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The Feedback and Feedforward Control of The Five CSTR Cascade Under The Effect of The Ramp Input

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SUMMARY

In this research, five continuous flow stirred tank reactors (CSTR) having exhotermic first order irreversible reaction were used. The effect of the several values of the continuous and discontinuous ramp variables given to the feed flow rate of the system to the output variables were examined for dynamic studying and then with introducing feedback and feedforward controls, the approaches of the similar variables to the desired values were investigated.

INTRODUCTION

There is much less reported work on the theoretical study of the ramp changes affected to the distributed and lumped–parameter system.

Himmelblau and Bishoff (1), showed theoretical example on the ramp input to the first order system.

Ercüment (2), has done theoretical work on the ramp input to the continuous well stirred tank with feedback control system.

Alpbaz (3), has described the dynamic properties of the five CSTR under the effect of the step change given to the input variables. Alpbaz introducing feedback and feedforward control mechanisim to the system which was under the similar e ffect has calculated the change of theoutput variables respect to the time on a digital computer.

The mathematical form of the ramp input is shown below,

$$f(t) = \begin{Bmatrix} 0 & t>0 \\ t & t>0 \end{Bmatrix} = Bt \qquad (1)$$

The continuous ramp input with tangent, B, is shown in Fig. 1. The Laplace Transform of the ramp change,

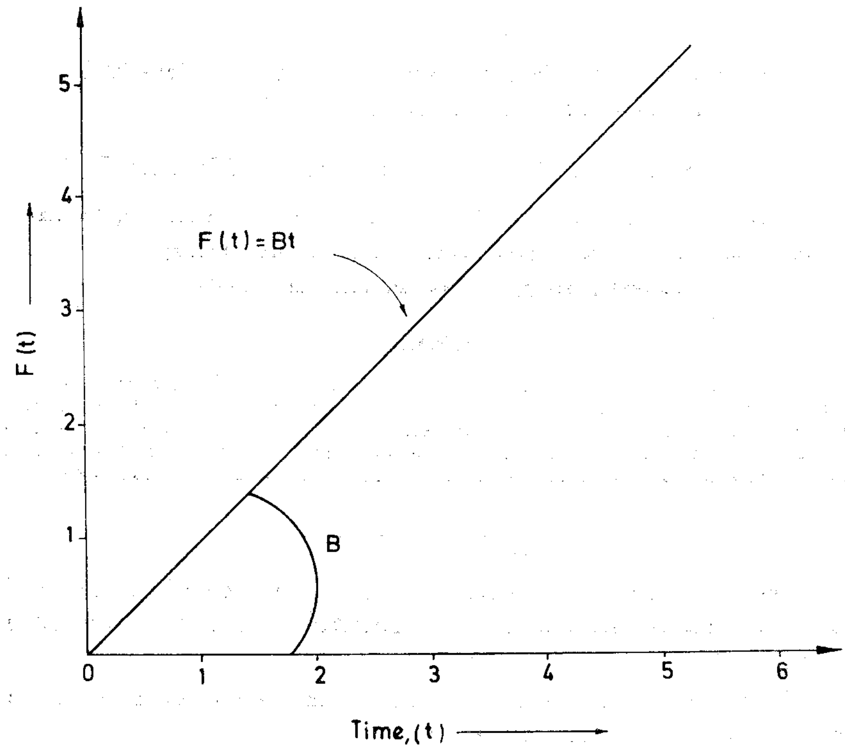

Fig. 1. Continuous ramp input with tangent B

$$L \{ f(t) \} = \frac{B}{S^2} \quad (2)$$

The five CSTR cascade, feedback and feedforward control systems are shown in Fig. 2. The mathematical model having mass and energy balance related with the five CSTR cascade and cooling water energy blance were given on the work of Alpbaz and Selek (4). Also the related computer solution and range of parameters were given in that work (4). The cooling water and feed enter the different ends of cascade as shown in Fig. 2, and pass in opposite direction. As described previously, feedback and feedford control systems were applied to the cascade.

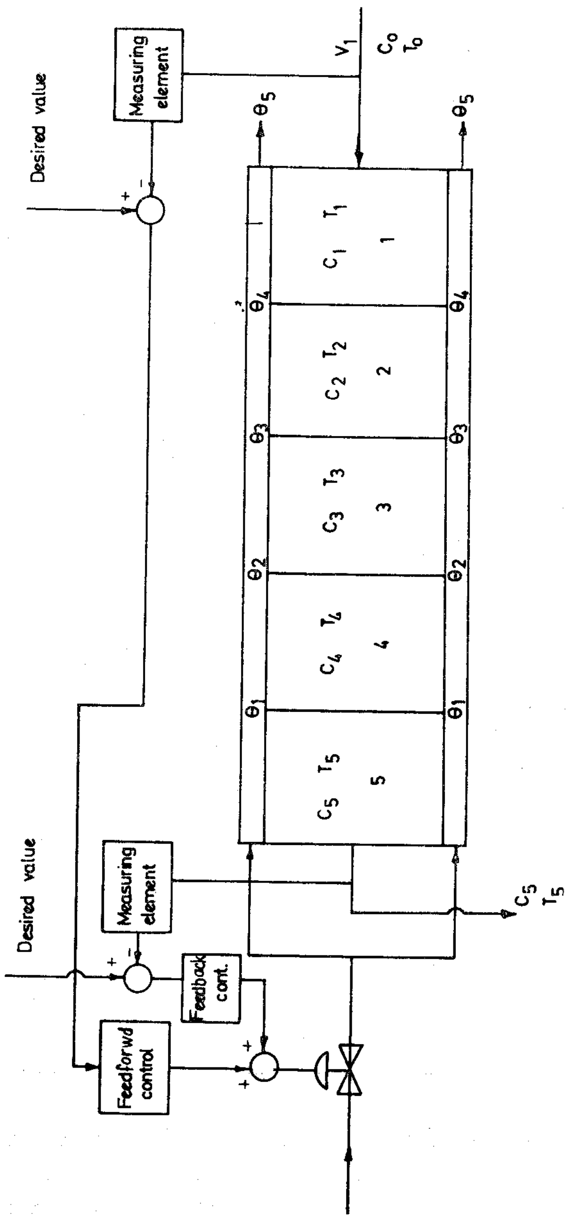

Fig. 2. Feedforward and feedback control of the five CSTR cascade.

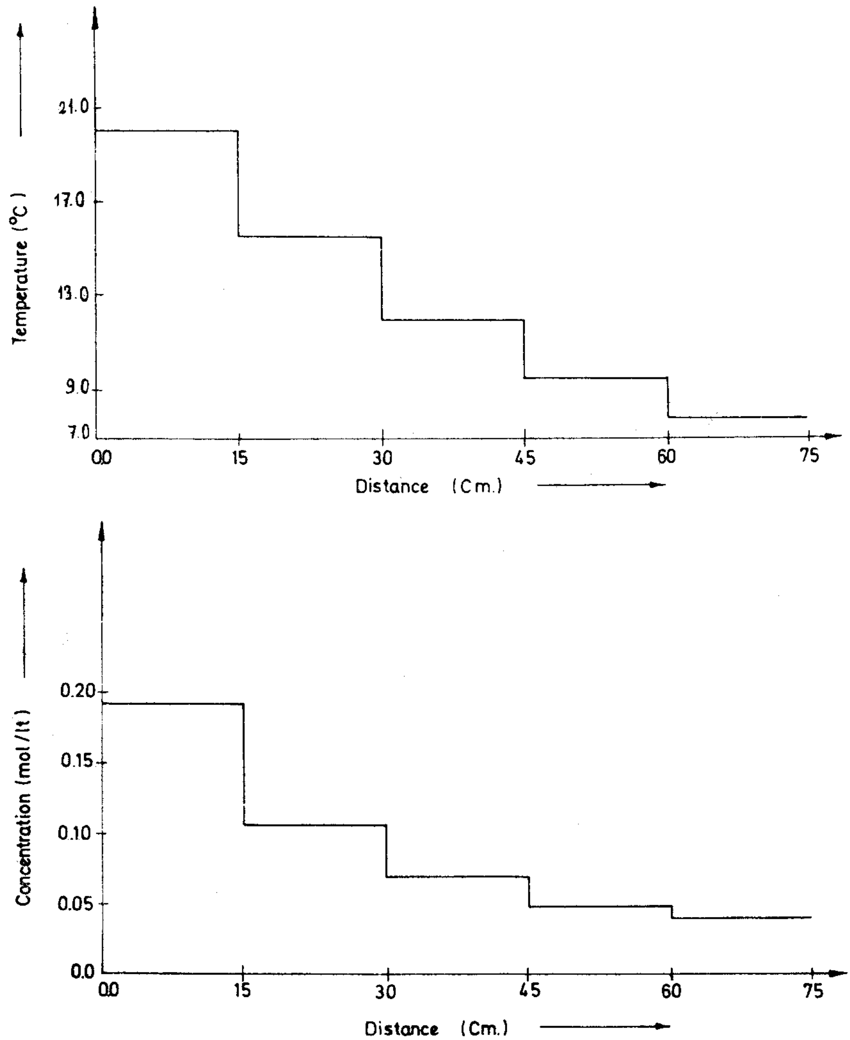

Fig. 3. Steady-state temperature and concantration profiles for the five CSTR cascade.

For feedback and feedforward controls two three–term controllers were used. In the case of feedback control, there are five different location points to detect the controlled variable. For the different imposed disturbance, one of these five locations can be used to get the best control performance. Thus if the detecting point is in the last tank the feedback controller will act purely as a feedback system. On the other hand if the detecting point is located between the first and fourth tanks the controller can partly act as a feedback and partly as a feedforward controller. Also the setting of the three modes can be different for each location. For temperature control, feedback controler detect the output temperature, T_5, and adjusted the cooling flow rate with control valve. When a ramp change disturbance is applied, feedforward control starts to act before this disturbance effects the control variables of the system and thus adjusts the cooling water immediately with the given control parameters. The differential valve operates in response to both the feedback and feedforward control. A combination of feedforward and feedback control can manipulate the cooling water to obtain better response of than either being used alone. The direction of valve operation has to be set on a knowledge of whether an increasing or decreasing coolant rate is required when the system throughput is increased. Prediction of the best values of proportionality constant K_c, reset time, TR, and derivative time TD were done with the aid of a computer.

RESULTS

In the first part of the present work, the dynamic properties of the system which was under the effect of the ramp input given to the feed flowrate were investigated.

When the five CSTR cascade came to the steady–state having input conditions given in Table. 1, the temperature and concentration profiles are shown in Fig. 3.

Table 1. The operating steady-state conditions for the five CSTR cascade.

V_1 lt/min	V_2 lt/min	C_0 mol/lt	θ_0 °C	T_0 °C
1.0	6.0	0.5	5.0	23.0

When the system was in the steady-state condition given in Fig. 3, the ramp input with three different tanget values (B = 1.0,0.5,0.1) were given to the feed flow rate. The time response of the output temperatures, T_1 and T_5, which were the results of the computer solution of the unsteady-state models are given in Figs. 4,5 As it is shown from Figs. 4,5 the output temperatures, T_1 and T_5, did not come to the second steady-state.

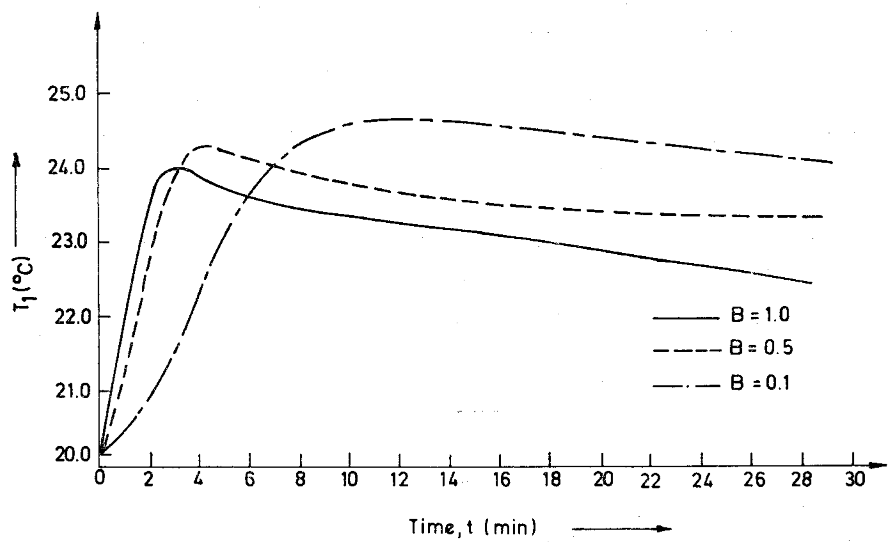

Fig. 4. Open loop dynamic temperature profile for the first tank.

When the cascade was in the steady-state condition given in Fig. 3 the discontinuous ramp input with the value of tangent (B = 1.0) and ceasing time (t = 8,4,2 min) were given to the feed flow rate. The results obtained from computer solution are shown in Figs. 6,7. As it is shown from Fig. 6,7 the output temperatures came to second steady-state in approximetly 6 minutes.

In the second part of the present work, the effect of the feedback and feedforward control systems on the output variable of the cascade which were under the effect of the continuous and discontinuous ramp input was examined.

On the same steady-state condition the effect of the continuous ramp inputs (B = 1.0, 0.5, 0.1) given to the feed flow rate were eli-

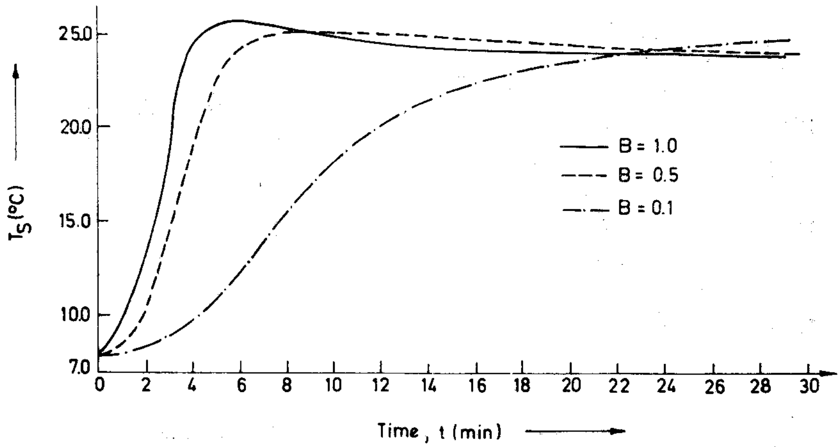

Fig. 5. Open loop dynamic temperature profile for the fifth tank.

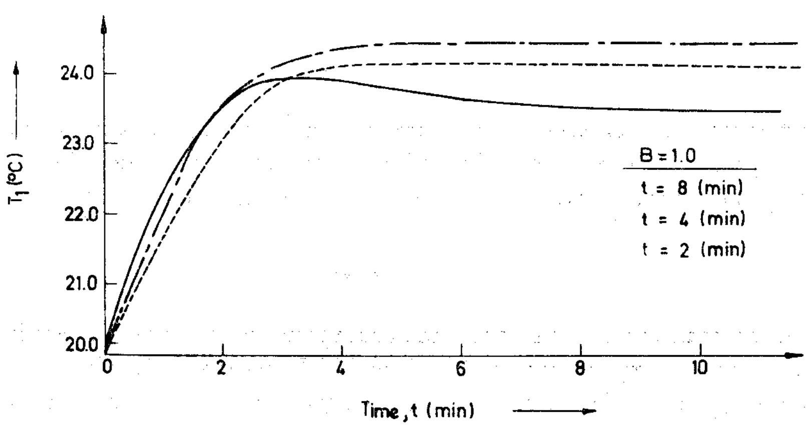

Fig. 6. Open loop dynamic temperature profile for the first tank.

minated with feedback and feedforward controllers. The computed results are shown in Fig. 8. The time response of the output temperature was stable but did not come to the desired or initial value.

With the discontinuous ramp input having the values (B = 1.0, 0.5, 0.1) and (t = 2 min), the efficiency of the control system were

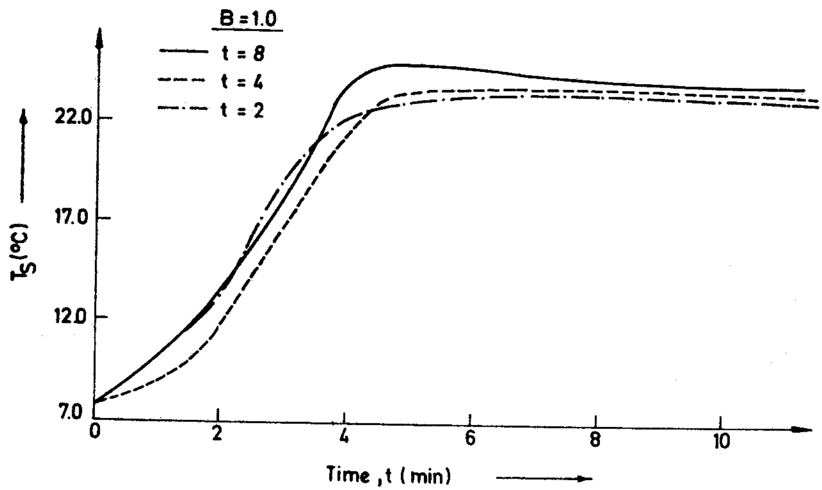

Fig. 7. Open loop dynamic temperature profile for the fifth tank.

investigated. In Figs. 9–10, the output temperatue, T_5, came to the desired value. When the value of tangent was getting smaller, the output temperature came to the desired value in a shorter time.

CONCLUSION

In dynamic work, the continuous ramp input gave the unstability to the output temperatures of the five CSTR cascade. The discontinuous ramp input gave stability and output variables came to the second steady–state.

In the control work, with feedback and feedforward control systems, the variation of output temperatures with time were stable but this variables did not come the desired value under the effect of continouous ramp input. With the discontinuous ramp chance the unstability were eliminated with the feedback and feedforward control and than output temperature, T_5, came to the desired value.

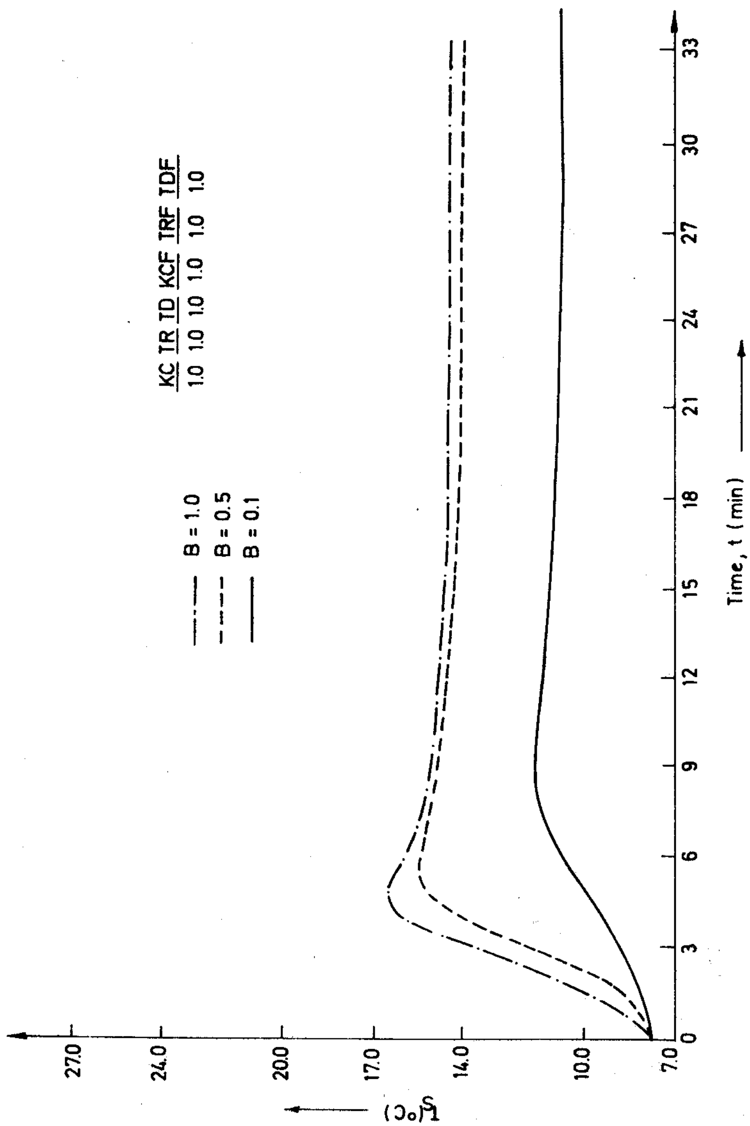

Fig. 8. Feedback and feedforward control of the fifth tank of cascade.

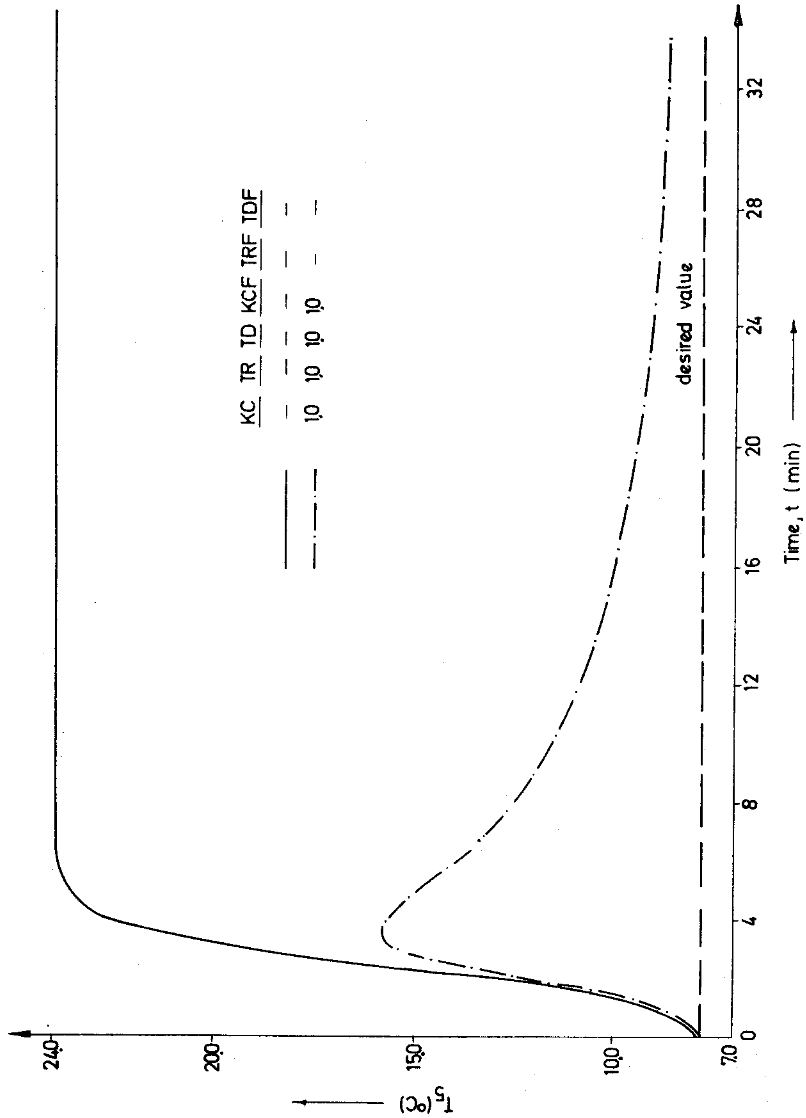

Fig. 9. Open loop dynamics, feedback and feedforward control of the fifth tank of cascade. (B = 1.0, t = 2 min).

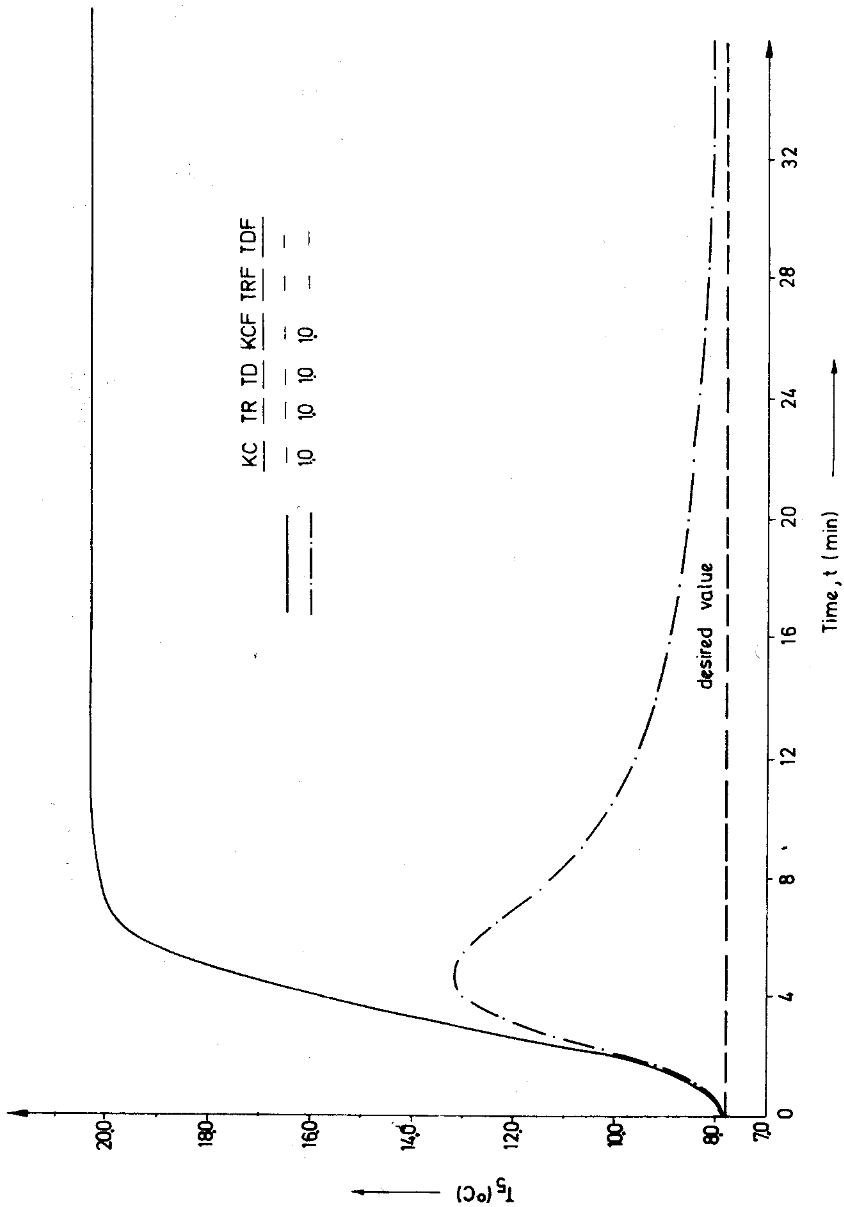

Fig. 10. Open loop dynamics, feedback and feedforward control of the fifth tank of cascade. (B = 0.5, t = 2 min).

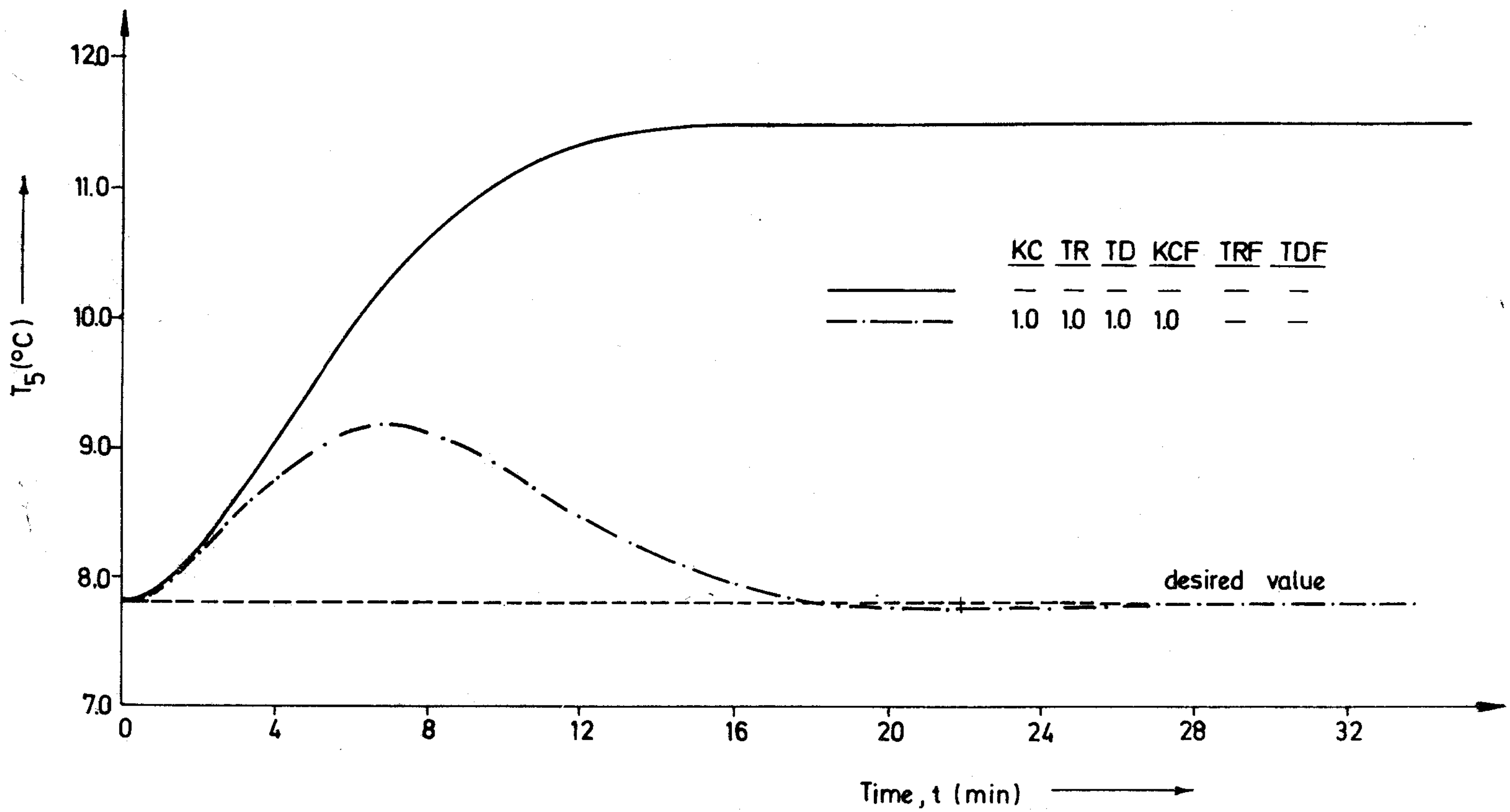

Fig. 11. Open loop dynamics, feedback and feedforward control of the fifth tank of cascade. (B = 0.1, t = 2 min),

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NOMENCLATURE

B	Tangent of ramp input.
C_o	Initial input concentration (mol / lt).
C_n	Concentration of n'th tank (mol / lt).
KC	Proportional acting factor for feedback control.
KCF	Proportional acting factor for feedforward control.
t	Time.
T_o	Input temperature of reactor (°C).
T_n	Temperature of n'th stage of reactor (°C).
TD	Derivative action time for feedback control
TDF	Derivative action time for feedforward control.
TR	Reset time for feedback control.
TRF	Reset time for feedforward control.
V_1	Feed flow rate (lt / min).
V_2	Coolant flow rate (lt / min).
θ_o	Initial temperature of input coolant (°C).
θ_n	Temperature of coolant in n'th tank (°C).

ÖZET

Bu araştırmada, birinci mertebeden tek yönlü ekzotermik bir reaksiyonu içeren beş tam karıştırmalı akım reaktörleri kullanılmıştır. Sistemin giriş besleme akımında verilen çeşitli değerlerde kesikli ve kesiksiz ramp değişiminin çıkış değişkenlerine etkisi dinamik çalışmalar olarak hesaplanmış ve sonra ileri ve geri beslemeli kontrol sistemlerinin ilavesi ile aynı değişkenlerin istenen değere gelişleri inceleumiştir.