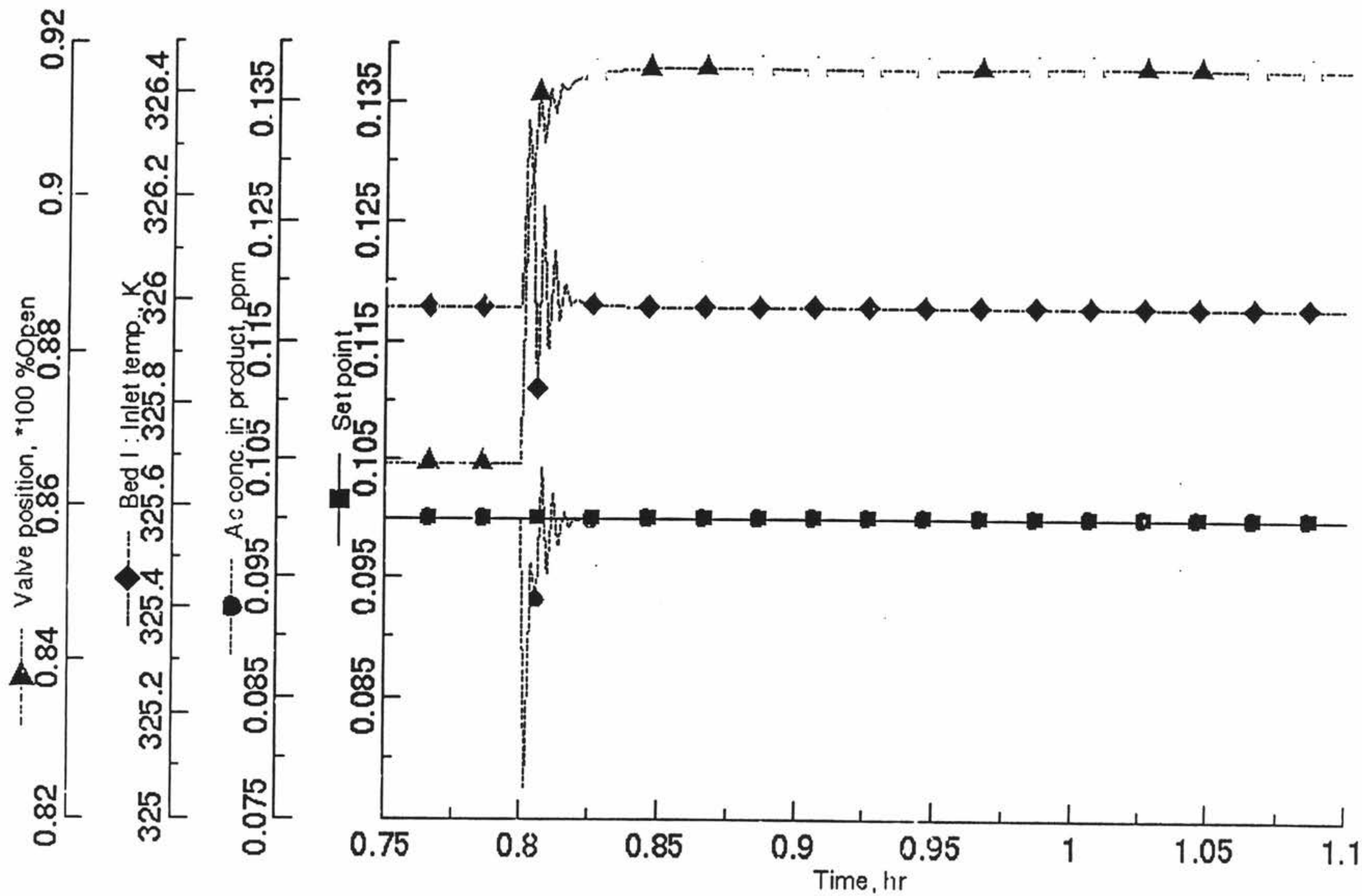

Figure 8.9 The control performance of the selected DMC to step change in feed temperature (from 320 K to 325 K)

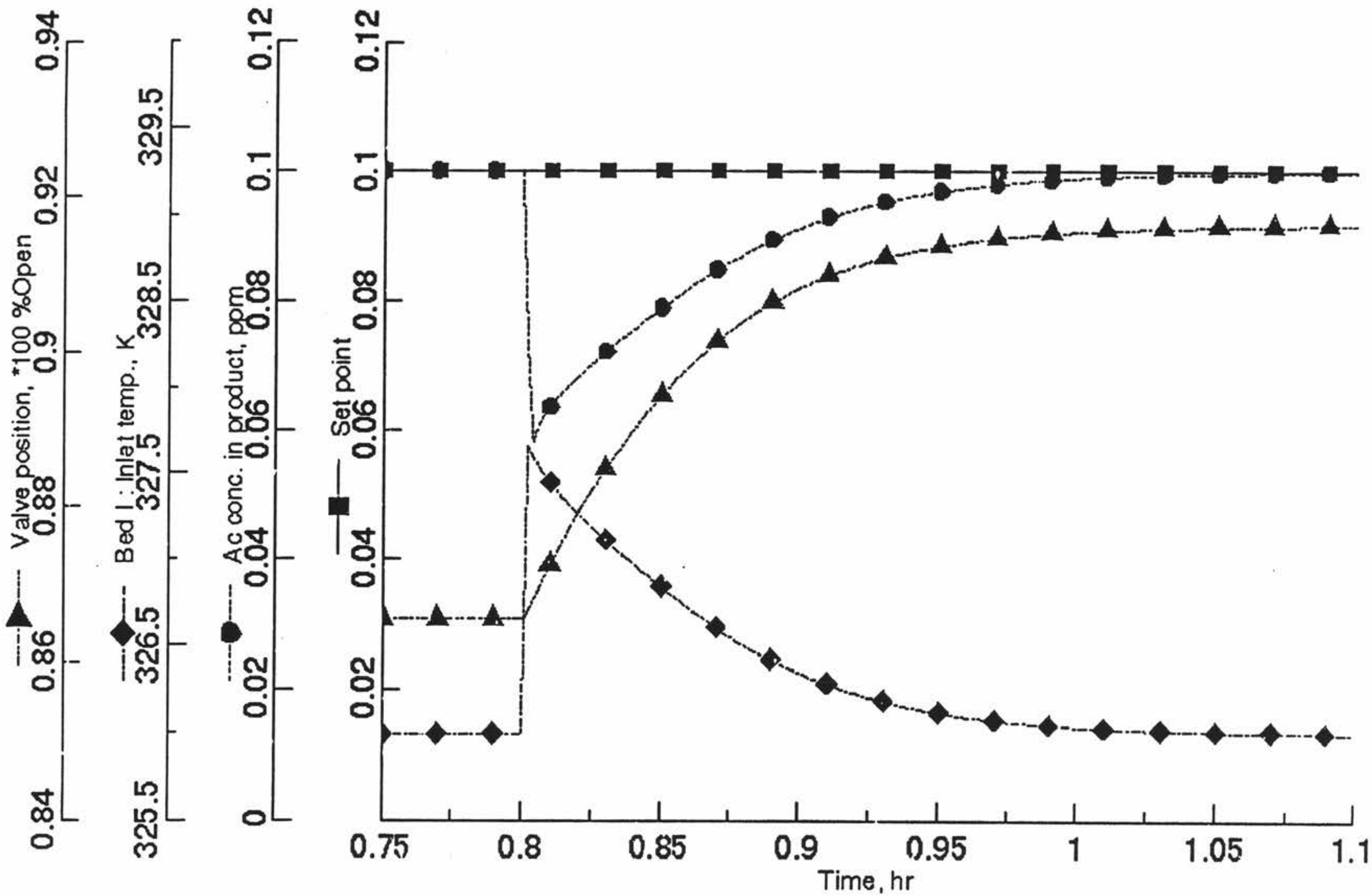

Figure 8.10 The control performance of the selected PID to step change in feed temperature (from 320 K to 325 K)

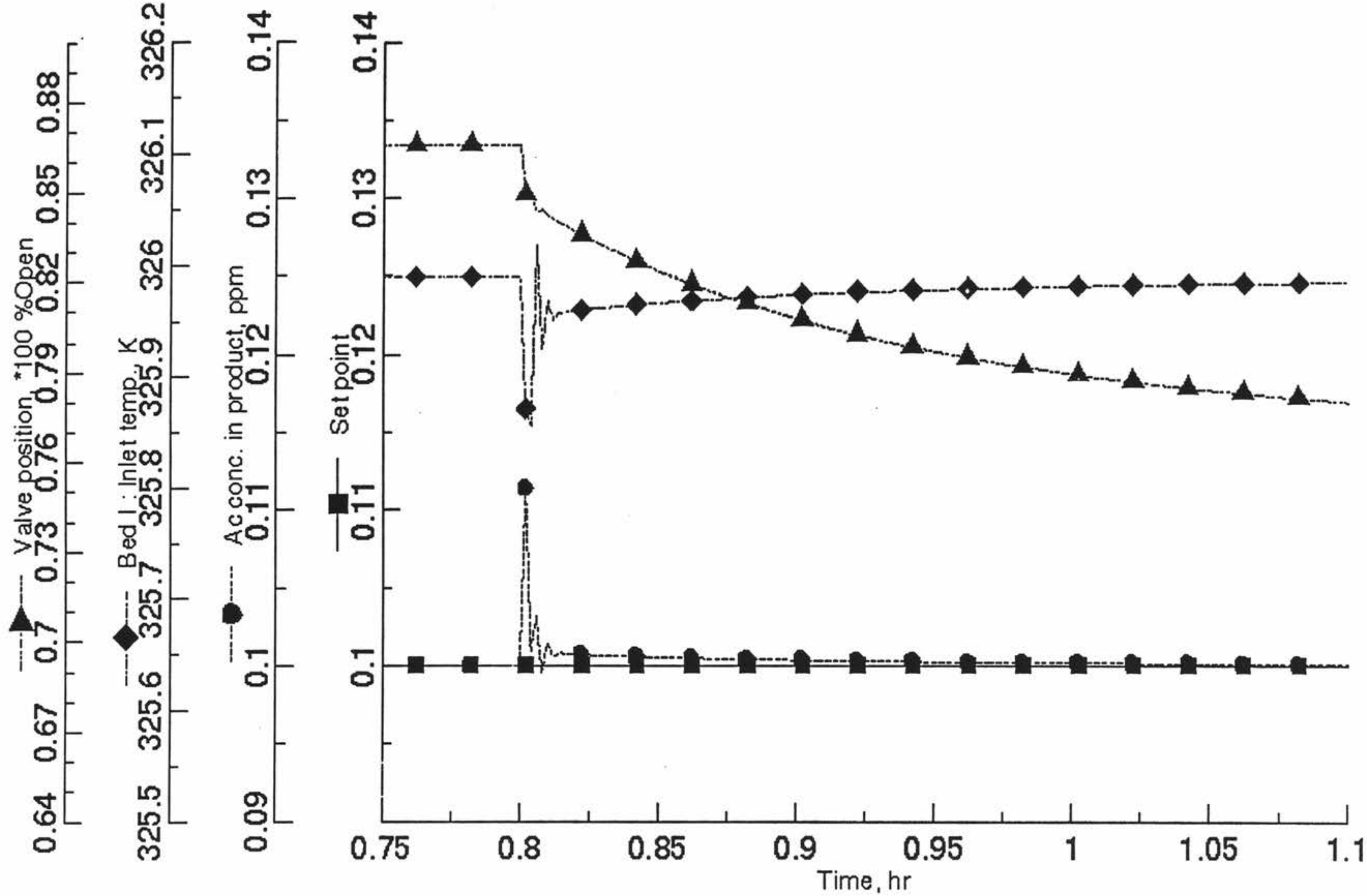

Figure 8.11 The control performance of the selected DMC to step change in feed temperature (from 320 K to 315 K)

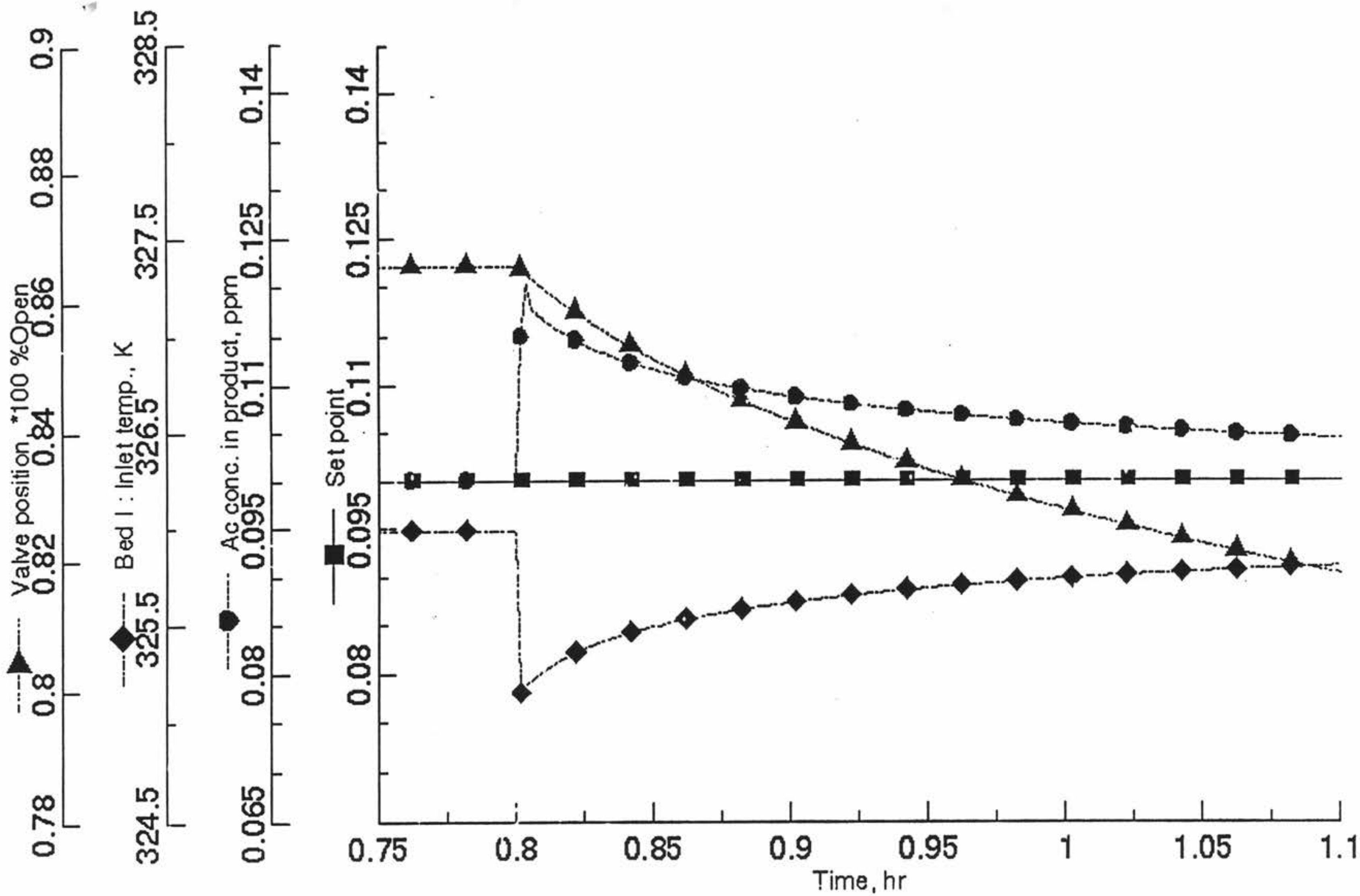

Figure 8.12 The control performance of the selected PID to step change in feed temperature (from 320 K to 315 K)

concentration has little overshoot but no oscillation. Similar to the other cases, it maintains a shorter time to reach the set point than those of using the PID controller. The performance of the PID controller to the same condition is shown in Figure 8.14.

Figure 8.15 shows the response obtained using the selected DMC controller to step change in feed flow rate. The flow rate is decreased 2%. The outlet acetylene concentration has little overshoot but no oscillation as same as the response to the positive step change in flow rate. It also maintains a shorter time to reach the set point than those of using the PID controller. The performance of the PID controller to the same condition is shown in Figure 8.16.

Figure 8.17 shows the response obtained using the selected DMC controller to step change in inlet acetylene concentration. The concentration is changed from 0.39 to 0.41 %mol. The outlet acetylene concentration has little oscillation and overshoot, and takes a shorter time to reach the set point than those of using the PID controller. The performance of the PID controller to the same condition is shown in Figure 8.18.

Figure 8.19 shows the response obtained using the selected DMC controller to step change in inlet acetylene concentration. The concentration is changed from 0.39 to 0.37 %mol. The outlet acetylene concentration has little oscillation and overshoot as same as the response to the positive step change in concentration, and maintains a shorter time to reach the set point than those of using the PID controller. The performance of the PID controller to the same condition is shown in Figure 8.20.

Figure 8.21 shows the response obtained using the selected DMC controller to step change in inlet hydrogen concentration. The concentration is changed from 14.9 to 14.5 %mol. The outlet acetylene concentration has little oscillation and overshoot as same as the response of the other cases, and maintains a shorter time to reach the set point than those of using the PID controller. The performance of the PID controller to the same condition is shown in Figure 8.22.

Figure 8.23 shows the response obtained using the selected DMC controller to step change in feed temperature. The control performance is considered in term of the outlet ethylene concentration. The change of ethylene concentration is compared with

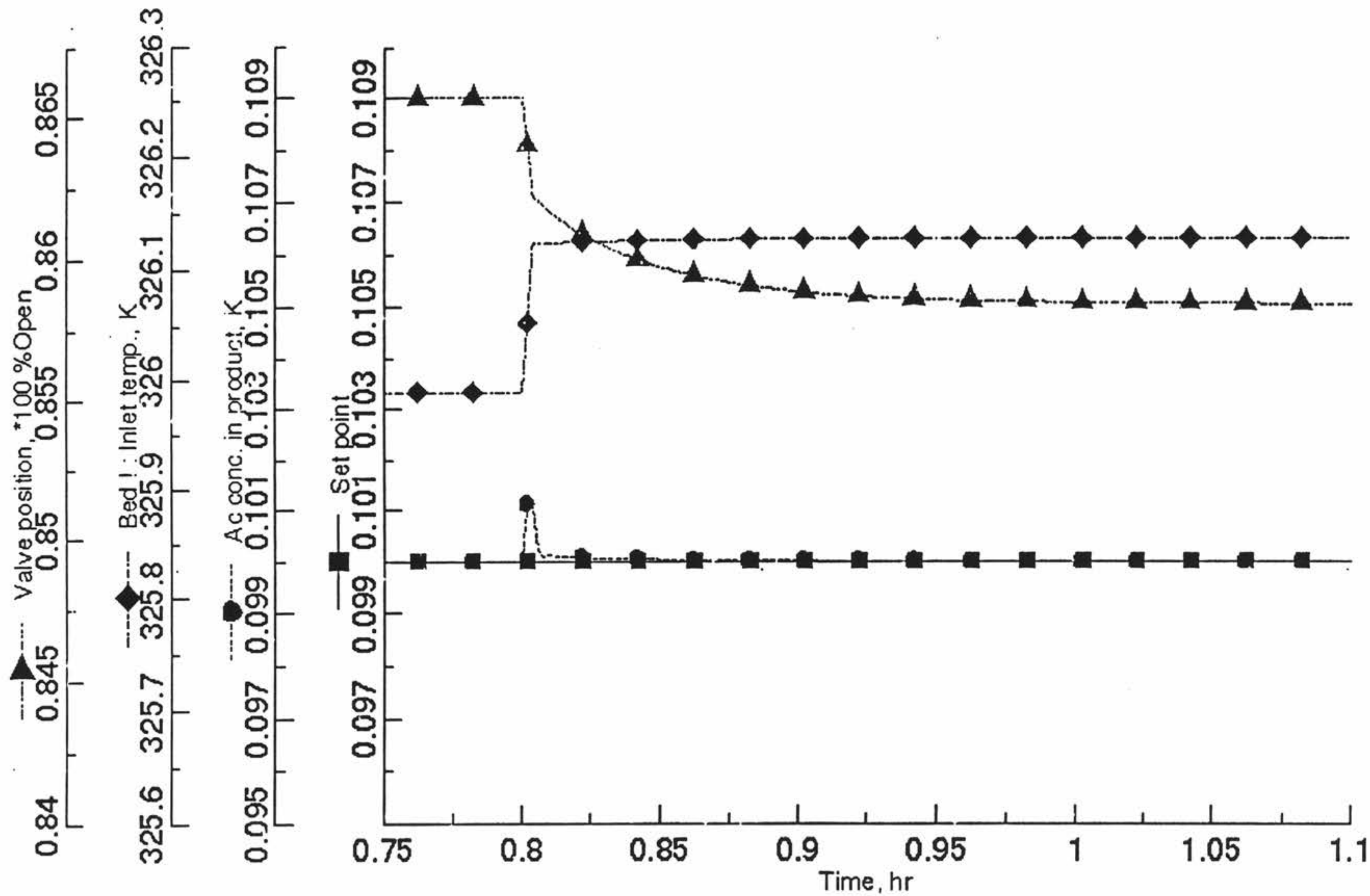

Figure 8.13 The control performance of the selected DMC to step change in feed flow rate (2% increase)

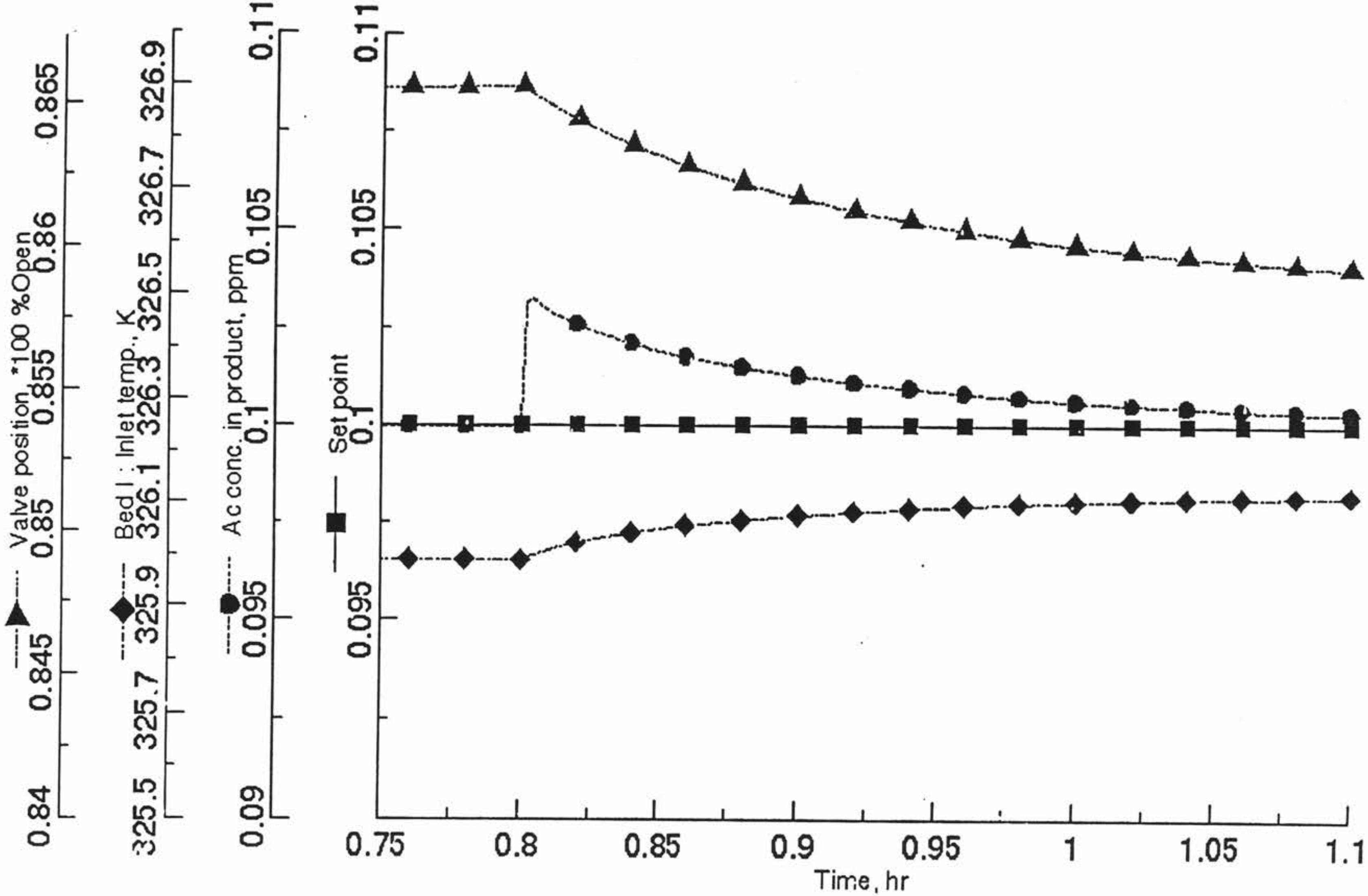

Figure 8.14 The control performance of the selected PID to step change in feed flow rate (2% increase)

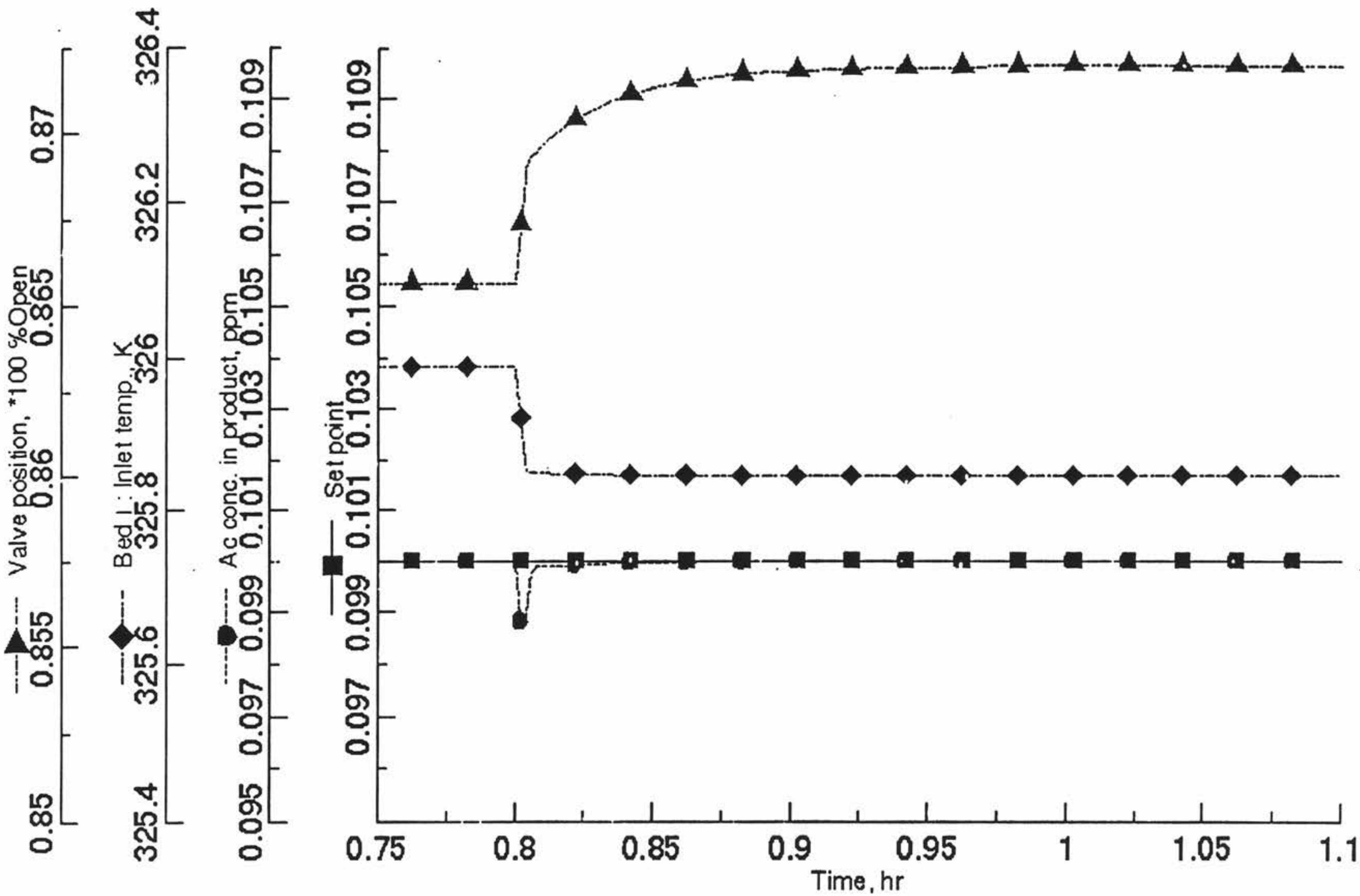

Figure 8.15 The control performance of the selected DMC to step change in feed flow rate (2% decrease)

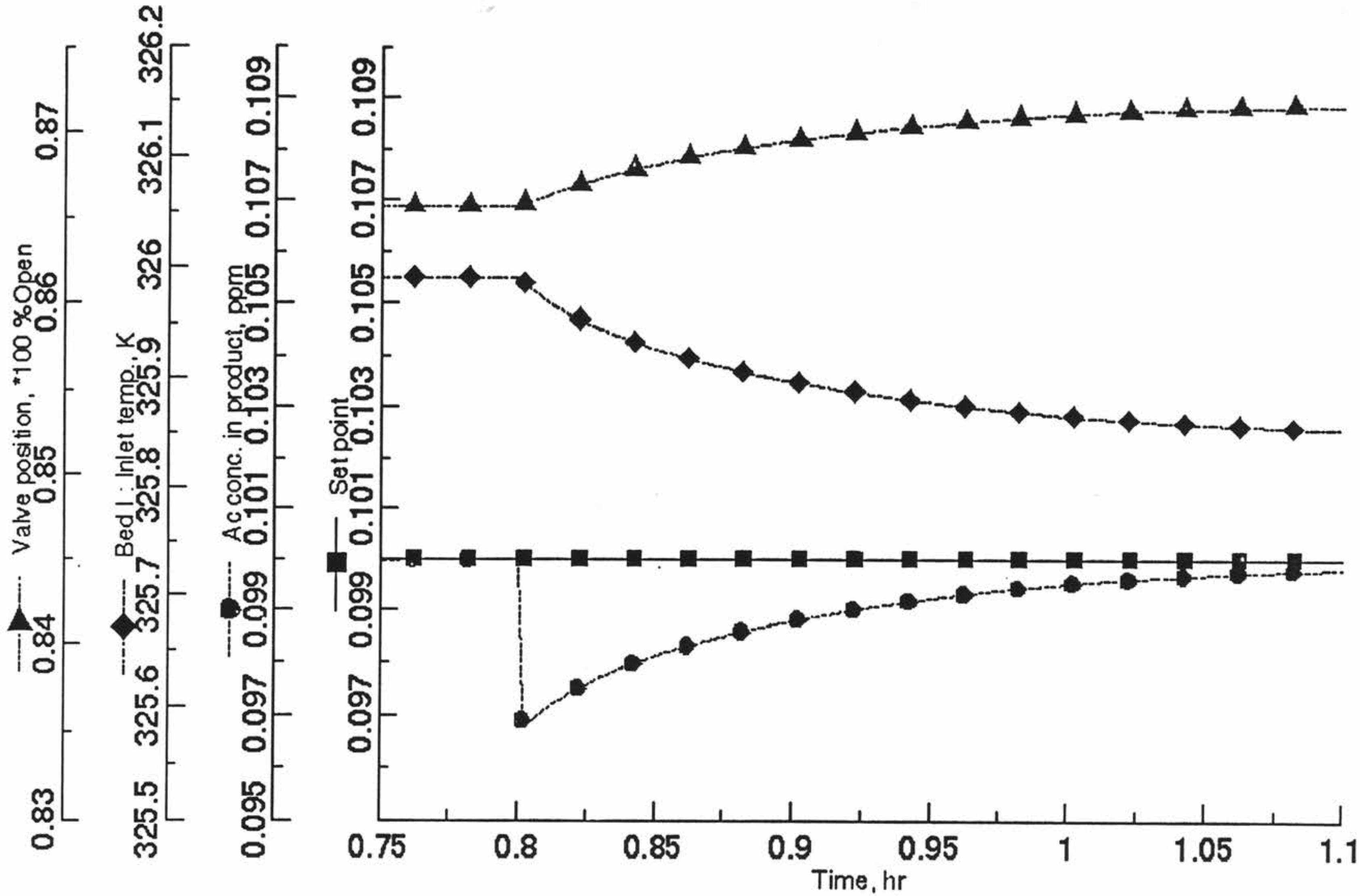

Figure 8.16 The control performance of the selected PID to step change in feed flow rate (2% decrease)

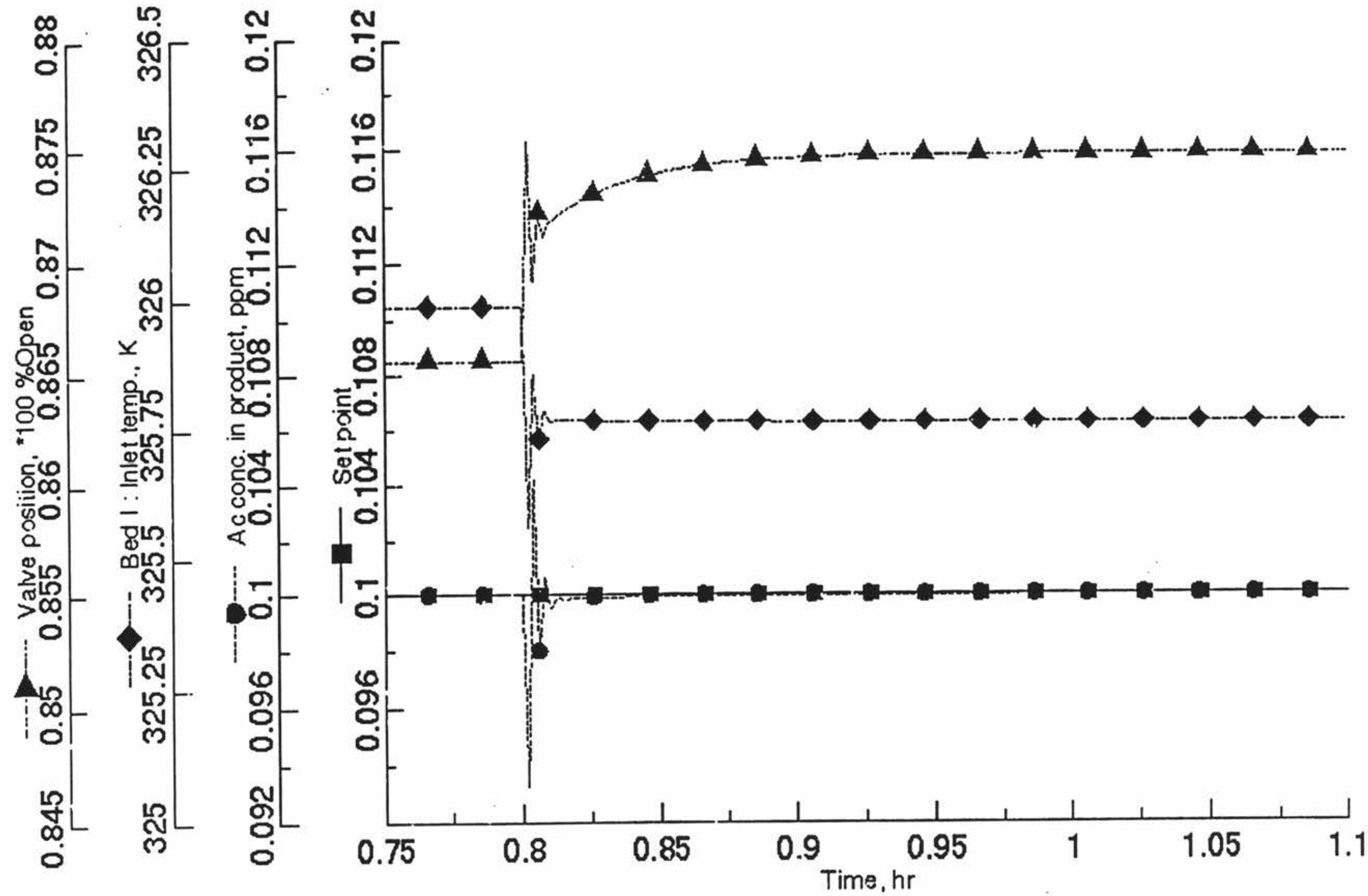

Figure 8.17 The control performance of the selected DMC to step change in inlet acetylene concentration (from 0.39 to 0.41 %)

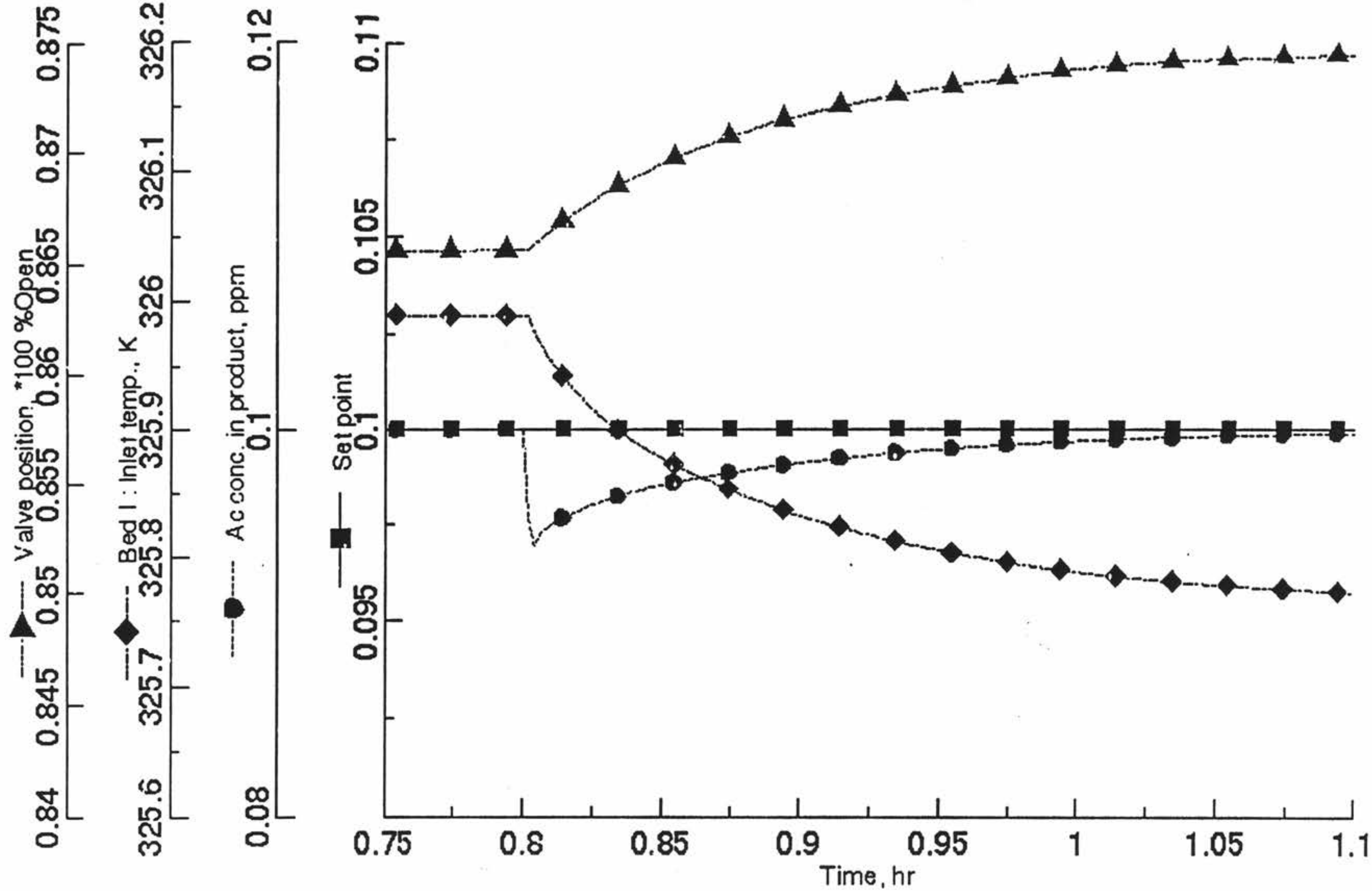

Figure 8.18 The control performance of the selected PID to step change in inlet acetylene concentration (from 0.39 to 0.41 %)

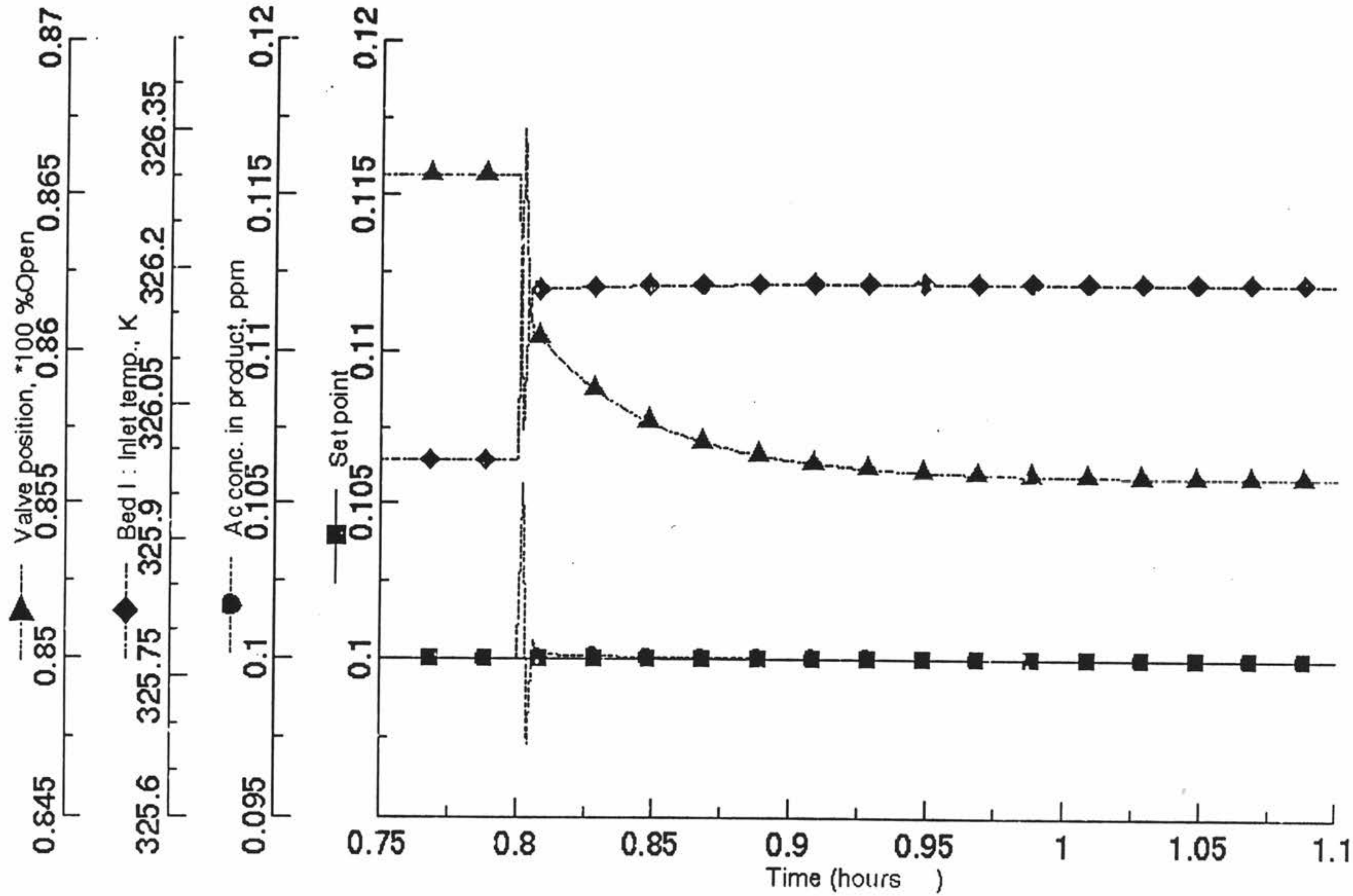

Figure 8.19 The control performance of the selected DMC to step change in inlet acetylene concentration (from 0.39 to 0.37 %)

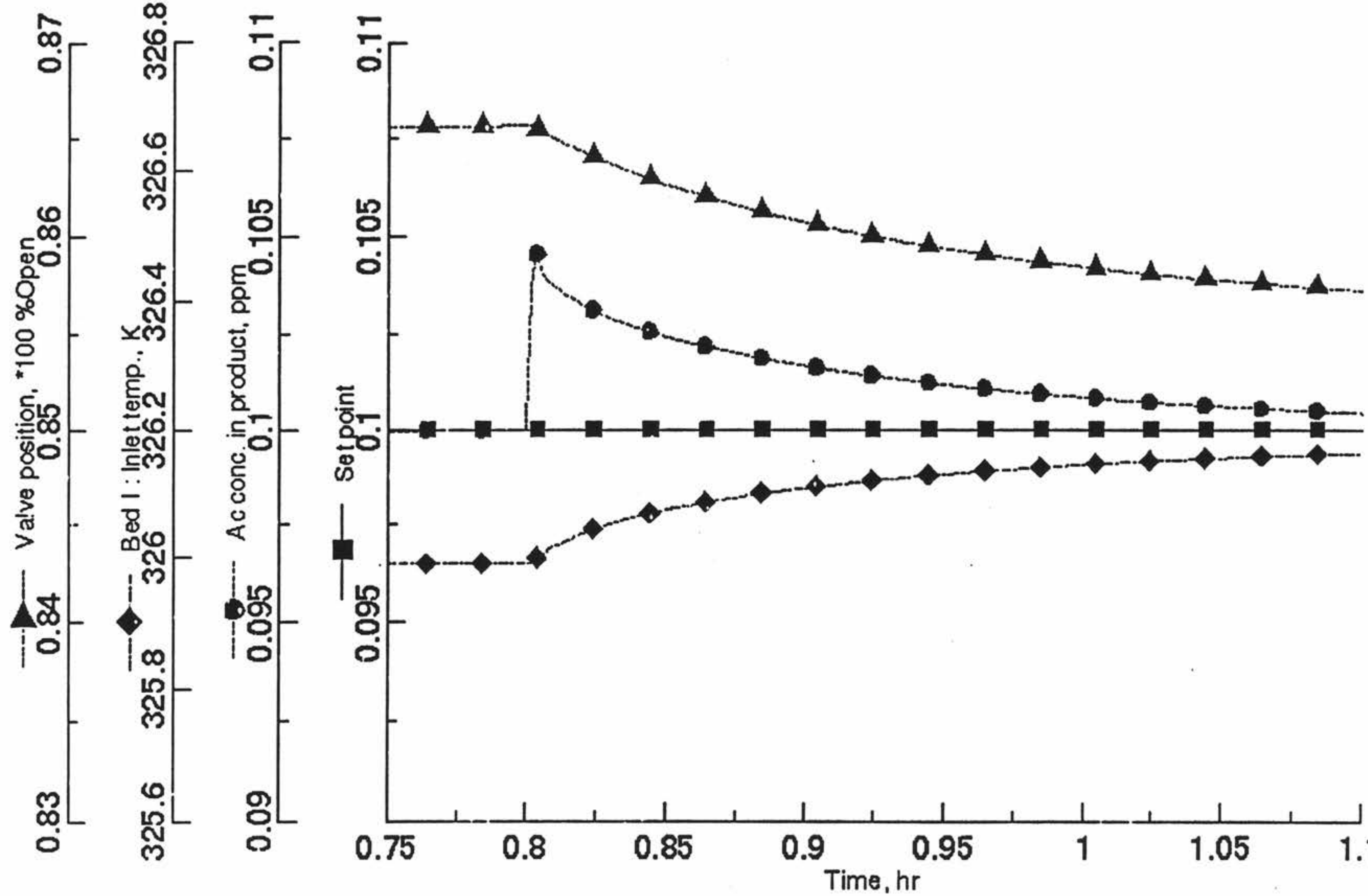

Figure 8.20 The control performance of the selected PID to step change in inlet acetylene concentration (from 0.39 to 0.37 %)

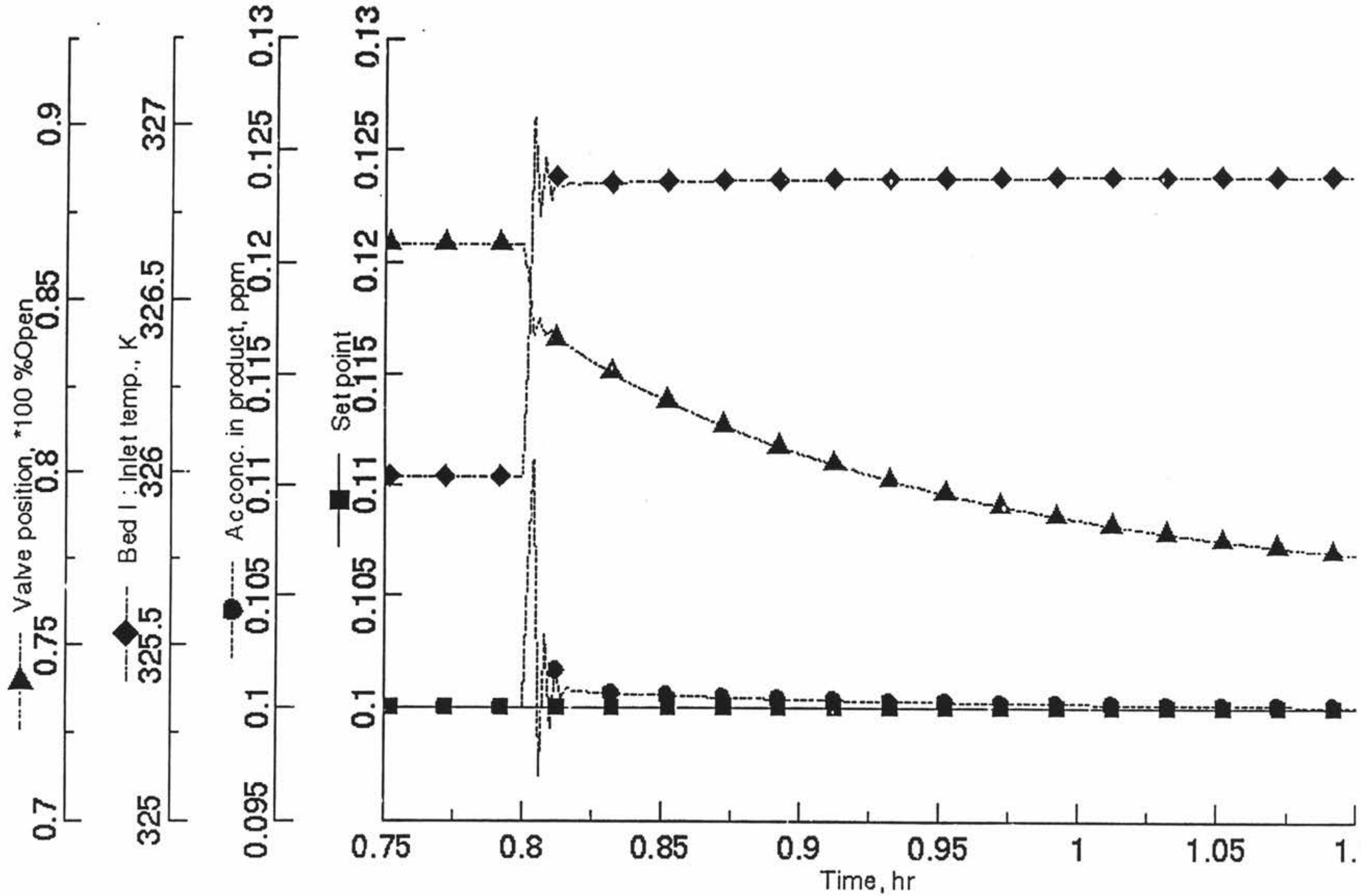

Figure 8.21 The control performance of the selected DMC to step change in inlet hydrogen concentration (from 14.9 to 14.5 %)

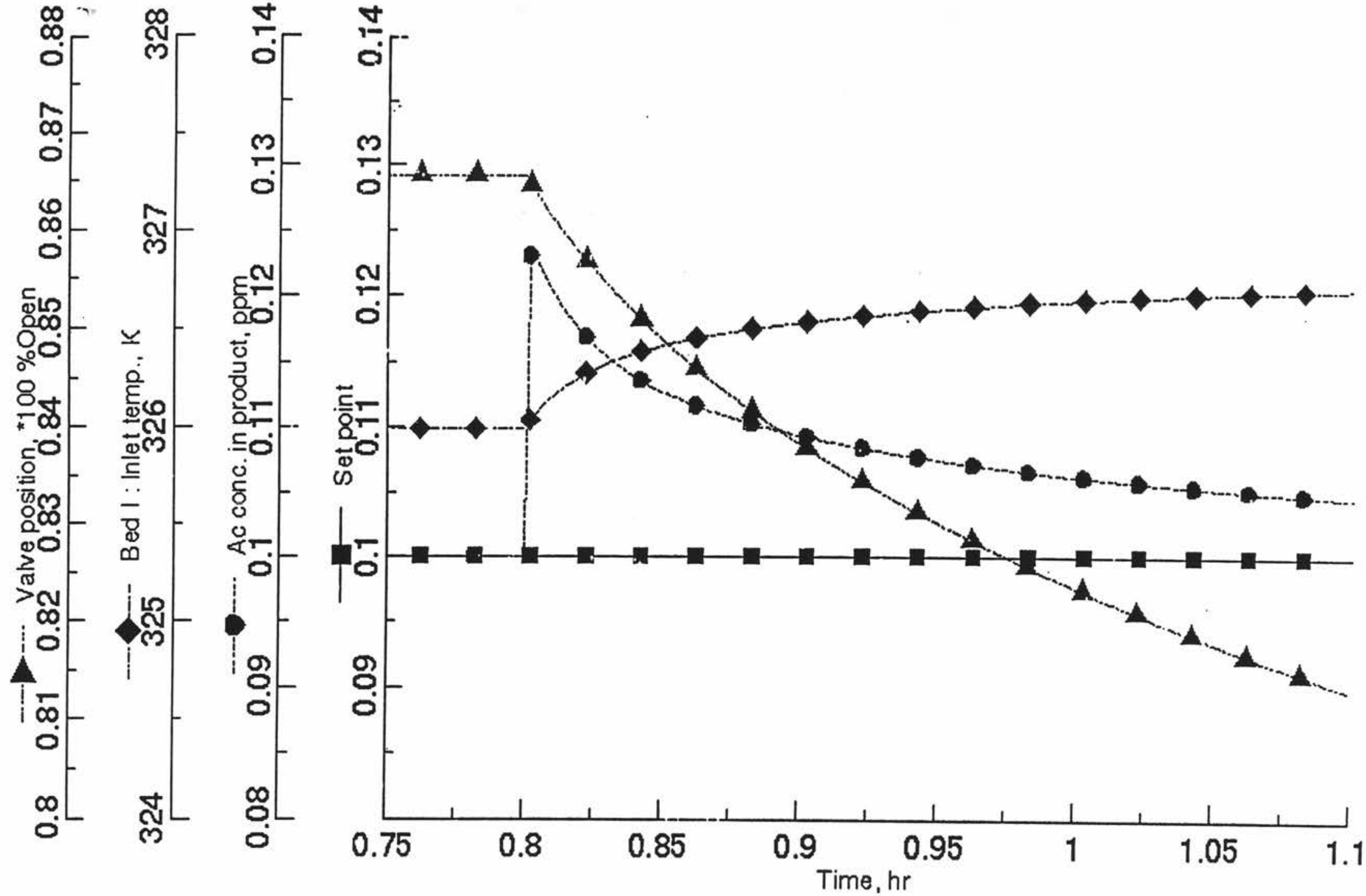

Figure 8.22 The control performance of the selected PID to step change in inlet hydrogen concentration (from 14.9 to 14.5 %)

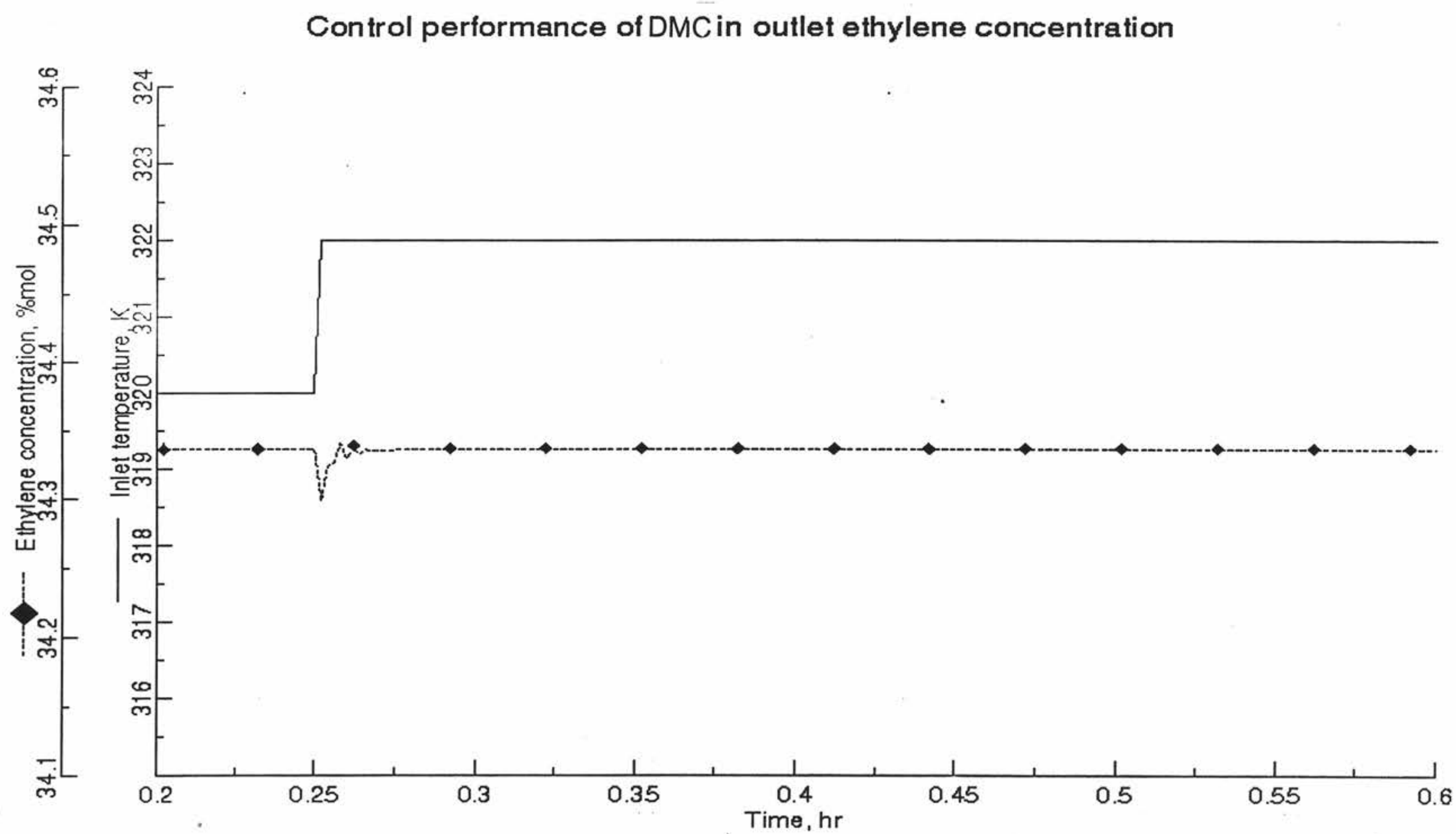

Figure 8.23 The control performance of DMC controller in the sense of outlet ethylene concentration to the step change in the feed temperature

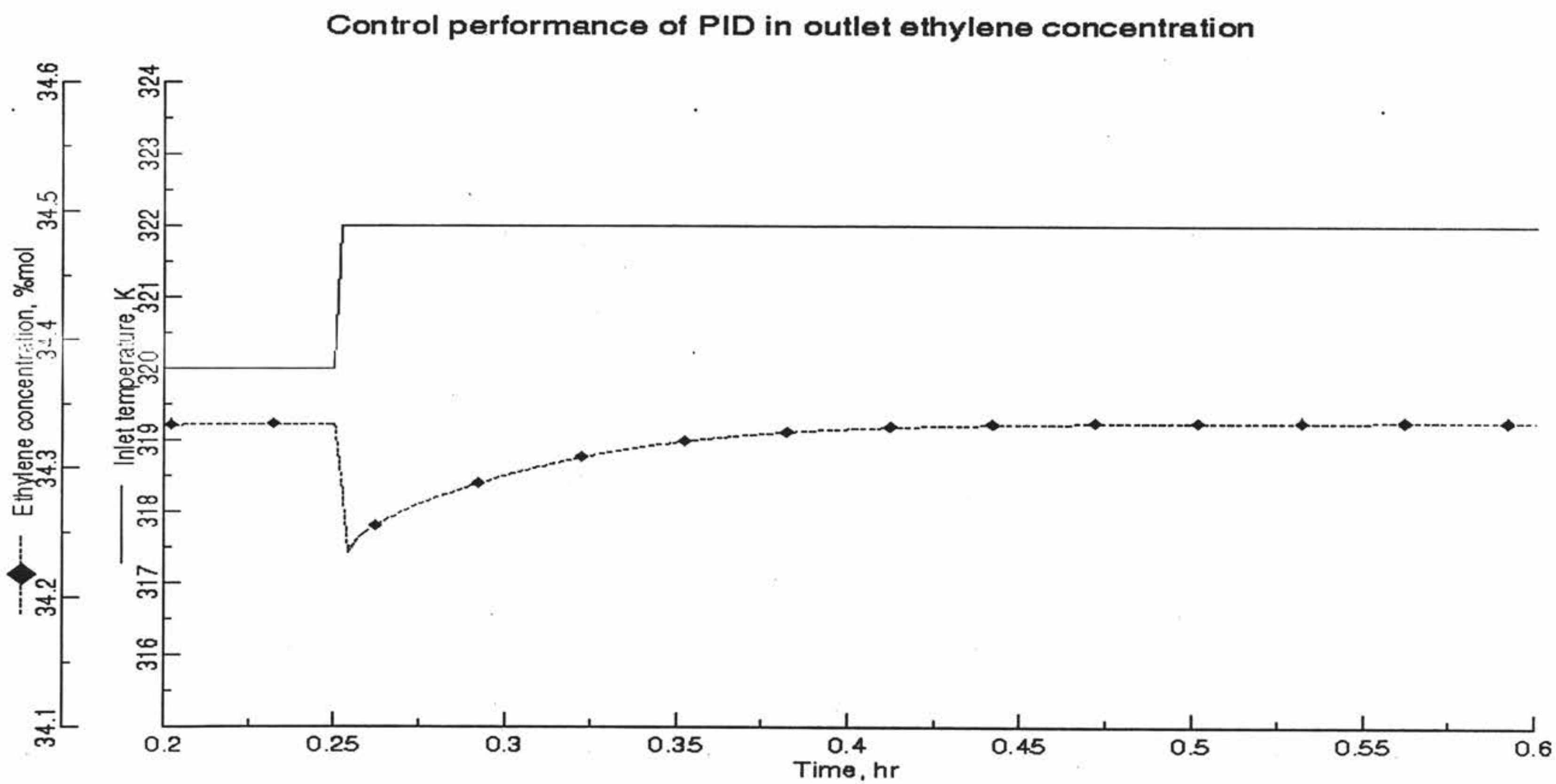

Figure 8.24 The control performance of PID controller in the sense of outlet ethylene concentration to the step change in the feed temperature

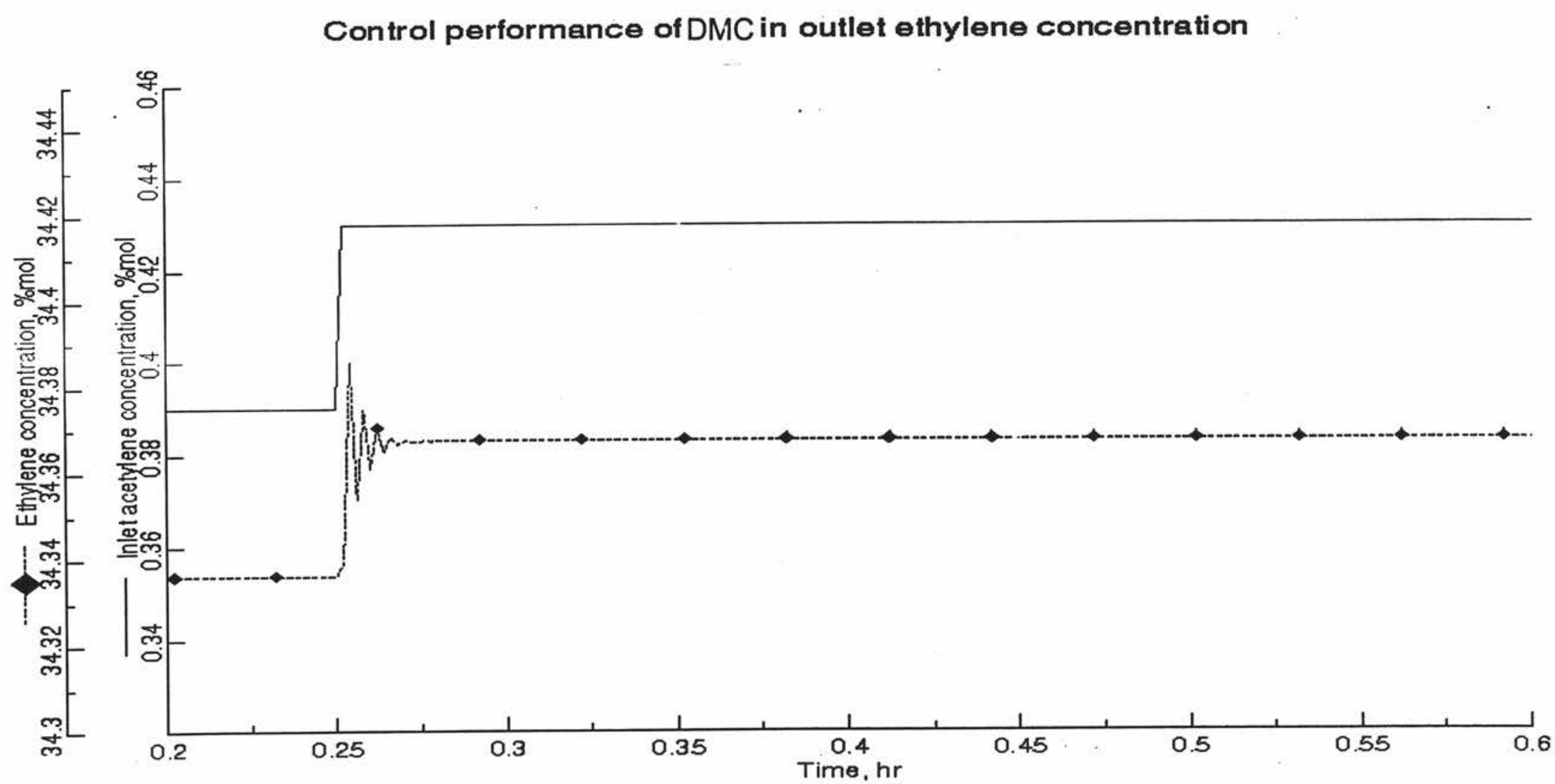

Figure 8.25 The control performance of DMC controller in the sense of outlet ethylene concentration to the step change in the inlet acetylene concentration

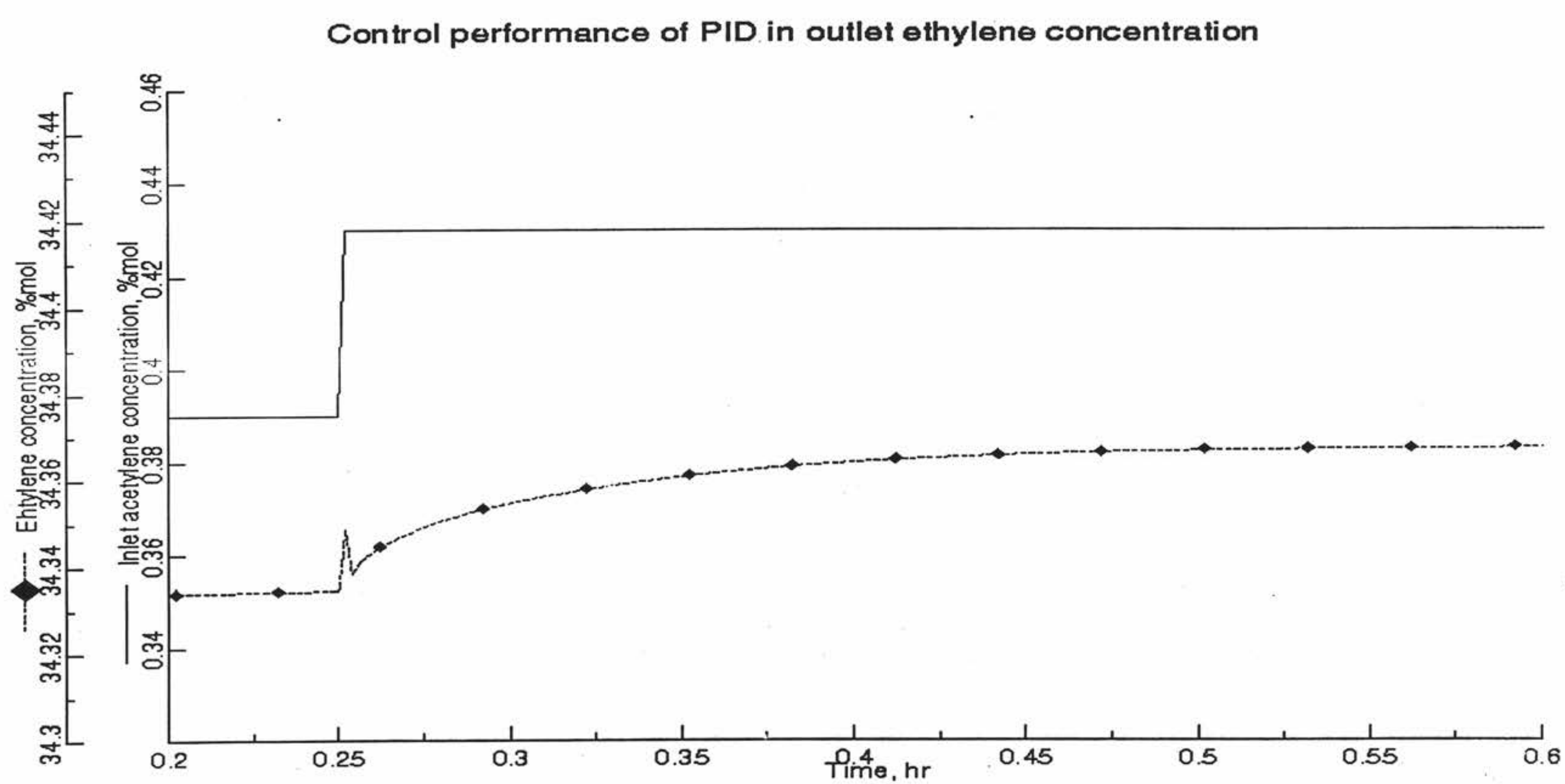

Figure 8.26 The control performance of PID controller in the sense of outlet ethylene concentration to the step change in the inlet acetylene concentration

the change of outlet ethylene concentration by PID that shown in Figure 8.24. When the process has the even of the change in the feed temperature, the amount of ethylene loss by using DMC controller is about 2.62 % over by using PID controller.

Figure 8.25 show the control performance of the DMC to step change in the inlet acetylene concentration. Similar to Figure 8.23 and 8.24, the control performance that is considered to show is the outlet ethylene concentration. The change of outlet ethylene concentration is compared with the change of outlet ethylene concentration by PID that shown in Figure 8.26. When the process has the even of the change in the inlet acetylene concentration, the amount of ethylene loss by using DMC controller is about 19.7 % over by using PID controller.

8.3 Summary

The Dynamic Matrix controller can be easily derived from the convolution model of the process. The suitable Dynamic Matrix Control design is the controller with the control horizon U = 3, the prediction horizon V = 2, sampling time = 7 seconds, and the control weight = 1000. For the even of the total mass flow change, the selected DMC controller gives

- ♦ The setting time = 21.6 seconds that is about 18.4% over the value of PID controller
- ♦ The overshoot = 0.0013 ppm that is about 39.4% over the value of PID controller
- ♦ The amount of acetylene that passed out with the product is reduce by 96% over by using PID controller

The selected DMC controller gives the good control action in the difference evens as shown in Figure 8.5 - 8.22. The selected DMC controller takes the shorter time to achieve the set point of the controller than the PID controller. The selected DMC controller can reduce the amount of ethylene loss if compares with the PID controller.