Proceedings of

IEEE Singapore International Conference on Intelligent Control and Instrumentation (IEEE SICICI '95)

1 – 8 July 1995
Shangri-La Hotel, Singapore

Organised by:

Control Chapter, IEEE Singapore

Technical Co-Sponsor:

IEEE Control Systems Society (CCS)

FUZZY-PID HYBRID CONTROL SCHEME FOR CEMENT KILN CONTROL

A.K. Swain and B. Subudhi

Department of Electrical Engineering
Indira Gandhi Institute of Technology
Sarang, Dhenkanal, India 759 146

Abstract

In a cement plant, controlling the rotary kiln is a very difficult task. The most advanced method to control the highly complex and nonlinear behavior of the kiln, is fuzzy logic. On the other hand, PID controllers are used in most of the industries due to its functional and structural simplicity. This paper presents a method of controlling the rotary cement kiln by the combined action of the both fuzzy and PID controllers.

1 Introduction

Despite the advent of many sophisticated control theories and techniques, proportional, integral and derivative (PID) controllers are still used as standard building blocks for industrial process automation. In chemical industries over 90 per cent of the existing control loops are of PI(D) type. The popularity of PI(D) controllers is primarily due to their functional and structural simplicity, which makes them suitable for manual tuning and offers robust performance in a wide range of operating conditions.

The traditional PID controllers can be totally ineffective in the control of nonlinear systems, linear systems with time delays, higher order linear systems, systems with input constraints and unknown interactions. Usually the control of these types of highly nonlinear and complex systems is tackled in practice by heuristics developed by experienced operators. Fuzzy logic control incorporates these heuristic rule-of-thumb very easily. This makes the fuzzy control easier to understand, and modify. However, it is less precise than purely mathematical models.

In this paper a hybrid fuzzy PID control system is described which combines the simplicity, adaptivity and flexibility of fuzzy control with the mathematical precision of PID control. It is reported in the literature [1, 2] that in a hybrid fuzzy-PID system a fuzzy system can either tunes the PID gains or selects the most appropriate PID controller for better performance.

Omron Corp. has developed a temperature controller E5AF which combines fuzzy logic with advanced PID algorithms [3]. Here the fuzzy logic control program monitors the deviation between the process value and set point, and also the rate of change of temperature (in degrees per second).

In this paper it is described the use of fuzzy logic control in tandem with PID algorithm for cement kiln control. At any instant of time only one out of the two controllers (i.e., fuzzy and PID controllers)will be active. During severe external disturbances fuzzy control takes over the charge of control, by-passing the PID algorithm.

2 Cement Kiln Control

The cement kiln process shown in Fig.1, is highly nonlinear, time varying and few process parameters available for its control. In such a case it is very much difficult to establish a mathematical model. Nonlinearity and time varying behavior of the process can be tackled by predictive control [4] and Self tuning control, respectively, also for infrequent measurements of low frequency, self tuning controllers can be used but it may converge very slowly or even may not converge. This is the exact case in a cement kiln process where some measurements like liter weight and free lime sample are not available in regular intervals due to its dependence on laboratory evaluation. Also kilns with identical measurements behave differently and so is not easy to develop a standard technique for identical kilns. Hence it is very difficult to establish an accurate mathematical model for the rotary kiln. Human operators control the cement kiln from their experience and a "rule of thumb". These rules are vaguely defined, linguistic quantities like "High", "Small", "OK" etc. For example, IF the CO content in the exit gas from the kiln at the preheater inlet is "High" THEN "reduce" the coal fed to the precalciner. Fuzzy logic is a technique which tackles this type of imprecise, vague linguistic expressions. The fuzzy logic kiln control system [5-8] was commercially available in 1980, by F.L. Smidth (FLS) of Denmark.

Fuzzy logic controller alone in an open loop fashion can not achieve the required process values. Being the PID control is essentially linear, a traditional PID controller may not be sufficient to control the cement kiln. The hybrid fuzzy-PID controller as shown in Fig.2 incorporates all the advantages of PID and fuzzy systems. Around an arbitrary point in state space, even highly nonlinear and complex systems can be approximated by a simple lower order linear system in certain neighborhood of the point making a PID controller suitable to control this [9]. But under disturbances in the kiln the set point change will be more thus makes the PID controller totally ineffective. This situation needs appropriate changes to be incorporated, which is taken care of by bypassing the action of PID controller alone. Hence the combined fuzzy and PID controller scheme can tackle all these cases effectively.

The major problem in fuzzy logic controller is the tuning of its membership functions, i.e., a slight change in the membership function alters its performance significantly, this makes the tuning most difficult and time consuming. Genetic algorithm, an iterative search algorithm based on natural selection (Darwinism) and evolutionary genetics, is used to tune the fuzzy controller [10].

3 Hybrid Fuzzy-PID Controller

The PID controller is essentially linear. Being the kiln operation is highly non-linear and complex a traditional PID controller may not be sufficient. Although the PID controller has been used to control a cement kiln, but for a hybrid fuzzy-PID scheme has been derived. This is shown in Fig.2. For each controlled variable one PID controller is used and the set point for each controller is decided by the fuzzy controller under normal operation periods. During disturbances, the control action for the set point change is drastic which makes the PID entirely ineffective. Under these conditions fuzzy control by-passes PID, and applies directly the input variables to the kiln which in turn drags the corresponding output variable to achieve the set point at minimum time.

4 Results

The entire routine has been developed in C language in a PC-AT 80486 system under DOS. One of the fuzzy rule block for the burning zone temperature control of the kiln is shown in Fig.3. A set of such rules for controlling different kiln variables has been developed. Also, a design strategy for controlling the kiln has been developed. With the implementation of the above procedure, it has been observed that the product quality improves with increased production. Also, this improves the run-factor of the plant.

5 Conclusion

This paper describes the novelty of combining fuzzy and PID controllers together to control a highly complex and nonlinear rotary cement kiln. Usually, in the conventional cement plants, kiln variables are controlled by PID controllers. Here, the proposed scheme highlights the use of a fuzzy controller to enhance the performance of the existing rotary kiln without much change in their setups.

References

[1] S. He, S. Tan and P. Wang, "Fuzzy Self-tuning of PID controllers," Fuzzy Sets and Systems, Vol. 56, pp.37-46, 1993.

[2] T. Munakata and Y. Jani, "Fuzzy Systems: An Overview," Communication of the ACM, Vol.37, No. 3, pp.69-76, March 1994.

[3] N. Infelise, "A clear Vision of Fuzzy Logic," Control Engineering, pp. 28-30, July 1991.

[4] L. A. Zadeh, "Outline of a New Approach to the Analysis of Complex Systems and Decision Processes," IEEE Trans. on Sys. Man & Cybern., SMC-3(1), pp. 28, 1973

[5] P. J. King and E.H. Mamdani " The application of Fuzzy Control Systems to Industrial Processes," Automatica, vol 13, pp. 235, 1976

[6] I. G. Umbers and P. J. King, "An Analysis of Human Decision Making in Cement Kiln Control and the Implications for Automation," Int. J. of Man-Machine Studies, vol.12, no 1, pp. 11, 1980

[7] L. P. Holmblad and J. J. Østergaard, "Control of a Cement Kiln by Fuzzy Logic," F L Smidth Review, 67, F L Smidth & Co., Copenhagen, Denmark.

[8] A. K. Swain and K. C. Patra, "Fuzzy Logic Based Kiln Control," Proceedings of 39th Technical Annual Session of Orissa Engg. Congress, Bhubaneswar, India, 22nd. Jan. 1994.

[9] S. Tan, "A Combined PID and Neural Controller Scheme for nonlinear dynamical systems," Proceedings 1992, Singapore Int. Conf. Intell. Control Instu., pp. 377-383, 1992.

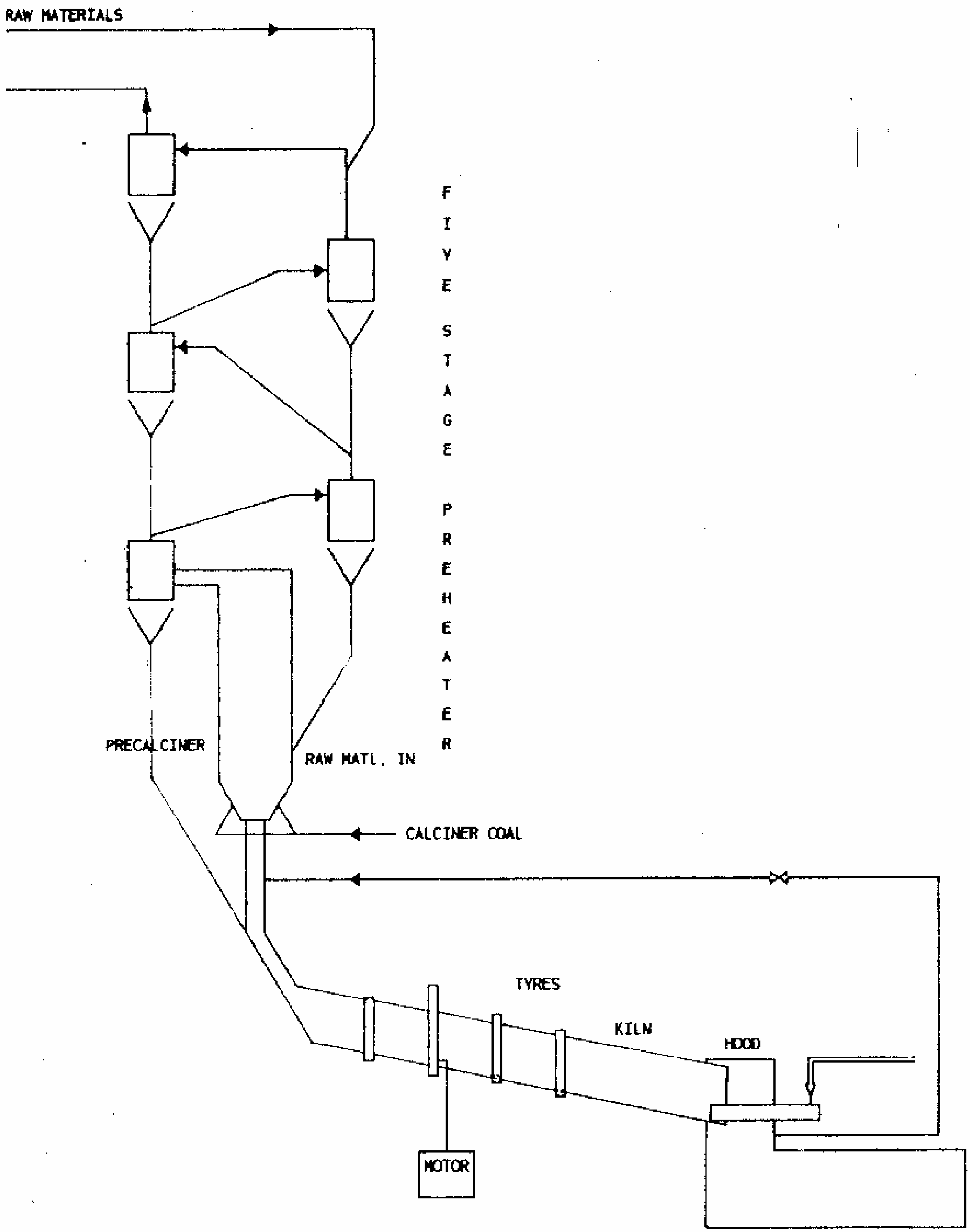

Fig. 1 A Typical Rotary Cement Kiln

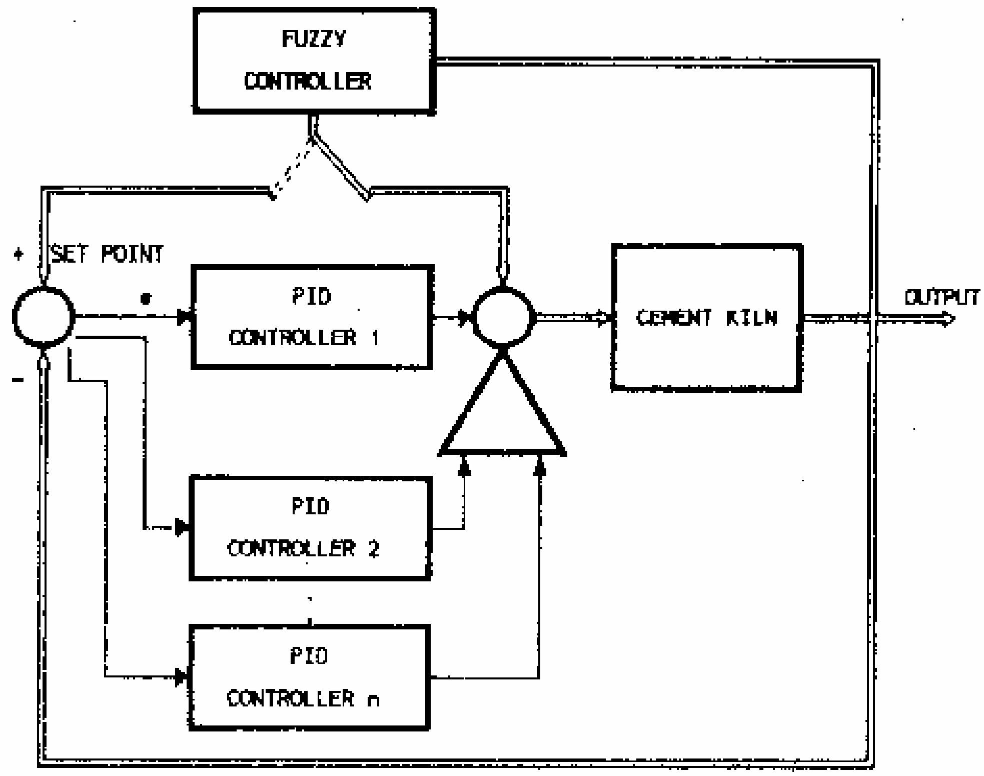

Fig.2 Fuzzy-PID Hybrid Control Scheme

Here INCR and DECR represents Increasing and Decreasing, respectively. Also LDECR, MDECR, SDECR, SINCR, MINCR, LINCR AND BZT represents Large Decrease, Medium Decrease, Small Decrease, Small Increase, Medium Increase, Large Increase and Burning Zone Temperature, respectively.

IF LOW(*FREE LIME*) AND INCR(*KILN SPEED*) THEN SINCR(*BZT*)
IF LOW(*FREE LIME*) AND OK(*KILN SPEED*) THEN MDECR(*BZT*)
IF LOW(*FREE LIME*) AND DECR(*KILN SPEED*) THEN LDECR(*BZT*)
IF OK(*FREE LIME*) AND INCR(*KILN SPEED*) THEN MINCR(*BZT*)
IF OK(*FREE LIME*) AND OK(*KILN SPEED*) THEN ZERO(*BZT*)
IF OK(*FREE LIME*) AND DECR(*KILN SPEED*) THEN MDECR(*BZT*)
IF HIGH(*FREE LIME*) AND INCR(*KILN SPEED*) THEN LINCR(*BZT*)
IF HIGH(*FREE LIME*) AND OK(*KILN SPEED*) THEN MINCR(*BZT*)
IF HIGH(*FREE LIME*) AND DECR(*KILN SPEED*) THEN SDECR(*BZT*)

Fig.3. Rule base for Burning Zone Temperature Control